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Guide to Wildland Fire Origin and Cause Determination

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Preface

The *Guide to Wildland Fire Origin and Cause Determination* is designed for use in the field as a guide for wildland fire investigators.

Accurate wildland fire origin and cause determination is an essential first step in a successful fire investigation. Proper investigative procedures which occur during initial attack can more accurately pinpoint fire causes and preserve valuable evidence that might be destroyed by suppression activities. If a fire is human-caused, the protective measures described in the guide can preserve evidence that may lead to effective and fair administrative, civil, or criminal actions.

The investigation should start at the time a fire is reported or discovered. First responders play an important role in protecting evidence, so it is important for the wildland fire investigator to help train first responders to identify and protect the *General Origin Area* of the fire. Wildland fire investigators should impress upon firefighters, law enforcement officers and other first responders that the preliminary protection of the General origin area and any associated evidence on any wildfire is their responsibility, and emphasize to them that they are the most important link in the subsequent origin and cause determination. Not only is it important for the first responders to recognize the need for an accurate origin and cause determination, it is important that they understand how their actions, both during and following suppression, can enable a qualified wildland fire investigator to accurately determine the origin and cause.

Laws are not cited or referenced in the field guide. The format is designed so that agencies, organizations, or individuals may add applicable rules, regulation or statutes if they so desire. Specific federal, state, and local laws and regulations give direction with respect to wildland fire investigations and the legislative authority to investigate wildland fires.

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Introduction

The Guide to Wildland Fire Cause and Determination provides recommended procedures, practices and techniques (methods) for use within a problem solving framework to conduct a systematic wildland fire investigation resulting in a determination of the ignition area, cause, and ignition sequence, including collection of factual data pertinent to the investigation, an analysis of data, formulation of a hypothesis(es), testing of the hypotheses, and selection of a final hypothesis.

The guidelines were developed to assist wildland fire investigators in using peer reviewed and accepted methods, generating evidence and informed conclusions to be used for legal proceedings, to serve as the basis for administrative decisions and policy development. There are many similarities between structural fire investigations and wildland fire investigations, there are also differences requiring specialized training and experience. This guide is not intended to be all-inclusive.

Purpose

The purpose of a wildland fire investigation is to determine the origin, cause, ignition sequence, and responsible party.

There are four basic directions the results of the investigation can take:

- Administrative actions to reduce future fires, risk to the public and/or property loss.
- 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.
- To assist in policy development, implementation of fire prevention programs, and pre-suppression planning.

General

Every wildland fire investigation is unique. Portions of the guide may not apply to every wildland fire investigation. The recommendations presented in this guide should be followed to the largest extent possible but are not meant to restrict the application of other specific practices to unique fire scene conditions. Further, it is recognized that policy, time, assignment and resources may dictate the scope and extent to which these guidelines may be applied to a specific investigation. The guidelines and recommendations were developed to follow a science-based, systematic methodology which has been peer-reviewed and is generally accepted by the wildland fire investigation profession. The methodology recommends coordinated use of the scientific method for problem solving and methods specific to the wildland fire investigation discipline.

Procedures, practices, or techniques applied during a wildland fire investigation which differ from those recommended within this document are not necessarily wrong, but the wildland fire investigator who uses procedures, practices, or techniques not commonly taught or accepted by the wildland fire investigation community should be ready to explain why such procedures, practices or techniques were applied. It is recommended that a systematic approach be applied to all wildland fire investigations.

The NWCG training course, *Wildland Fire Origin and Cause Determination*, FI-210, is the primary vehicle by which the principles, procedures, practices, and techniques provided in this guide are transmitted to wildland fire investigators; the course is based on the guidelines established in this document.

2016 Edition Changes

The 2016 edition of this guide includes a number of new recommendations, procedures, practices and techniques not included in the 2005 version.

- The Introduction section of the guide includes changes in language to reinforce that this guide is a consensus document and serves as a *Guideline* with recommendations and does not preclude application, as appropriate, of other procedures, practices or techniques to fit each unique fire scene. It is ultimately up to the wildland fire investigator to select the appropriate methods to apply to the investigation and to explain why those methods were adequate.
- Chapters 1A and 1B
    - Changes include a reduction from 14 to 11 fire pattern indicators. The fire pattern indicators that were dropped are; 1) die out, 2) depth of char, and 3) degree of damage.
    - A change in the use of the term *burn indicator* to *fire pattern indicator*.
    - A change in the use of the term *degree of damage* from indicator category to a term used to describe general fire intensity patterns consistent with advancing, lateral, or backing fire areas and transition zones.
- Chapter 2
    - Methodology reflects an expanded section on conducting a systematic wildland fire investigation, including the scientific method for problem solving and recommended wildland fire specific methods for application within the framework of the scientific method.
        - A new term, *Ignition Area*, has been added, defined as: The smallest location which a fire investigator can define, within the Specific Origin Area, in which a heat source and fuel interacted with each other and a fire began. It is recommended that the historical use of the term Point of Origin or P.O. to represent an area be discontinued and the term Point of Origin or P.O. be used only as defined as the exact point where a heat source came into contact with the fuels first ignited. The addition of Ignition Area reflects the reality of fire dynamics which makes it uncommon that an exact point where a heat source and first fuel ignited came together be identified to a reasonable degree of certainty. The term Ignition Area representing the smallest area which should be defined using fire pattern indicators in order to determine the cause of a wildland fire.

        - An emphasis on the use of white flags as designating only the location of evidence, and not the Point of Origin. This includes the recommended addition of a lime green colored pin flag for use as designating items or points of interest other than evidence. This may include the use of lime green flags to mark the corners or perimeter of the Ignition Area.
    - The addition of two recommended search patterns, the *parallel lane* technique and the *grid* technique along with the retention of the *lateral lane* technique.
- Chapter 5
    - Reflects the addition of a new Documentation Unit. The use of GPS to document fire spread and reference points is discussed in Chapter 5, recognizing this tool for use in wildland fire investigation, its various applications and its varying degrees of accuracy and limitations.
- Chapter 7
    - Arson Investigation, no longer includes mention of an arson profile due to the lack of pertinent supporting data, the use of the study being cited, and its lack of specific application to wildland arson incidents.

- An emphasis on the consistent use of the recommended terminology.

Safety

Fire scenes may be dangerous. Wildland fire investigators have a duty to exercise due caution during their investigations. The wildland fire investigator should abide by safety-related policies and procedures established by their agency, federal, state, provincial and local governments, or industry.

Investigating the Scene

Fire scene examinations *should not be undertaken alone*. At least a minimum of two individuals should be present for safety. If it is impossible to be accompanied by a second wildland fire investigator, a firefighter or other suitable person should accompany the lead wildland fire investigator. It is critical that the wildland fire investigator have communications with the suppression forces on the incident. Use of cellular phones is NOT recommended as an adequate substitute for radio communications as cellular phones frequently will not work in remote or rural areas, and may be difficult to use in emergency or high stress situations.

Hazards

Safety is the highest priority on wildland fires. Investigating wildland fires involves specific hazards that must be considered while on the fire scene. The wildland fire investigator must be aware of areas where the fire may still be burning or where fire has been extinguished but could become active. An escape route must always be present and continually evaluated as fire conditions change. A rekindle and availability of fuels, along with a change in the wind direction may create hazards as extreme as a crown fire, which may block the previously planned escape route.

Underground burning 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. Also, a danger exists if the wildland fire investigator steps into an area burned out from below such as in peat or a stump hole.

Wildland fire suppression operations may also present safety hazards to the wildland fire investigators. Operation of aircraft dropping water or retardant, heavy equipment, tree felling, and suppression tactics such as burning out or backfiring unburned fuel in and around the origin area are all potential hazards. Investigative personnel must contact the appropriate incident personnel and coordinate their planned investigative activities with them.

Other associated hazards are falling debris from charred, fire-weakened trees and limbs. Additional hazards may be present in sloped terrain. Logs or rocks can be loosened from their location as a result of the fire, from suppression operations, or from the actions of a wildland fire investigator. When the root structure is destroyed by fire, soil may begin to lose its stability, which in turn can cause slides that may injure the wildland fire investigator or destroy evidence.

Stinging or biting insects such as bees or scorpions can cause painful injury and in some instances life threatening emergencies. Poisonous snakes can survive the passage of a wildfire and should be watched for.

Wildland fire investigators should always be alert to the possibility that hazardous materials (HAZMAT) is sometimes found in or near the origin of wildland fires. If HAZMAT is located or suspected, the wildland fire investigators should immediately take appropriate action to protect themselves and others, and notify the Incident Commander.

Power lines, railroads, and roadside fires present obvious hazards. Wildland fire investigators should take appropriate precautions.

The weather can also cause or contribute to hazards. Rain can create slippery footing. Lightning may be a concern as well. During lightning conditions, follow established safety procedures. Hot and dry temperatures and reduced shade due to the fire passage can present conditions which may subject the wildland fire investigator to heat stress.

Personal Protective Equipment

The use of personal protective equipment (PPE) such as protective clothing, safety equipment and law enforcement defensive equipment will vary depending on the circumstances. The wildland fire investigator should comply with agency or industry requirements for personal protective equipment applicable to wildland firefighting.

Investigation Team

The Investigation Team, as a minimum, should consist of a qualified and trained wildland fire investigator. Some wildland fire investigations may be better conducted when additional wildland fire investigators are assigned. Additional wildland fire investigators may be responsible for interviewing, the care and handling of evidence, or a combination of competencies.

Initial investigations may be handled by local law enforcement or fire management officials. As needed, additional expertise may be requested and staffed according to availability.

Another wildland fire investigator may be consulted for a second opinion. This can add weight to the conclusions in subsequent proceedings if the second opinion corroborates that of the original wildland fire investigator. Courts usually place greater weight on corroborated evidence.

Management of Major Investigations

Major fire investigation management includes control of the scene in which many interests may participate. The wildland fire investigator should follow agency policy or practices when dealing with these interests. These interests may include multiple public agencies and private parties and sometimes an investigation team for each interested party. A protocol should be developed to meet agency objectives.

While major incidents are not always large in size or magnitude, they do tend to be more complex. As a result, the primary goals in such circumstances are to preserve the scene, determine the origin, determine the cause, determine potential responsible parties, protect evidence and to preserve the interests of all parties as far as possible.

Thorough investigations do not just happen, but instead are the result of careful planning, organization, and the ability to anticipate problems before they arise. Prior to actually beginning the scene investigation, numerous events, facts and circumstances should be identified and considered before decisions are made as to how the investigation will proceed.

Confidentiality

During an investigation, all evidence and information obtained is confidential in nature. Premature release of information prior to any adjudicative action may jeopardize the outcome.

- Wildland fire investigators need to assure that first responders are aware of the responsibility to maintain confidentiality of any information that they may have received relating to the investigation.

- Wildland fire investigators should only disclose information to authorized personnel.
- 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, the Freedom of Information Act and similar privacy legislation apply to all investigative work products.

Chapter 1A - Fire Behavior

Principles of Fire Spread

Determining the origin, the cause, how the ignition source came into contact with the materials first ignited (ignition sequence), and identifying the responsible party, if any, are the fundamental purposes of a wildland fire investigation. This is generally done by employing a systematic method of investigation. 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 individual fire direction indicators can reveal fire progression at that precise location and forms a portion of the overall fire pattern. Analyzing the relationship of the majority of individual fire pattern indicators reveals the overall fire pattern. This in turn will reveal overall fire progression.

For a wildfire to occur an ignition source must contact the host fuel, materials first ignited, and have sufficient heat over a sufficient duration of time to raise it to its ignition temperature. The smallest area that the wildland fire 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 combustion or flaming combustion and evidence of each should be noted as it pertains to the ignition sequence. Any physical remains of the ignition source will most likely be located within this area, if it has not been removed, completely consumed, or destroyed by suppression efforts.

Fire Behavior Factors

Understanding the basic principles of fire behavior is critical for the wildland fire investigator. The ability to re-create the fire progression, based on knowledge of these principles will greatly assist the wildland fire investigator in identifying and correctly interpreting fire pattern indicators and overall burn patterns. It is strongly recommended that a wildland fire investigator take additional training in the area of wildland fire behavior to enhance their understanding of these principles.

A wildland fire is influenced by three main elements. These are *weather, topography and fuels*. Each of these elements has multiple sub-elements. It is the combination of these elements that form 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: *Wind, temperature and relative humidity* are the three components that comprise weather.

Wind normally has the greatest effect of all the elements on fire spread and intensity. Wind speed and direction are important to the wildland fire investigator when determining both the origin of a fire and the potential ignition sources. Wind speed and direction can vary dramatically at ridge levels and above the canopy of the vegetation as compared to wind speeds and directions below the canopy, and particularly at the mid flame level and ground fuel level where most fires originate and initially burn.

Wind data from most automated weather stations is normally taken at the 20 foot level and in areas often cleared of vegetation, thus having no canopy to affect the speed and direction of the wind. Winds below the 20-foot level, below the canopy, can be reduced through friction loss, by as much or more than 90 percent by the canopy and other obstructions at mid-flame levels. Wind direction at mid flame level can be dramatically different than those indicated by the smoke column after the fire is established and on-site data should be taken as soon as possible after the ignition and compared to wind information taken at the 20-foot level. Further, air movement at the ground level is important when evaluating the potential for a smoldering ignition and transition to flaming combustion.

Fire moving with the wind generally burns faster than a fire backing into the wind. You will be able to observe the difference in the fire patterns and the amount of fuel consumed. After the fire reaches a certain size, it will begin to create its own wind and burn even faster than before. This may result in the creation of in-draft air flow into the main fire which may change the direction of the wind at the flanks and heel or may increase the pre-fire wind speeds in those areas. This in-draft influence may be present when the main fire plume (smoke column) establishes itself as dominant and is referred to as a plume-driven fire. Fires will generally spot in advance of the main fire in the direction the wind is blowing near the head and shoulders of the fire.

Weather patterns can change quickly. A switch in wind direction can substantially affect fire patterns. Winds are rarely steady out of one direction. Winds will typically swing in an arc around the general wind direction.

Relative humidity directly affects ignition probability and fire intensity. The relative humidity also controls fine dead fuel moisture, one-hour time-lag fuels less than ¼ inch in diameter. It is important to understand the lag time and relationship of fuel moisture content and the relative humidity. Fine fuels of less than ¼ inch in diameter respond fairly quickly to changes in the relative humidity while larger diameter fuels will take longer to gain and lose fuel moisture content, often lagging behind changes in the relative humidity. The wildland fire investigator should collect and consider the changes in relative humidity prior to 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, thus both slope aspect and canopy cover should be noted during the investigation of a fire.

Like wind speeds, temperatures at ground level can be different from those readings taken from Remote Automated Weather Stations (RAWS) or by handheld instruments. This difference can be significantly higher, by as much as 40 ^{o}F (Fahrenheit).

Topography: Topography consists of *slope, aspect, and terrain*. Following wind, slope is the next greatest potential influence on the rate and direction of fire spread. Fires will burn faster uphill than downhill because of the preheating of the uphill fuels and the influence of daytime upslope and up-canyon winds. A fire backing downslope will normally move slower than a fire advancing upslope. Slope may also contribute to the propensity for hot debris to roll or slide downhill creating spot fires which may burn back uphill to the main fire.

Consideration of the aspect of the slope is also necessary. Generally, due to greater exposure to the sun and the subsequent solar heating, south-facing slopes exhibit higher intensity and more rapid rates of spread. The converse of this is true for fires in the southern hemisphere.

Terrain can also affect both intensity and rate of spread, particularly when there are either barriers or natural chimneys present. Barriers such as a log, bare dirt, or rocks, can cause a fire to slow down or even go out. 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, at least for short distances. Don't confuse the effect of a barrier's temporary change of a fire's direction with the actual direction the fire came from. Natural chimneys can increase wind velocity due to the channeling effect and accelerate fire spread and increase intensity substantially.

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

Wildland Fire Terminology

The following terms are recommended for use in wildland fire investigation. Each will be discussed in detail in the following pages.

- Fire Pattern Indicator.
- Fire Pattern.
- Fire Progression.
- Fire Pattern Indicator Vector.
- Advancing Fire.
- Backing Fire.
- Lateral Fire.
- Transition Zone.
- Macroscale Fire Pattern Indicator.
- Microscale Fire Pattern Indicator.
- Indicator Cluster.
- Damage Differential/Compare and Contrast.
- Systematic Methodology.

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.

Fire effects are the observable or measurable changes in or on a material as the result of a fire. The term *fire effects* has a similar but broader meaning in the context of prescribed fire (the physical, biological, and ecological impacts of fire on the environment), but in fire investigation it refers to the specific changes that are caused to a combustible or non-combustible object when it is exposed to heat, flame and/or the byproducts of combustion.

Fire pattern indicators that are in disagreement with the majority of indicators in an area used to be called *false indicators*, but they are not false, they simply represent fire progression at that precise point, which may not be reflective of overall fire progression, and therefore could be misleading if not interpreted within the overall fire progression and fire behavior context.

Fire Pattern: The visible or measurable physical changes formed by a fire effect or group of fire effects. This can be over a small area or it can include the overall pattern of fire spread as determined by the entirety of fire pattern indicators over a larger area. Analyzing the relationship of the majority of individual fire pattern indicators reveals the overall fire pattern. This, in turn, will reveal overall fire progression.

Fire Progression: The spread of fire from one location to another. Most fires start small, with smoldering or glowing ignitions. A fire will transition to flaming combustion under the right conditions and burn in all directions until influenced by: wind, slope, fuel, suppression activity, or combination of these factors. Once influenced, the fire will progress outward in a direction influenced by these factors, with the most dominant factor(s) establishing the primary advancing direction. Vector areas (advancing, lateral, and backing) will become established.

Fire Pattern Indicator Vectors: A group of individual fire pattern indicators located near each other, which as a group reflect the fire spread vector within that area or the physical characteristics of a single fire pattern indicator that shows the direction of fire progression at that point (vector being the same as direction).

Fire pattern indicator vectors identify transition zones which are often subtle in nature.

There are three vector areas based on the dynamics of fire spread; Head, *advancing*; Flanks, *lateral*; and Heel, *backing*.

Advancing Fire Vector: The advancing fire vector is characterized by:

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

Figure 1. Example of advancing fire vector.

Backing Fire Vector. The backing fire vector is characterized by:

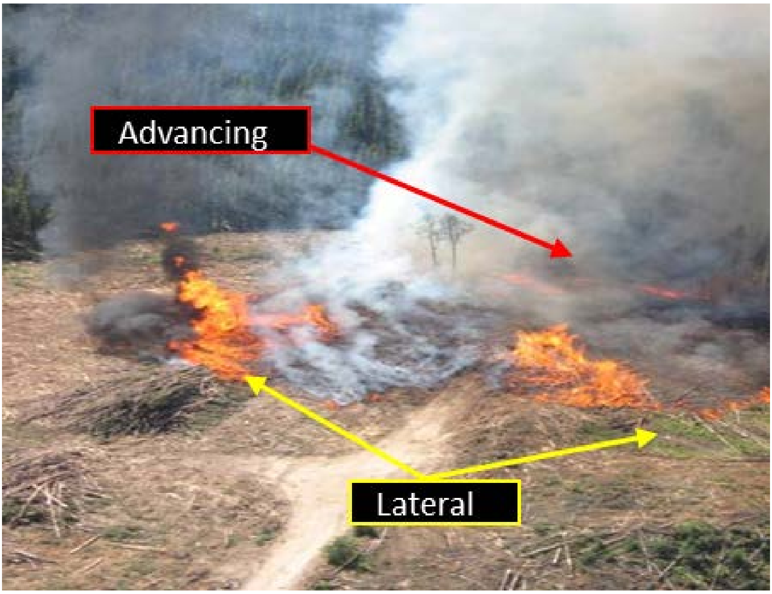
- Slower rate of spread.
  - Against wind.
  - Down slope.
- Lower intensity.
- Lower flame length.
- Less damage when compared with advancing and lateral areas.
- Microscale fire pattern indicators.

Figure 2. Example of backing fire vector.

Lateral Fire Vector. The lateral fire vector is characterized by:

- Rate of spread and intensity between advancing and backing.
  - Flank fire.
  - Spread lateral to main fire.
- Indicators can have characteristics of backing or advancing, depending on fire behavior circumstances.

Figure 3. Example of lateral fire vector.



Lateral Fire Pattern Indicators

- A higher intensity flank may leave indicators consistent with advancing fire spread:
  - Exhibits a more defined and narrower transition zone.
- A lower intensity flank may leave backing-type indicators:
  - Exhibits a more subtle and wider transition zone.
- Intensity on flanks may change with wind, slope, and fuels.

Flanks are defined by strips of unburned or partially burned fuel and their location is influenced by change in wind and slope.

Heat or Flame Exposure Lateral Fire Pattern Indicators

- Sooting, staining, and white ash deposits appear on the exposed side.
- Protection indicators will appear on the unexposed side.
- Generally 45 to 90 degree angle to the direction of advancing fire spread.

Exposed side is generally oriented towards the origin. Unexposed side generally oriented away from the origin.

Wind Influenced Lateral Fire Pattern Indicators

- Foliage freeze, grass stem, cupping, white ash deposits, and angle of char.
- Generally appear on the exposed side of the object.
- Usually aligned with advancing fire indicators:
  - May be at 45 degree angle to advancing spread.
- Grass stems are intensity dependent:
  - May fall into the burned area at 45 to 90 degree angle and remain on ground.
  - May be consumed completely.

Wind influenced lateral fire pattern indicators will align mostly with the direction the wind is blowing, up to about a 45 degree angle from the direction the main advancing fire is progressing. For example, foliage freeze will generally be in line with the wind direction in the advancing zones; grass stem indicators along the flanks will typically fall into the already burned lateral zone with the stem heads facing back to the origin area at an approximate 45 degree angle; angle of char on the flanks will present between direct alignment with the angle of char fire pattern indicators in the advancing zone and out to about a 45 degree angle to the main direction of the advancing zone. Cupping and white ash fire pattern indicators will be similar.

An exception is when high wind vortex flame wrap occurs.

Transition Zone

- Area of **directional** change based on variations in intensity.
  - Advancing to lateral.
  - Advancing to backing.
  - Backing to lateral.
- Change in appearance and characteristics of indicators.
- Transition zones may outline specific origin area.
- A key to accurately interpreting fire patterns is identifying transition zones.

Transition Zone Fuel Effect

Advancing fire will spread at different rates depending upon the type and availability of the fuels. A fire may spread very quickly under the influence of a 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. Once the fire in the timber burns past to the grassy fuels again, it will typically pick up its rate of spread.

These changes in the composition of the fuels are part of the fire behavior context that the wildland fire investigator must observe, understand, and take into account. Very few wildland fires burn in the same fuel conditions during their entire duration.

Transition Zone Wind Change Effect

During the duration of a fire, the wind direction may change many times. In actual practice, it is rare for there to be a constant wind direction. Typically, winds that are noted to be out of the south will actually vary in direction to one side of south or the other over short and long periods of time.

These changes in wind direction will affect the spread direction of the advancing fire and the transition zones. An example would be the wind switches to the right and the right lateral becomes the advancing fire vector, the left lateral fire vector becomes backing, and new laterals form around where the old advancing and backing areas were.

Transition Zone Spot-fire or Rolling Material Effect

If the wind picks up embers and carries them downwind, causing spot-fires ahead of main fire front, this will result in the formation of new transition zones which will interact with the main fire. 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 fires to start below the main fire, forming new transition zones which will interact with the main fire. Each fire from rolling material behaves as a separate fire until they join with the main fire.

Fire Pattern Indicator Categories

There are 11 categories of fire pattern indicators. They are based on fire behavior and the materials the fire effects. Each category can exhibit any of the three vectors, advancing, lateral, or backing. The physical appearance will differ with the vector (direction of fire progression). The fire pattern indicators are also divided into two general classifications which are:

- Macroscale Fire Pattern Indicators.
- Microscale Fire Pattern Indicators.

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

Microscale Fire Pattern Indicators: Associated with smaller objects or areas, microscale fire pattern indicators may not be as easily observed from a distance. The importance of microscale fire pattern indicators increases with the proximity to the ignition area.

Because microscale fire pattern indicators are typically more subtle than macroscale indicators, these indicators generally need to be observed from a close up position (kneeling, squatting or hands and knees position), not from a standing position.

Fire Pattern Indicator Clusters: Indicator clusters are a group of fire pattern indicators within close proximity which contain fire effects which portray a consistent vector among them. Clusters are most reliable when a variety of fire pattern indicator categories are represented within the group or cluster.

Close proximity of fire pattern indicators within a cluster is relative based on the size of the fire pattern indicators, such as five trees in a cluster. The distance between the fire pattern indicators in a cluster draws closer as you near the ignition area. Macroscale clusters tend to have greater spacing than microscale clusters.

Damage Differential: Damage differential is one of the underlying principles that govern the interpretation of most fire pattern indicators.

Damage differential on individual fire pattern indicators is the change that occurs to combustible and non-combustible 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 which 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 large scale damage differential is part of the process of identifying the general origin area. 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.

The degree of material lost is applied to individual items. When comparing and contrasting damage differential, as far as possible it should be on a similar size of fuel, same category of indicator, and at separate locations.

General Principles of Fire Pattern Interpretation

The interpretation of fire pattern indicators is governed by general principles which have been found to be reliable and which the wildland fire investigator needs to apply while conducting their origin investigation. These general principles have been around for many years. First known documentation was by Bob Bourhill of the Oregon Dept. of Forestry (Bourhill, 1982). These principles 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 more reliability. Employ a systematic method when selecting fire pattern indicators in an effort to include the greatest variety.

- **A single fire pattern indicator may be accurate within a 180° arc.** Fire does not burn in perfectly straight lines. Radical but brief directional changes may occur. The actual progression of the fire is primarily based 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 fire pattern indicator.

- **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 by interviewing witnesses such as 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 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 origin which 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 *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 your investigation.** Use directional flags, fire spread sketches, diagrams and photos to document the fire progression. The use of directional flags (discussed in detail in Chapter 5, Documentation) helps the wildland fire investigator to visually 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**. As the fire spreads, it will create transition zones between these areas of progression. A key to accurately interpreting fire patterns is identifying transition zones. A transition zone is an area of directional change based on variations in intensity. Transition zones may outline the specific origin area. These zones can be identified by the appearance of the fire pattern indicators and can be subtle in nature.

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 wildland fire 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 origins.

- **Avoid attempts to prematurely locate the Ignition Area.** Indicators become increasingly subtle the closer you get to the ignition area. Wildland fire investigators will need to pay closer attention to detail and take their time, and avoid the pressure to rush. Working the specific origin area and the ignition area is typically the dirtiest and most time consuming portion of the search for the origin of the fire. Wildland fire 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 fluid movement of fire is similar to 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 as the fire works its way around, through or over obstacles.
- **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 different angles. Photo-document contrasting views where appropriate.

Chapter 1B - Fire Behavior and Fire Patterns

As a fire progresses, it will leave visible marks of its passage on combustible and non-combustible objects in its path. These markings are called *fire pattern indicators*. A fire pattern indicator's vector, (direction of travel, for example, advancing, backing, lateral), can usually be determined by examining the appearance of the fire pattern indicator. When analyzed within the fire behavior context they will form distinct overall fire patterns. These fire patterns will identify areas of fire progression and the accompanying transition zones. Fire progression can then be traced back to the fire's ignition area.

General Reliability and Possible Exceptions

Indicators accurately reflect fire behavior at the particular place and time the fire passed, however the individual vector displayed may not be consistent with general fire progression. Wildland fire investigators must be familiar with the fire behavior conditions (fire behavior context) that may cause an indicator to be inconsistent with other indicators.

Fire pattern indicators may be misleading if not correctly interpreted. Certain circumstances occur creating possible exceptions that apply to most fire pattern indicator categories. Other circumstances may occur creating possible exceptions that only apply to a specific fire pattern indicator category. Reliability and exceptions that apply to most fire pattern indicator categories include: heavy or uneven fuel loading; long-term fire residence; high winds or directional changes; fire backing, downslope, against wind; high variation in sound and rotten fuel; fire pattern indicators that may have moved; and previous fires in the same area (reburns).

Fire pattern indicators should be tested to determine their reliability.

Assess indicators for reliability

- Fire pattern indicator consistent with:
  - Fire behavior context.
  - Other indicators within a nearby pattern cluster.
  - General known fire progression.
  - Eye witness observations.
  - Video or photo evidence.
- Did any of the circumstances that can create exceptions exist during the fire's initial stages?
  - Test the reliability of fire pattern indicators with these exceptions in mind.

Fire Pattern Indicator Categories

Fire pattern indicators are classified into 11 categories and will be discussed further in this chapter. These categories are based on how the fire pattern indicator is formed and the materials upon which they are found. A category can exhibit any one of the three fire vectors, depending on the direction of the fire's progress at that point. Many of these fire pattern indicators will be apparent on both large and small objects and fuels.

The 11 fire pattern indicator categories are:

1. Protection.
2. Grass Stem.
3. Freezing.
4. Angle of Char.
5. Spalling.
6. Curling.
7. Sooting.
8. Staining.
9. White Ash.
10. Cupping.
11. V or U Patterns.

1. Protection Fire Pattern Indicators

A non-combustible object or the fuel itself shields the unexposed side of a fuel from heat damage. Fuels will be unburned or exhibit less damage, less staining, less sooting, less white ash, on the side unexposed to the fires advance (Figures 4 and 5). Look for charring, staining, white ash and clean burn lines on exposed sides of fuels and non-combustible objects. Compare and contrast to the opposing sides of objects. Lift or remove objects to compare and contrast the damage and protection after photographing in place. Objects resting on top of the ground and surface fuels will protect the fuels on the side opposite the fires approach. Surface fuels on the exposed side will exhibit a clean burn line. Surface fuels on the protected side will appear ragged and uneven (Figures 6, 7, and 8).

Figure 4. Protection on a log.

Figure 5. Protection on a pinecone.

Figure 6. Picture of non-combustible object shielding fuel from heat damage.

Figure 7. Picture of fuel with clean and protected burn lines after the non-combustible object has been removed.

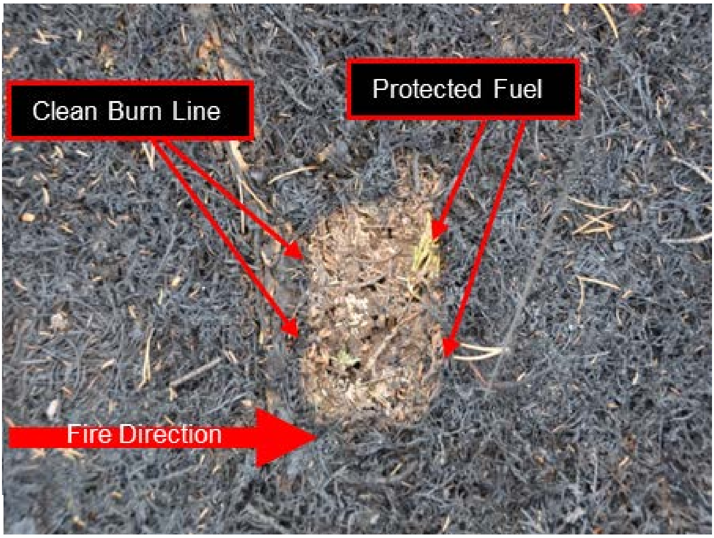


Figure 8. Close-up picture of the clean and protected burn lines.

Figure 9. Close-up picture of burned grass with protected burn lines.

Object shields fuels from heat and flame. Both combustible and non-combustible objects can provide shielding. The same object may shield itself on unexposed side.

General Reliability and Possible Exceptions - Protection

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

Possible Exceptions: Pithy stalks: A vascular plant that has a usually continuous central internal strand of spongy tissue in the stem. Pithy stalks may be annual or perennial. Because the outer sheathing is very thin, it may burn through on the unexposed side due to vortex flame wrap, with the fire becoming embedded in the soft, porous tissue. This may cause more damage on the unexposed side of the stem.

Suspended fuels: Limbs and tree trunks may be suspended by other fuels or objects. Gaps between the fuel and the ground causes vortex flame wrap on the unexposed side of the object, creating more damage and leaving protection on the exposed side. It may appear that the fire came from the opposite direction, especially if the object falls to the ground after the fire has passed where damage may be on the opposing side or equally distributed on both sides under above conditions.

Figure 10. Example of vortex flame wrap on exposed and unexposed side of suspended fuels.

The transition area of a suspended fuel, where it goes from suspended to in contact with the ground, will show less damage on the protected side and increasing damage on the unprotected side.

Figure 11. Picture showing transition area of suspended fuel and fuel in contact with the ground and the differences in damage.

Protection - Advancing fire pattern indicators.

Advancing fire macroscale protection fire pattern indicators are clearer on larger objects. On smaller objects they may be difficult to discern due to the entire object being charred. Difference from exposed side to unexposed side can still be determined (compare and contrast).

Advancing fire microscale protection fire pattern indicators can be used to validate macroscale patterns and indicators. Use when macroscale patterns do not exist. Microscale protection advancing fire pattern indicators may be found in pattern clusters and include fuels shielded from damage on unexposed side; for example, downed logs and tree limbs; pine cones; grass clumps; small stumps; brush; and deer or rabbit pellets.

Figure 12. Example of microscale protection on smaller object that can be used to validate macroscale patterns.

Protection – Backing fire pattern indicators.

Backing fire microscale protection fire pattern indicators are generally on the more protected and smaller fuels and objects due to lower intensity of fire in the backing area.

Protection – Lateral fire pattern indicators.

Lateral fire macroscale protection fire pattern indicators generally exhibit more damage on the side closest to the advancing fire front and presents at 45- 90 degree angle to advancing fire progression. Protection is more noticeable when contrasted against advancing fire area.

2. Grass Stem Fire Pattern Indicators

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

Figure 13. Picture of advancing, lateral and backing fire vectors.

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

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

Backing and Lateral Grass Stem Fire Pattern Indicators. Description: Backing fire weakens the side exposed to the oncoming fire. The fire burns the exposed side and causes the stem to fall in the direction the fire came from. This effect is similar to that of putting in an undercut on a tree to direct its fall. Backing and lateral fire pattern indicators are more reliable on lower intensity fires. Grass stems pointing towards the direction the fire came from occurs primarily in backing areas, but may occur in lateral transition zones also.

Grass stems in the following photograph have fallen towards the bottom of the photograph, heads pointing back towards the ignition area. The high degree of grass stem remains is consistent with a lower intensity backing fire.

Figure 14. Picture showing example of lower intensity backing fire.

Grass Stem Transition Zone Patterns Near Origin

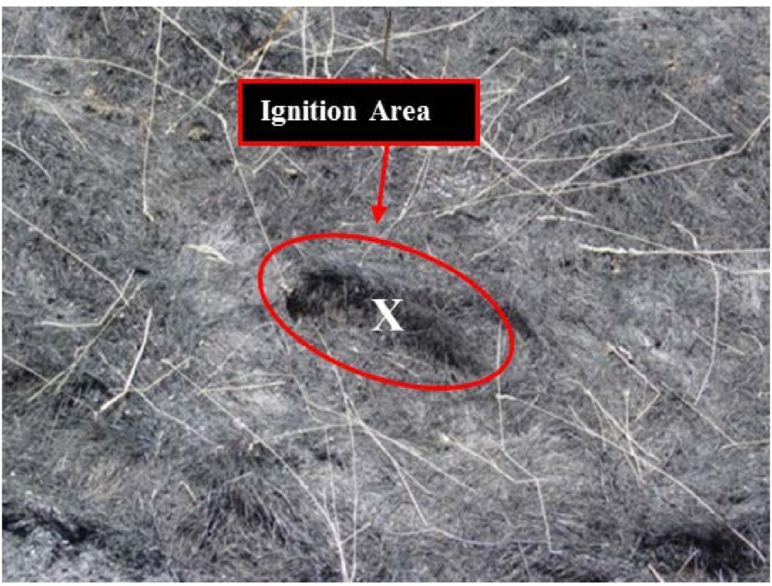
Grass stems may form recognizable patterns within the specific origin area:

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

Circle Fire Pattern:

- Generally, fire burns away from ignition area equally in all directions.
- No wind or slope influence in specific origin area.
- Grass stems fall inward toward ignition area and remain relatively intact forming a circle.

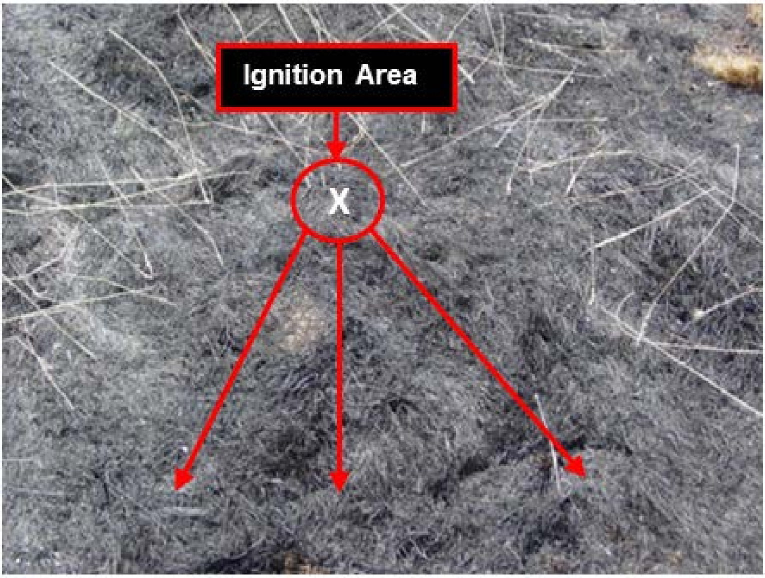
Figure 15. Example of a grass stem circle fire pattern.



V or U microscale fire pattern:

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

Figure 16. Example of a V or U shaped fire patterns.



General Reliability and Possible Exceptions – Grass Stem

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

Possible exceptions include:

- Snow mat: may leave stalks in all areas and inconsistent direction of fire spread.
- High wind, steep slope: may consume stalks in all areas.
- Wind throw: may leave stalks in all areas and inconsistent direction.

- Uncured fuel: may leave stalks in all areas and inconsistent direction.
- High intensity: may consume stalks in all areas of fire progression.

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

Grass stems that have fallen in the same direction 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.

Advancing Macroscale Fire Patterns - Grass Stem

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 shape fire pattern.

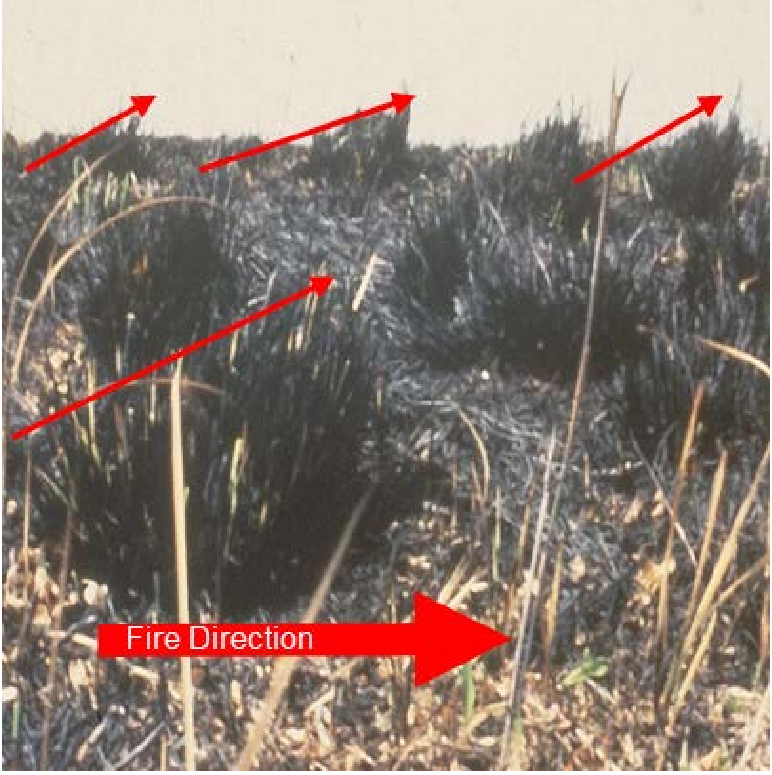
Figure 17. Picture of a *clean* burn showing no grass stems in advancing are with grass stems outlining the lateral and backing areas.

Advancing Microscale Fire Patterns - Grass Stem

- 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.

Advancing grass stem microscale fire pattern indicators near the specific origin area will generally have less grass stem remains than the lateral and backing transition zones located nearby but will often have more stem remains than in the larger advancing area where the intensity of the advancing fire is much greater. There will often still be a V or U pattern.

Figure 18. Example of microscale fire patterns in grass.



Backing Fire, Macroscale Fire Patterns - Grass Stem

Backing macroscale grass stem burn indicators will show a littering of unburned or partially burned grass stems and seed heads. The majority of stems and seed heads will point in the direction the fire came from.

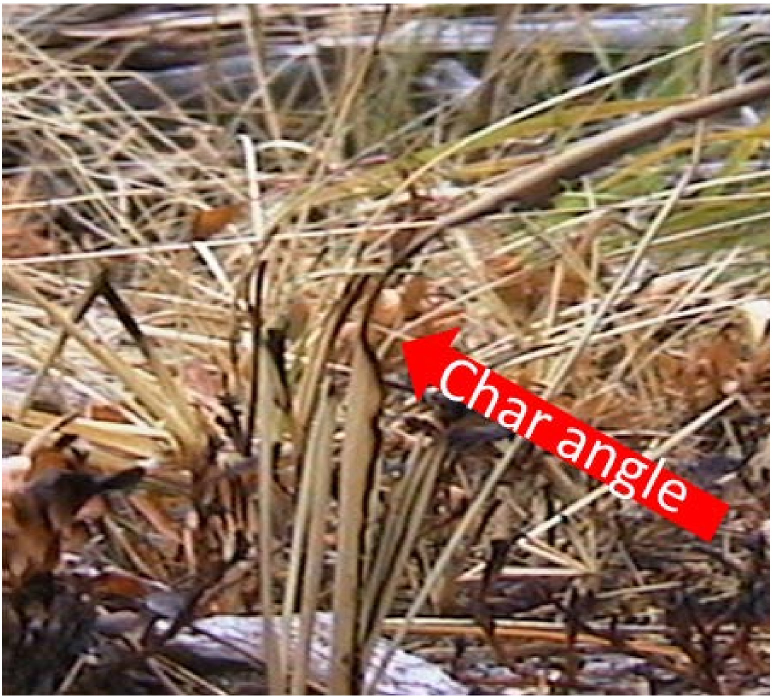
Figure 19. Backing area showing *littering* of grass stems generally pointing back to the Ignition Area of the fire.

Backing Fire, Microscale Fire Patterns - Grass Stem

Grass stem microscale fire pattern indicators in the backing fire area will be viewed by the individual heads and stems which generally point towards the oncoming fire, as well as cupping in some of the individual stems of grass.

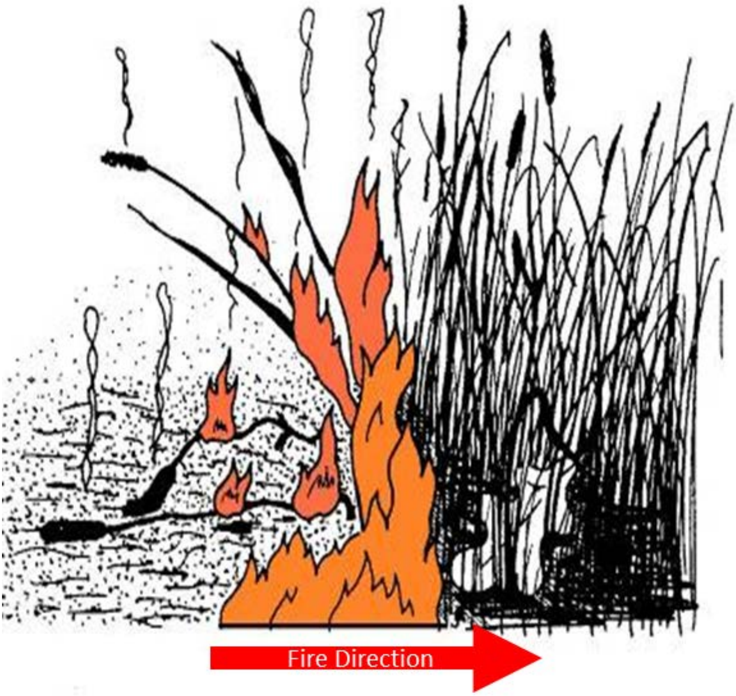
Grass that grows in clumps may not be entirely consumed, showing protection on the unexposed side. When this occurs in advancing areas, the residual basal stalks will normally show an angle of char that is steeper than the slope and exhibit cupping on the tips, with the low side of the cup on the exposed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

Figure 20. Picture of grass stalk showing char angle.



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

Figure 21. Drawing showing the effects of a backing fire on grass stems.



Backing fire weakens the side exposed and stem falls in direction fire came from. Like undercut on tree:

- More reliable on lower intensity fires.
- Occurs primarily in backing areas, but may occur in lateral transition zones.

Fire in the following photo is backing from right to left. Notice wind pushing flames back towards the burn and grass stems falling back into the burn.

Figure 22. Picture showing backing fire with grass stems falling back toward the burn.

3. Foliage Freeze Fire Pattern Indicators

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

Figure 23. 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 for lateral spread vector determination.

Figure 24. Picture showing foliage freeze in a backing or lateral fire.

General Reliability and Possible Exceptions - Foliage Freeze

General Reliability: Accurate wind direction indicator. As fire vector indicators, foliage freeze is most reliable within the advancing fire area. Foliage freeze in the lateral areas of the fire will reflect the wind direction and may not reflect the lateral spread vector at 45-90 degrees from the advancing fire.

Possible Exceptions: Locations with a natural prevailing wind where the foliage is already fix in a position and pre-existing drought conditions in green hardwoods.

Advancing Fire, Macroscale Fire Patterns – Foliage Freeze

Advancing fire macroscale foliage freeze is a good indicator of wind direction and often reflects the vector of the fire advance also. This is more common as the wind increases in speed and effect of the spread of a fire. Foliage freeze fire pattern indicators being used for the determination of the fire vector should be contrasted and compared to other fire pattern indicator categories in the same area to check for consistency.

Backing Fire, Macroscale or Microscale Fire Patterns – Foliage Freeze

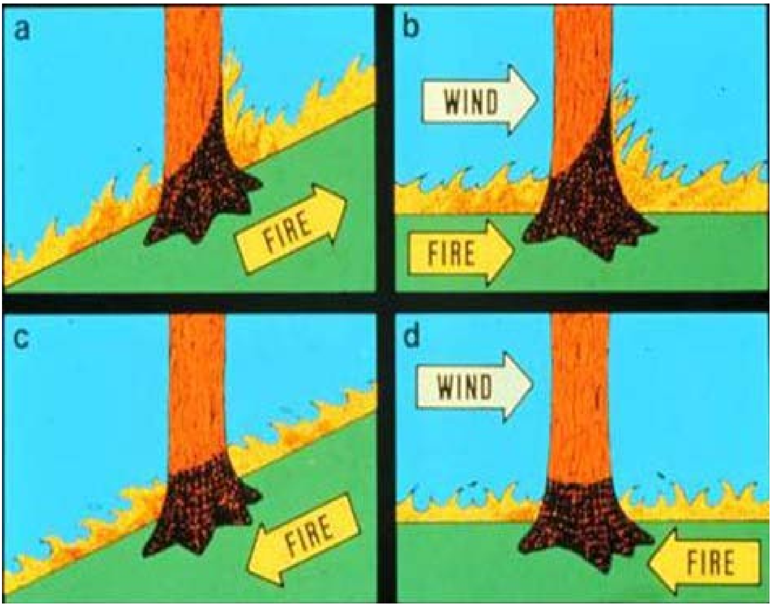
Backing fire macroscale foliage freeze is not as common as foliage freeze in the advancing and lateral fire areas. In backing fire areas, foliage freeze is more likely to be on the foliage of low brush and the lower level of tree crowns near the ground. It may be observed when fire backs into strong 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.

Figure 25. Example of macroscale foliage freeze with drooping and brittle appearance in the backing area of a low intensity ground fire.

4. Angle of Char Fire Pattern Indicators

The angle of char fire pattern indicator is formed when fire burns up to, past, and beyond a standing fuel, such as a tree, utility pole, or bush. Flame height and angle corresponding to advancing, lateral, and backing fire vectors and intensities char the fuel at an angle compared to both the unburned portion of the object and the slope. The angle differs with the fire vector when compared and contrasted. When the fires passage only heats and dries out the canopy of a tree or bush, without actual charring, the fire effect is called angle of scorch.

Figure 26. Examples of char angles on level ground and on slopes and different fire direction.



Description: Angle of Char Indicators – Scorch vs. Char

Angle of char and angle of scorch fire pattern indicators are formed by the same process, fire and 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 crowns of trees or brush where the foliage was not consumed but simply heated and dried, scorched. Char is the result of the burning away of portions of the actual crown or charring of the bark or wood of a standing fuel.

Both terms may be applied to this category of fire pattern indicator as the conditions dictate. Char denoting the angle pattern left when material is actually consumed, and scorch used to denote the angle pattern found on foliage which was not consumed, but simply dried.

Figure 27. Example of angle of scorch and char.

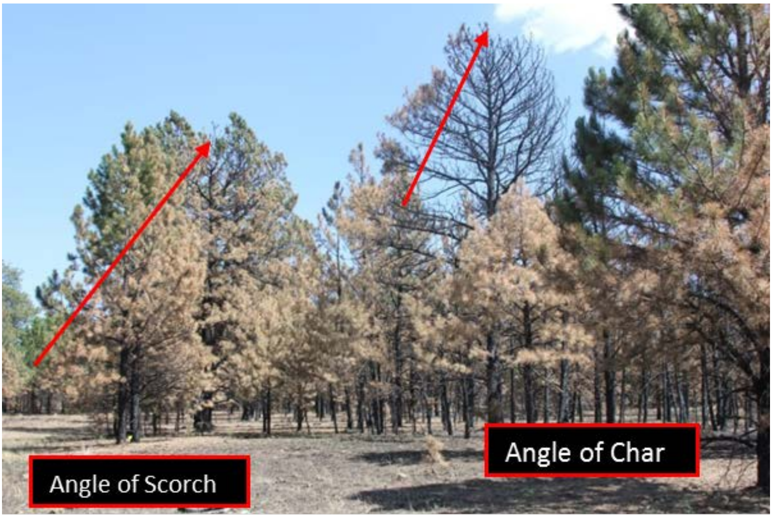


Figure 28. Angle of char on a tree trunk.

Figure 29. Angle of char on a tree crown.

General Reliability and Possible Exceptions – Angle of Char or Scorch

General Reliability: Generally reliable, especially for assessing advancing fire areas.

Possible Exceptions:

- Flat surfaces, small diameters, short heights.
- Fuel accumulations - uphill side when fire is backing downhill.
- Old burns pre-existing char patterns.
- Thin barked conifers, hard woods - evenly blackened on all sides.
- Areas where fire did not burn entirely past the fuel (near control lines, etc.).

Advancing Fire, Macroscale Fire Patterns - Angle of Char

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 comes out high, due to flame angle and wind influences, creating the typical angle fire effect. Angle of char and scorch are often found in clusters in the advancing area of the fire. Contrast and compare the angle and height of the char or scorch to backing and lateral fire areas.

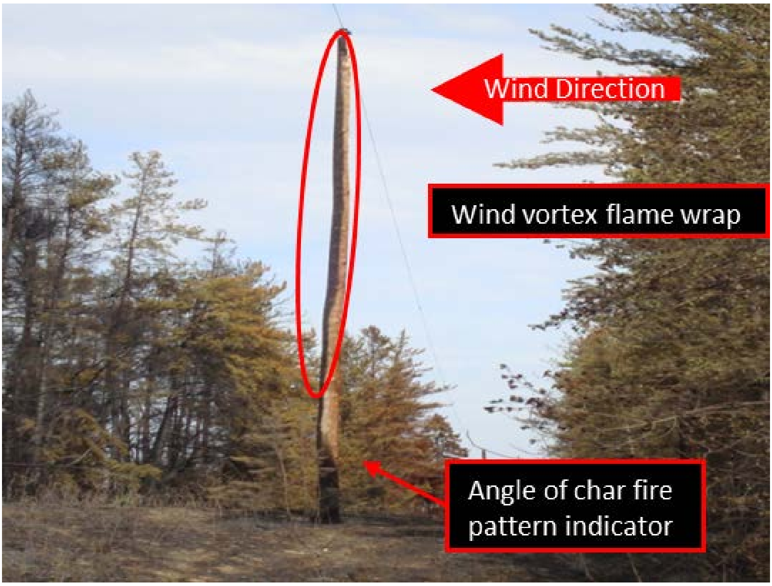
Figure 30. Photo shows advancing angle of char fire pattern indicators in a cluster which are consistent with each other. Angle of char is steeper than the slope and angle indicates the fire vector.

In the advancing fire area, due to the effects of wind, flame is drawn up the lee side of pole-like objects. Under high wind conditions this char pattern can extend to great heights. This phenomenon 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 31. Two photos showing wind vortex flame wrap on downwind side of trees.

In Figure 32 the arrow shows the angle of char fire pattern indicator present 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 downwind side of the object. It is the lower fire effect, angle of char (arrow) which 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 the wind vortex flame wrap will be.

Figure 32. Picture showing wind vortex flame wrap and angle of char on a pole.



Advancing Fire, Microscale Fire Patterns - Angle of Char

Microscale angle of char fire pattern indicators have many of the same fire effects that macroscale angle of char fire pattern indicators have. 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 towards the exposed side.

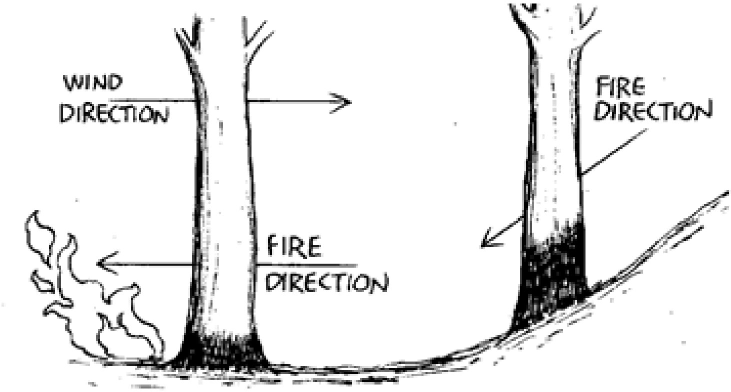
Figure 33 is an example of a microscale fire pattern indicator. The advancing fire is moving from left to right, with an angle of char greater than the slope.

Figure 33. Grass clump microscale fire pattern angle of char.

Backing Fire, Macroscale Fire Pattern - Angle of Char

Fires backing against the wind or down slope, the char angle will be parallel to the slope angle (Figure 34) 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 34. Example of macroscale fire pattern angle of char for a backing fire.

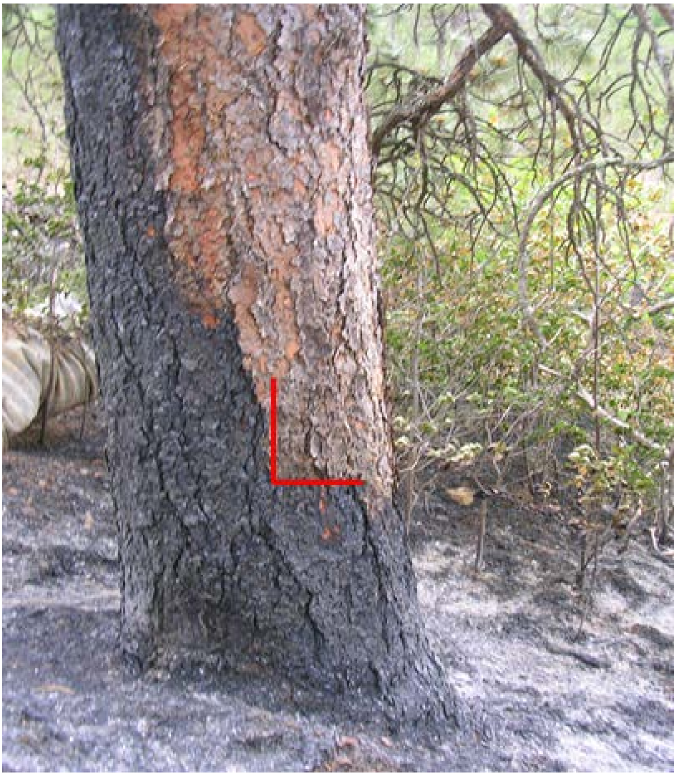


In Figure 35, the angle of char fire pattern indicator is level with the ground consistent with a backing angle of char fire vector. The height of the char pattern above the ground is a clue as to fire intensity.

Figure 35. 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, catface, exposure to other nearby fuels or backing into high wind can create this char pattern.

Figure 36. Example of L shaped char pattern on tree trunk.



Backing Fire, Microscale Fire Pattern - Angle of Char

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 vector areas will be parallel to slope, whether backing down-slope on a hill or against the wind on flat ground.

Figure 37. Example of microscale fire pattern on small shrub.

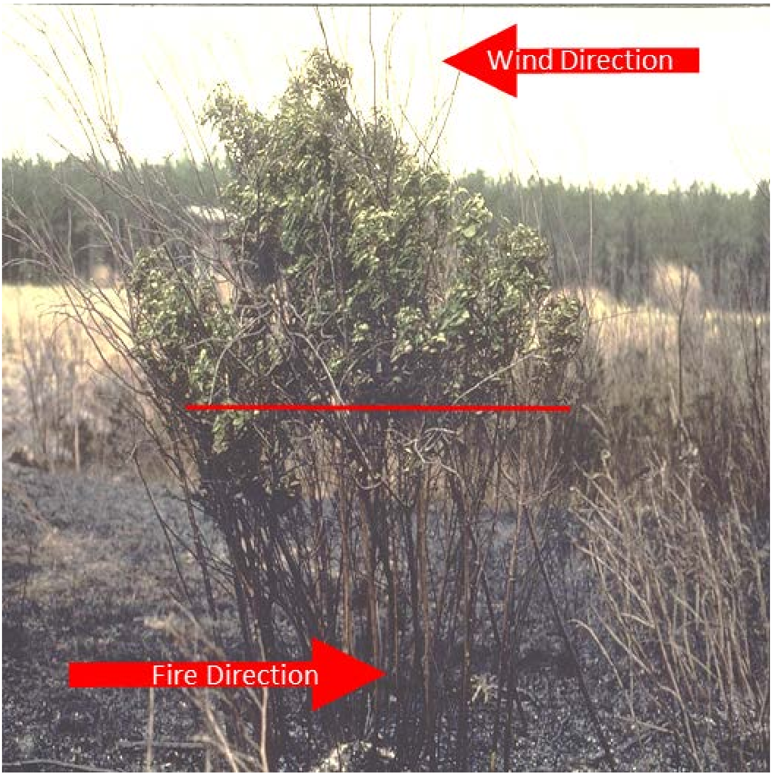
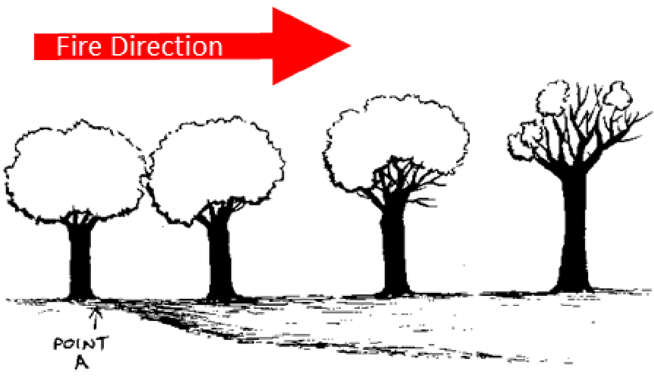


Figure 38 shows the typical effect on the crown of trees or brush as a fire starts at point A and moves out, slowly building up heat and speed. At the ignition area, the fire is still relatively cool as surface fuels involved are only partially consumed and the area involved is limited, therefore the tree's crown is left mostly intact. Farther from the ignition area, the fire has spread out and gained intensity as it involves a larger area and component of the fuel bed, resulting in a higher heat release and more crown is burned. All the crowns may be burned as the fire intensifies.

Figure 38. Example of angle of char effect on tree crowns as the fire moves away from the Ignition Area, Point A.



5. Spalling Fire Pattern Indicators

Description: Spalling fire effects will appear as shallow, light-colored craters or chips in the surface of rocks within the fire area (Figure 39). They will usually be accompanied by slabs or flakes exfoliated from the surface of the rock. 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).

In Figure 39, 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 spalling occurred 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 39. Photo showing example of spalling.

Also known as exfoliation, spalling is caused by exposure to the 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 break off, usually after the fire front has passed.

Figure 40. Combination of spalling and the surrounding area of sooting.

General Reliability and Possible Exceptions – Spalling

General Reliability: Usually reliable for advancing fire areas. Spalling is not commonly encountered in backing areas where 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 Exceptions: In areas of high fire intensity or long term fire residency spalling may be present on multiple sides. Large rocks which have the backside protected from exposure, as when they are buried in the ground, may not be as reliable as those where all sides are evenly exposed. Moisture in the rock or type of rock may affect the occurrence of spalling. Pre-existing stress cracks may also provide unreliable spalling fire pattern indicators. Contrast and 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 has been disturbed by the equipment and thus the mechanical damage can be excluded. Areas appearing to have spalling which have sooting within the face of the crater may also indicate mechanical damage that took place prior to the fire.

Advancing Fire, Macroscale Fire Patterns – Spalling

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

Advancing Fire, Microscale Fire Patterns – Spalling

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

Figure 41. Example of spalling on a small rock.

Backing Fire, Microscale Fire Pattern – Spalling

Microscale spalling fire pattern indicators are not usually associated with backing areas and spalling in these areas may be the result of fuel accumulations. Compare and contrast with spalling on the same type rocks in the advancing area. Spalling should be on the exposed side unless influenced by fuel accumulation.

6. Curling Fire Pattern Indicators

Description: Curling occurs when green leaves curl inward toward the heat source. Not normally a macroscale indicator. They may also exhibit wind influenced foliage freezing.

Figure 42. Example of leaf curling.

The process that creates curling is similar to that which forms foliage freezing. Heat exposure causes leaf to dry out and shrink on surface exposed to heat. Shrinkage causes edges to curl in towards the source of heat. The leaf folds in the direction the fire is coming from. 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 and Possible Exceptions

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

Possible Exceptions: Degree of curing, long term drought may cause leaves to be already curled. Direct flame impingement may create false indicators. Fire may impact leaves from a variety of different directions. Thick leaves with strong central vein may not curl at all or may curl in towards vein. Wind driven foliage freeze is an indication of wind direction at the time that the fire passed that point and should be confirmed by other indicators for determining a reliable direction of fire spread. Leaves may curl towards approaching heat source, but then move and freeze with the wind.

Advancing Fire, Microscale Fire Patterns – Curling

Curling will typically only form in the advancing vector during low intensity advancing fire due to light fuels, weather and fuel moisture conditions. Curling is not commonly associated with advancing fire. If present in the advancing area, the curling will take place on the exposed side of the vegetation.

Backing Fire, Microscale Fire Patterns – Curling

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

Figure 43. Example of leaf curl on small vegetation.

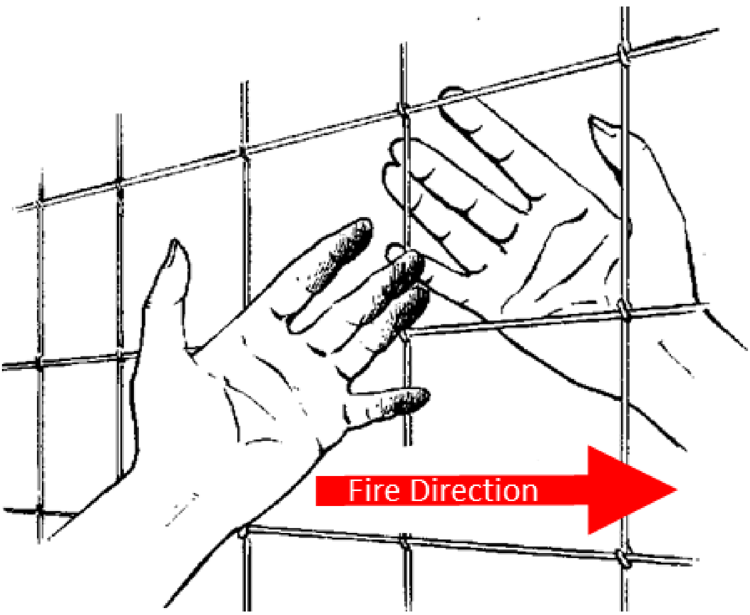
7. Sooting Fire Pattern Indicators

Description: Black, carbon based deposit caused by incomplete combustion and the natural fatty oil content in some vegetation. Carbon is typically more heavily deposited on the side facing the approaching fire.

Figure 44. Example of sooting on a rock.

Soot will be deposited on the side of fence wires facing toward the direction the fire came from and can be detected by rubbing your fingers along the wire. On larger objects, soot deposits can also be noticed by rubbing your 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, check the lower wires as they will show more evidence of soot than higher wires.

Figure 45. Example of sooting on fence wires.



The process which creates sooting fire pattern indicators includes airborne particulates resulting from the incomplete combustion of a hydrocarbon. These particles, in the form of a complex mixture of organic compounds, adhere to rocks, cans, fence wire, metal posts, and some vegetation.

General Reliability and Possible Exceptions – Sooting

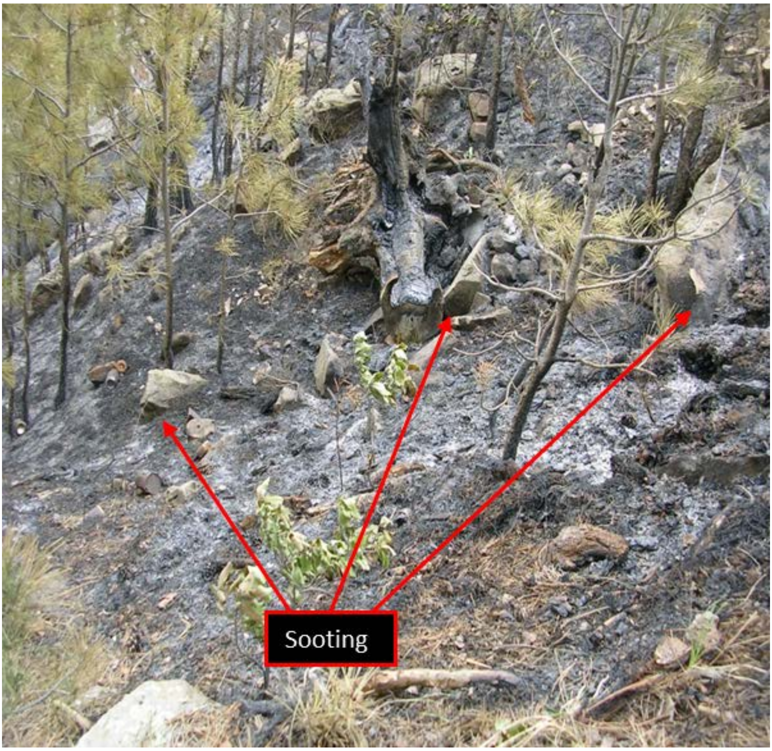
General Reliability: Generally reliable.

Possible Exception: Accumulations of debris that generate large volumes of sooty smoke.

Advancing Fire, Macroscale Fire Patterns – Sooting

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

Figure 46. Example of sooting on multiple rocks.



Advancing Fire, Microscale Fire Patterns – Sooting

Advancing fire microscale sooting fire pattern indicators may be more subtle as the smaller objects which soot is deposited on may have soot on all sides, the degree of sooting may be the only difference between the protected and non-protected sides.

Figure 47. Example of sooting on a small object.

Backing Fire, Microscale Fire Patterns – Sooting

Backing fire microscale sooting fire pattern indicators are generally not as heavy. Once again, the predominant sooting will be on the exposed side of objects, primarily smaller objects due to the lower intensity of the fire.

8. Staining Fire Pattern Indicators

Description: Staining is caused by vaporized volatile oils and resins in the flame and smoke column condensing on cooler surfaces of objects. Staining will appear glossy or varnish-like (or both), and light yellow-orange to dark brown in color. This occurs most commonly with non-combustible objects such as metal cans or rocks. Stains will appear on the side of the object exposed to the on-coming flames. These yellow-to-dark brown stains may feel tacky to the touch and may be covered with a thin layer or specks of white ash and other light-weight fire debris.

Figure 48. Example of staining on a metal can.

Staining is more commonly a microscale indicator and is more pronounced in advancing than backing fire areas and is often subtle. Examine small pebbles, rocks and other similar items close-up to find staining indicators in backing areas. Smaller objects may have staining on all sides but can display more of a varnished (shiny) look on the exposed side than on the unexposed side. The color of the staining generally is darker on the exposed side of small objects than on the unexposed side.

General Reliability and Possible Exceptions

General Reliability: Generally reliable.

Possible Exceptions: Repositioning of lightweight objects by wind or suppression activities. Accumulation of man-made debris.

Advancing Fire, Microscale Fire Patterns – Staining

Generally, advancing area microscale staining will be darker and cover a larger area of an object when compared to backing area staining. Stain in advancing area may be all the way to the top of a rock when the same size rock in the backing area may only have staining halfway up.

Figure 49. Example of advancing fire staining on a can.

Backing Fire, Microscale Fire Patterns – Staining

Staining on small objects is less noticeable in the backing areas, and may be very subtle. Examine small pebbles, rocks and other similar items. Small pebbles with staining are often present in the specific origin area and assist in determining the fire vector in that area.

Staining on rock in Figure 50 is on the right side of the rock but not on the left, indicating fire moving from right to left. After photographing in place, the rock was lifted from its resting place showing that it had not been moved and was a reliable indicator.

Figure 50. Example of staining on small objects in a backing fire.

Sooting vs. Staining

Sooting:

- Dull black in color.
- Can be rubbed off with fingers.
- White ash will generally not adhere to it.

Staining:

- Glossy pale yellow to dark brown in color.
- Cannot be rubbed off, but may be tacky to the touch.
- White ash may adhere to it.

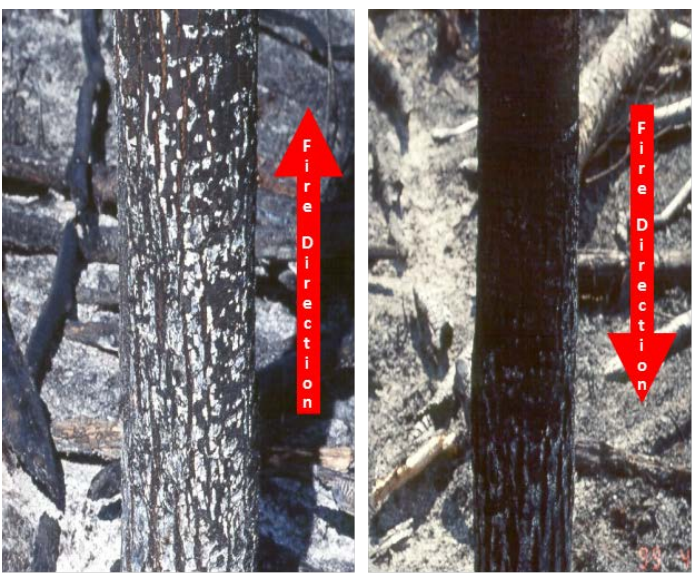
9. White Ash Fire Pattern Indicators

Description: There are two subsets of the white ash fire pattern indicator. White ash caused by exposure to heat and flame and still in place on its host vegetation is the byproduct of more complete combustion. More white ash will be created on the sides of objects exposed to greater amounts of heat and flame. White ash can also be dispersed downwind and deposited on the windward sides of objects. Generally, fuels facing the on-coming fire will appear lighter on the exposed side, darker on the unexposed side in both cases of exposure and deposits.

White Ash Fire Pattern Indicator: Exposure

The following picture, Figure 51, photo on left shows white ash on the tree bole on the side facing the oncoming advancing fire, the origin side. Photo on the right shows the back or unexposed side of the same tree. By comparing and contrasting the two opposing sides, you can distinguish that the side facing the on-coming fire has more white ash present. The arrows correspond with the direction of the advancing fire progression.

Figure 51. Example of white ash on tree trunk facing the fire and the backside (shielded side) of the same tree.



In grass stands, white ash may be more noticeable when looking away from the origin. Looking back towards the origin, the grass may appear darker or may have more *color* due to protection on the unexposed side.

Figure 52. Photo comparing white ash in burned grass looking toward where the fire went, and where the fire came from.

General Reliability and Possible Exceptions (Exposure)

General Reliability: Generally reliable.

Possible Exceptions: Thin-barked conifers and hardwoods may show more white ash on the protected side, particularly during strong winds. Long term fire residency.

Advancing Fire, Macroscale Fire Patterns – White Ash (Exposure)

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

In Figure 53 the white ash on the exposed side of tree and the intensity of the burn around the tree is consistent with an advancing fire area. The two elements together with other confirming fire pattern indicators in the area provide an advancing fire vector.

Figure 53. Example of advancing fire with white ash.

Advancing Fire, Microscale Fire Patterns - White Ash (Exposure)

Advancing microscale white ash fire patterns may be 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 to twigs and branches on low lying brush and trees.

Figure 54. Example of white ash on small tree trunk or sapling.

Backing Fire, Macroscale Fire Patterns - White Ash (Exposure)

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 *color* when compared to advancing areas due to unburned fuels.

Figure 55. Photo showing both darker burned vegetation and unburned vegetation with color.

Backing Fire, Microscale Fire Patterns – White Ash (Exposure)

Backing areas exhibit a lack of or less white ash than advancing areas. White ash (exposure) fire effects 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 56 shows backing area microscale white ash fire pattern indicator caused by exposure to heat and flame. White ash fire pattern indicators may also be on even smaller items.

Figure 56. Photo showing white ash on a twig from a backing fire.

White Ash Fire Pattern Indicator: Deposits

White ash, dispersed downwind in fine particles, can be layered on fuels and non-combustible objects. White ash on objects created in this manner are generally referred to as white ash *deposits*.

Figure 57. Example of white ash deposits on a stem.

General Reliability and Possible Exceptions - White Ash (Deposits)

General Reliability: Reliable in advancing and lateral fire areas.

Possible Exceptions: Reliability or presence decreases with time.

Inconsistent dispersal under strong and variable wind conditions may cause vector information only reliable during the time of the wind variation. Generally, white ash created and blown in the backing area will present on the protected side of objects.

Advancing Fire, Macroscale Patterns - White Ash (Deposit)

In the advancing area, windblown transport will place white ash deposits on similar objects over wide areas. Look for consistency within an area and identify clusters of fire pattern indicators.

Advancing Fire, Microscale Patterns - White Ash (Deposit)

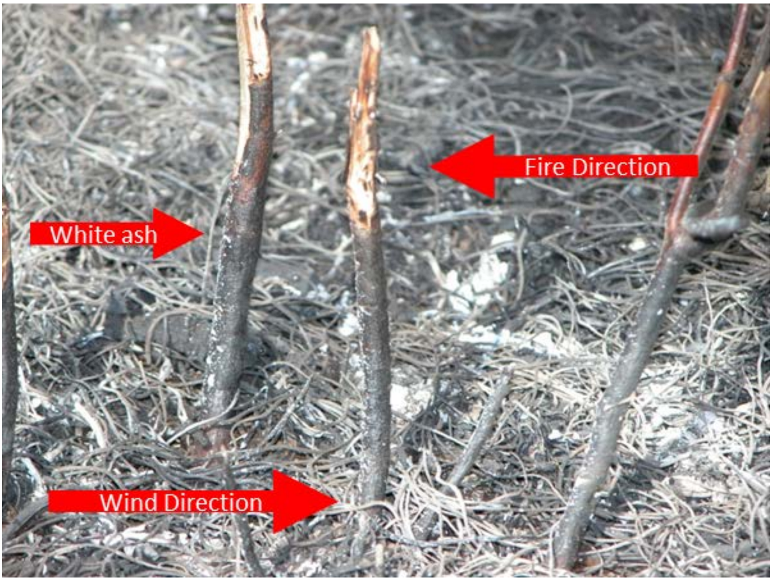
Concentrated areas of white ash on the ground are a result of more complete combustion of fuels. These deposits come from nearby fuels which have sustained high heat. Where little or no remains of the nearby fuels are still present, the depth and amount of white ash deposits will provide information concerning fuel loading in that area and fire intensity, helping to establish the vector.

Backing Fire, Microscale Patterns – White Ash (Deposit)

White ash deposits can be created in backing areas, but transported downwind and deposited on the unexposed side of objects.

It is important to determine if white ash is due to more complete combustion at its location or has been blown by the wind and deposited. As in Figure 58, windblown white ash deposits in a backing area will be on the reverse side of the object.

Figure 58. Example of windblown white ash on vegetation.



10. Cupping Fire Pattern Indicators

Description: Cupping is a concave or cup-shaped char pattern on grass stem ends, small stumps (generally 10 inch diameter and less are more reliable) and the terminal ends of brush and tree limbs (less than ½ inch diameter best). Limbs and twigs on the exposed side will have their tips burned off by the approaching flames leaving a rounded or blunt end. On the opposing side, twigs and limbs will be exposed to flames from underneath, along the base to the terminal end, creating a tapered point. Therefore, in advancing areas of the fire, twigs and limbs on the unexposed side will show a sharply pointed or tapered end. Limbs on the exposed side of the brush or tree will usually be blunt or rounded off.

Small stumps, terminal ends of upright twigs and the remains of grass stems can also exhibit a tapered point, with the sharp end on the unexposed side. The low side of the cup will face the origin (Figure 59). This indicator is usually not associated with backing areas of the fire, except in areas of steep slopes or under high wind conditions.

Figure 59. Example of cupping on limbs of a bush and on a stump.

Partially charred branch tips may sometimes be found on the ground on the origin side of brush and small trees, where they have fallen after being burned off.

Large diameter stumps and limbs should not be considered when using this indicator due to their longer term fire residency.

General Reliability and Possible Exceptions

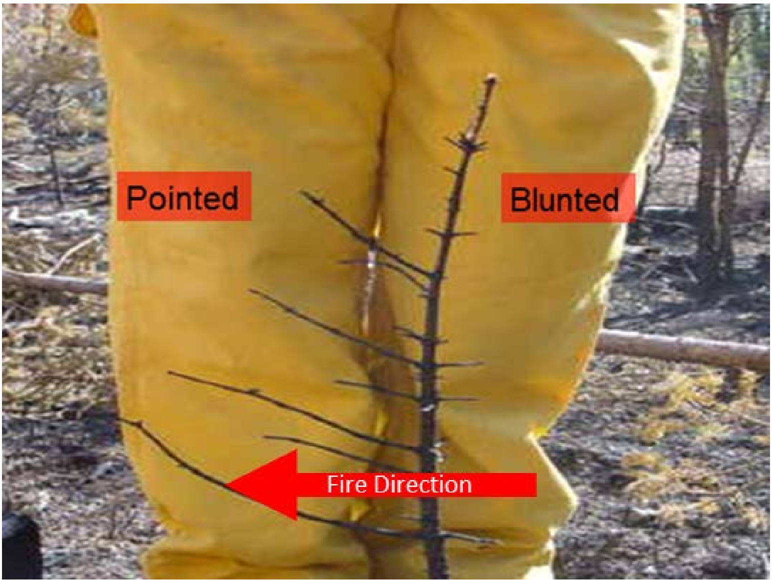
General Reliability: Most reliable in advancing areas of the fire. Cupping is usually not associated with backing areas. When in backing areas cupping is usually the result of high winds or long term fire residency.

Possible Exceptions: On large diameter fuels, the cup direction may be inconsistent with spread vector due to long term fire residency and possible change of wind direction. Small diameter fuels may not be reliable when wind is gusty and erratic.

Advancing Fire, Microscale Fire Patterns – Cupping

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

Figure 60. Example of pointed and blunted twig ends.



Backing Fire, Microscale Fire Patterns – Cupping

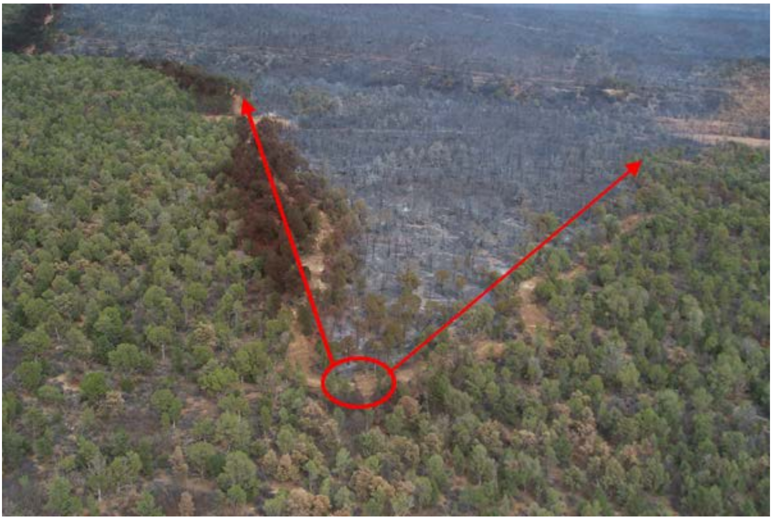
Cupping is not normally associated with backing fire areas. If cupping appears to be present in a backing area, it is usually due to high winds or long term fire residency.

11. V and U Fire Pattern Indicators

Description: This is the overall V or U shape associated with typical wildfire progression in the early stages of the fire. Lateral transition zones form exterior perimeter V or U shape with an advancing vector in between. The lateral transition zones 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 cup of the U or apex of the V. View and document this pattern from an aerial perspective, if possible.

Figure 61. Example of a V shaped burn pattern.



Wildland fire 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 where the ignition area is often located near a shoulder of the cup. A U shaped pattern can be an indication of 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.

When determining the boundaries of the V or U pattern, consider the conditions of the fuels both where the crown no longer exists and where the crown still exists based on ground fuel consumption. View these indicators from a combination of aerial and ground perspective.

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

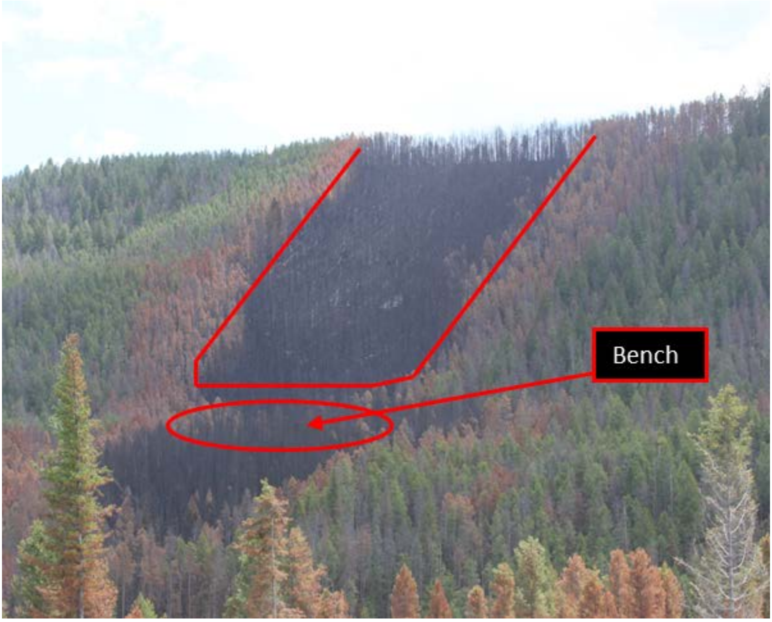
V and U indicators can be both macroscale in size and smaller. Because V and U patterns can be formed over shorter and longer periods of time, multiple V or U patterns may be formed due to wind speed and direction changes. Changes in slope may also effect the formation of V and U patterns.

Figure 62. Example or irregular V or U shaped fire pattern.

Figure 63. Example of how wind or slope can be the primary influence in creating a V pattern.

Figure 64 is 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 vector to the ridgeline.

Figure 64. Example of a U fire pattern.



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

Figure 65. Example of wind direction and a road on fire pattern.

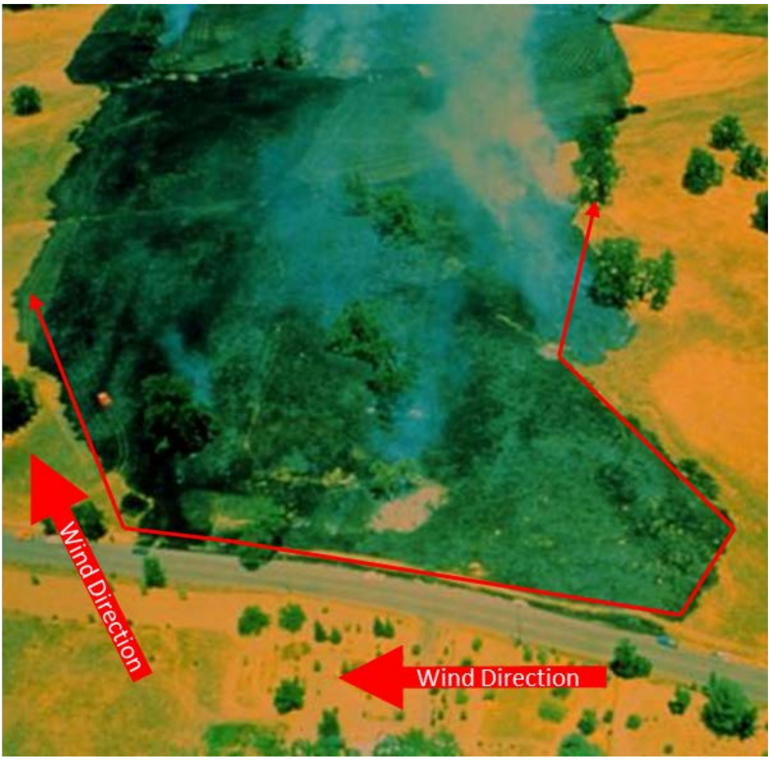
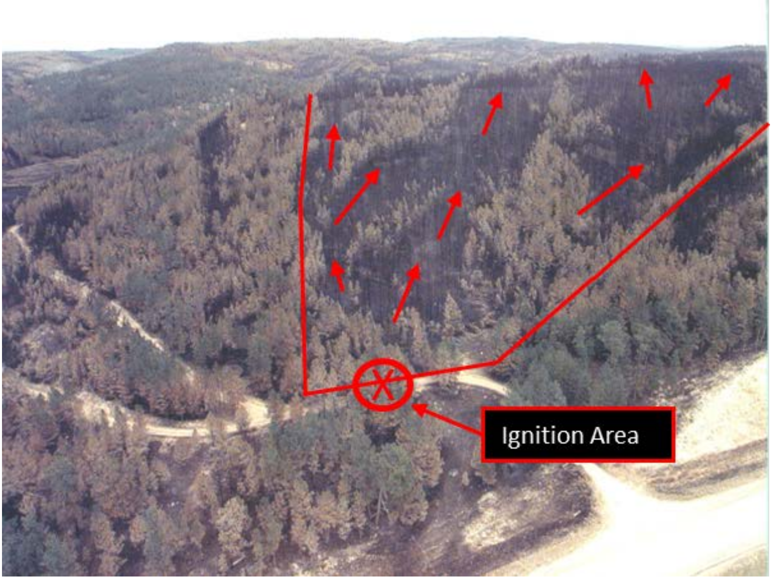


Figure 66 is an example of larger scale U pattern made up of multiple V patterns created due to changes in the terrain, fuels, and wind conditions.

Figure 66. Example of multiple V patterns.



General Reliability and Possible Exceptions

General Reliability: Can be very reliable.

Possible Exceptions: Fire suppression tactics and fire behavior can alter the shape of the initial pattern and must be considered. Rolling material, wind shifts, fuel type changes, spot fires, man-made or natural barriers are some influences that may affect the reliability of a V or U pattern indicator. V or U patterns will often die out due to slope reversals, changes in aspects, fuel bed changes, and other factors. The fire may then go through a period of microscale V or U pattern production or may back or lateral against a slope or wind. Once the slope or wind changes, the macroscale V or U may manifest itself again in the form of what looks to be a separate advancing fire. It is important to follow the indicators that connect these patterns together. V or U patterns may be generated which have no immediate relation to the ignition area.

Advancing Fire Macroscale Fire Patterns – V and U

Always consider the effects of fire suppression methods, barriers, wind changes and slope changes. Advancing V fire patterns are most likely to take place and indicate a wind or slope influenced advancing fire vector.

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.

Advancing Fire Microscale Fire Patterns – V and U

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

The closer you get to the ignition area, the more likely the macroscale V or U fire pattern will turn into a microscale V or U fire pattern. Conversely, fire burning away from the ignition area will likely 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 V or U fire pattern to a macroscale fire pattern may be due to an increase in slope, wind, or a change in wind direction, including the fire coming under the influence of upper level ridge winds different than normal up canyon daytime winds.

Chapter 2 - Methodology

Methodology: A methodology is the systematic application (framework) of practices, procedures, and techniques (methods) common to the field of wildland fire investigation as applied to solve the problems of specific scene conditions and needs. It is a combination of two processes, a framework for problem solving, and the specific methods applied to gather data during a wildland fire investigation.

Systematic approach: A systematic approach includes the orderly, thorough, methodical, and regular (systematic) application of practices, procedures and techniques (methods) specific to the investigation of wildland fires. There exists more than one systematic approach to fire investigation. The framework for problem solving within a systematic methodology discussed in this guide is the scientific method used in the physical sciences. This framework for problem solving provides for the organizational and analytical process desirable and necessary in a successful wildland fire investigation.

Methods: There are numerous methods which can be used within the framework of the scientific method to accomplish a systematic wildland fire investigation. These methods are often unique to the specific discipline and scene. The scientific method is a framework which in and of itself does not provide or specify the methods that should be applied in solving each problem. It is up to the wildland fire investigator(s) to select the best methods to apply to the specific scene or circumstances. This guide includes recommended methods generally suitable for application to most wildland fire investigations.

Selected methods used during a wildland fire investigation should be those which are recommended and accepted by the discipline and profession of wildland fire investigation. Methods which have not been generally taught or reviewed by the wildland fire investigation community are not excluded from use but should be explained in the documentation of each investigation report along with the reasons for the application of such methods.

A systematic application of methods which have been peer reviewed and accepted by the profession of wildland fire investigators will reduce the number of challenges on purely procedural grounds and add the credibility of the wildland fire investigation community to each investigation.

Consistent application of recognized methods used during wildland fire investigations leads to the development of good investigative habits and practiced skills.

Applying Systematic Method(s)

Facilitates investigative competency

- Helps avoid premature conclusions.
- Helps avoid bias.
- Helps avoid use of rumor, conjecture, speculation.

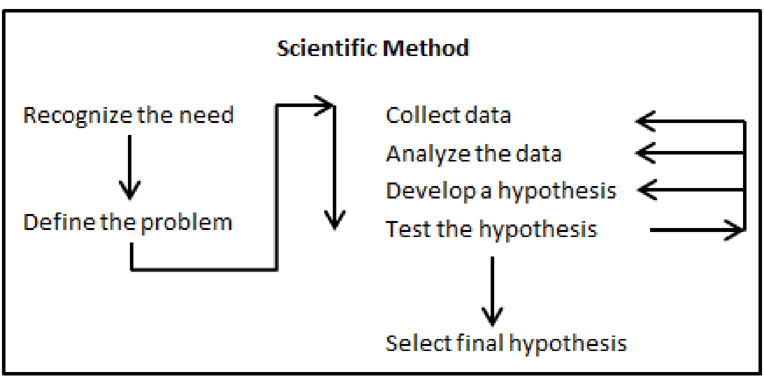
Facilitates consistent approach

- Investigation methods.
- Complete documentation.
- Applicable testing.

Relating fire investigation to the scientific method: The *scientific method* was not designed specifically for the investigation of wildland fires, or for that matter the investigation of any crime or violation. Therefore it may not be a perfect fit for all types of investigations but provides a framework for problem solving to which appropriate methods 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 a form of inquiry that is applied using the processes shown in Figure 67.

Figure 67. Diagram of scientific method.



A wildland fire investigation is really made up of a number of processes or parts (such as, fire pattern analysis, origin determination, cause determination, ignition sequence), each process or part can be accomplished individually or in concert with other parts by applying the scientific method to each. This often results in different parts of the scientific method being applied to different processes at, or nearly at the same time.

While some outlines of the scientific method show a step-by-step process, it should not be thought of as a linear process but rather an interactive process. Several parts of the process are often taking place at the same time or are repeated at different phases of the investigation. For instance, during the collection of data, analysis of the data will often be taking place relating to the reliability of the data, what the data means, and the formation of a working hypothesis. Further, during the testing of hypotheses, additional data may be used and existing data may be re-evaluated potentially causing new hypotheses to be formed.

Use of the Scientific Method

1. **Recognize the need**: In this case, a wildland fire has occurred and the cause must be determined and documented to identify potential responsible parties and focus future prevention efforts. The needs may be numerous and/or more general, such as; "*The agency needs to prevent future fires and to do so it must investigate each origin and cause to provide data for a fire prevention plan of action*."

2. **Define the problem**: Having determined that a wildland fire has occurred, the wildland fire investigator should define how the problem can be solved. In order to determine cause, an origin investigation must be conducted first. The problem may be defined more specifically, such as: a wildland fire was ignited ten days ago and the area of origin is only available for examination and investigation of the origin and cause.

Applying the scientific method, clearly recognizing the need, and specifically defining the problem, leads to the formation of an investigative plan which will assist in solving the problem and increase the potential of success. An investigative plan will focus on methods which generate empirical data (facts). An investigative plan will identify questions that need answering, specific sources of data, and how data is to be collected.

An investigative plan may be provided in writing or communicated verbally. During extended investigations, written plans are encouraged.

It is important that each member of the investigative team understand what the plan is and what their role is in carrying out the plan. To coordinate and update the plan on an extended investigation, one person should be responsible for reviewing all new data, convey the needed information into modifications of the plan, and make the wildland fire investigators aware of new pertinent data and how it relates to the plan and the investigation as a whole.

The key is to brief the investigative team members and provide them with the knowledge they need to be able to identify what the issues are and how data/information relates to the overall investigation. This may generate follow-up leads and inquiries.

A investigative plan states what the problem is, the objective(s), task(s) for reaching the objective(s), responsibility of tasks, and due date(s).

An investigative plan is valid until new data is collected which indicates a need to change the plan. Sometimes, this is simply done by crossing off a task when it is completed and other times it includes modifying the plan to reflect new investigative leads (tasks) that need to be assigned to someone and a due date established. As empirical data continues to be collected, the plan is modified to reflect the new information gained and new data collection needs. All investigation plans should be viewed as fluid and flexible, rather than a rigid framework that cannot be altered as circumstances change.

3. **Collect data**: In the investigative world, *empirical data* are simply *facts* based on observation and experience that justifies a belief in the truth or falsity of an empirical claim. The definition of empirical data (Merriam-Webster) contains three parts:

- Originating in or based on observation or experience <empirical data>.
- Relying on experience or observation alone often without due regard for system and theory <an empirical basis for the theory>.
- Capable of being verified or disproved by observation or experiment <empirical laws> (Merriam-Webster, n.d.).

The term *facts* is often used in investigative reports to mean much the same as empirical data. The wildland fire investigator should be aware that they may be questioned using the term, *empirical data* and they should know what it means.

Data collection starts upon dispatch. Data collection and analysis often take place at nearly the same time and at all stages of the investigation.

Facts (empirical data) about the fire are collected. This does not include rumor, conjecture, or speculation. This includes an examination and processing of the scene, consideration of the fire behavior context, interviewing of witnesses or other knowledgeable persons, collection of physical evidence and the results of scientific research.

Specific sources of empirical data include:

- Observations.
- Witness statements.
- Physical evidence.
- Experiments.
- Experience.
- Other data collection processes.

4. **Analyze the data**: Prior to using the collected data to form a hypothesis, an analysis for reliability should take place to assure that it is factual and verifiable (empirical data).

Only empirical data, that which is based on observation or experience, which is verifiable or true is used to form working hypotheses. Data collection may continue during this process.

A second analysis is then conducted to determine the meaning (explain the problem) of the empirical data. All of the empirical data (facts) collected are carefully examined in the light of the wildland fire investigator's knowledge, training and experience. Subjective or speculative information should not be included in the analysis, only facts that can be proven clearly by observation or experiment.

The wildland fire investigator should ask, is the data pertinent to the case? If so, what does it mean to the case? While a wildland fire investigator may be able to answer this question based on their knowledge, training, experience, and expertise, sometimes they may not be qualified or only minimally qualified to answer these questions. In that case, requesting assistance from a more qualified person in that specific area of inquiry may be the appropriate level of analysis. In many instances, an initial analysis may be made by the wildland fire investigator(s) which is later subject to further analysis by someone more specifically qualified. For example, the wildland fire investigator may have found a downed conductor within the ignition area of the fire that exhibits artifacts consistent with electrical arcing, based on their training and/or experience. The wildland fire investigator may legitimately form a working hypothesis that the conductor was the cause of the fire, but further examination and testing by an electrical engineer may be necessary to test this hypothesis.

Data collection may continue during this process, leading to the need for further analysis. The process of empirical data analysis continues as new data is received, validated, and compared to existing working hypotheses.

The ongoing analysis of new data may result in the reinforcing or modification of existing working hypotheses, disproving or exclusion of existing working hypotheses and/or the creation of new working hypotheses.

The analysis portion of the systematic process assists the wildland fire investigator in forming working hypotheses by avoiding speculation and conjecture.

5. **Develop working hypotheses:** Hypothesis: "…*an interpretation of a practical situation or condition taken as the ground for action*", "*a tentative assumption made in order to draw out and test its logical or empirical consequences.*" (Merriam-Webster, n.d.)

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 may be considered if the data supports such formation and consideration.

Empirical data collected is used to form working hypotheses using inductive reasoning. Empirical data is later used to test each working hypotheses in an effort to reject them using deductive reasoning.

Inductive reasoning is based on experience or empirical data alone, often without regard for system or theory. It is capable of being verified or rejected by observation (further empirical data) or experiment. The whole body of evidence (empirical data) is reviewed and considered using inductive reasoning to objectively analyze the data and form working hypotheses for a fire origin, cause, ignition sequence, etc.

Until data has been collected and analyzed, no hypothesis should be developed. It is not necessary to have all possible data prior to developing a working hypothesis but the data used should be reliable and adequate to form a working hypothesis which can be later tested against all the available empirical data. A hypothesis formed using initial empirical data may be later rejected or modified based upon new empirical data.

Based on the data analysis, the wildland fire investigator produces one or more working hypotheses that explain all of the known data regarding the origin and cause of the fire. These working hypotheses should be based solely on the empirical data that the wildland fire investigator has collected.

If more than one working hypothesis can fit all the data, it may be an indication that further data should be sought in an effort to come to a final single hypothesis. If one of the hypotheses is considered to be probable when compared to the empirical data, and others are only possible, then that is the hypothesis that will most likely be correct. (Probable and possible will be discussed later in this chapter.) Additional relevant data may be developed which will allow for further analysis of the working hypotheses and/or their rejection and/or the formation of additional hypothesis.

Potential Ignition Sources: Addressing potential ignition sources found in a specific origin area and developing working hypotheses should be based upon the data collected during the investigation, not the lack of data of a cause. Almost anything may be possible. Wildland fire investigators need to address what is reasonable based on the empirical data obtained.

Since the very basis for a working hypothesis is empirical data, there is no process for forming working hypotheses absent data which supports a given cause. For this reason, the exclusion of standard cause categories is not necessary unless there is data which indicates one or more categories 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 the formation of 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 determining the ignition area or finding physical evidence of an ignition source in an ignition area. This is an exception and typically includes admissions or eyewitness statements or other conclusive reliable data.

In most cases, the clear determination of a specific origin area and the search of that area in a systematic way will lend further data which can provide stronger evidence of a cause. Absent direct evidence of an ignition source, the wildland fire investigator may use the factors listed below to develop a working hypothesis and provide an opinion that the fire was of a specific incendiary or accidental cause.

Incendiary Factors Include:

- Origin area clearly defined and searched.
- No reasonable accidental ignition source is found after a thorough search of origin.
- Lack of accidental ignition sources.
- History of known and documented incendiary fires in area.
- Geospatial clustering of incendiary fires.
- Temporal clustering of incendiary fires.
- Multiple fires not related to accidental cause.
- Modified fuel bed.
- Ignitable liquids present not associated with other uses.
- Remote location with view blocked.
- Roadside area with low detection risk.
- Access blocked (gate, cut tree, etc.).
- Normally blocked access is open (unlocked gates).
- Fire suppression equipment committed or disabled.
- Witness statements.

The history of incendiary fires in the area should be recent, within the last few years. While two fires in close 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 incendiary can be formed.

The locations of historical incendiary fires should be such that when compared to the fire under investigation, the physical location is near other known incendiary fires, or in locations which are similar in nature to the other known incendiary fires, thus creating a *cluster* of like fires.

The time of day, day of the week, months, etc. create a common pattern which cannot be easily explained by coincidence. This may include the absence of fires during certain times of the day, days of the week, etc.

Multiple fires not related to an accidental cause, does not include two ignition area s near each other which can be attributed to evidence of a common accidental cause. For example, multiple fires along a roadside at the same general time may be determined to be incendiary in nature except when evidence of catalytic converter parts is found at the origin of one or more of them.

Modified fuel bed means the fuels in the ignition area have been arranged to facilitate the ignition, delay, and/or spread of the fire.

Remote area relates to the ease with which the scene is accessed and the level of protection from detection that the remote site allows.

Roadside areas with low detection risk includes nighttime fire starts when traffic is low and headlights can be seen from a distance or portions of a highway which allow someone to pull over to the side of the road and see long distances down the roadway for other traffic. This may also include areas where bends in the road at each end allow a person to eject an incendiary device without being seen by other traffic on the road.

Access blocked includes anything that may hamper fire suppression resources during their response. This may be created by the responsible party or simply taken advantage of by the responsible party.

Open areas that are not normally open indicate forced entry.

Fires occurring consistently during periods of fire suppression commitments to other incidents or when local fire equipment may have been tampered with to make it useless for fighting the fire.

Witness statements include those from reliable witness(es) who observe a person or vehicle of similar description leaving the area on multiple occasions or who actually see someone light a fire or other directly related observations. The wildland fire investigator should be cautioned against relying upon a single incident of a person or vehicle leaving the area as there are often witnesses who have nothing to do with starting the fire who leave the area without being identified.

These factors are not all-inclusive, the wildland fire investigator may consider other similar factors but should not rely on just one or two factors to determine a cause of incendiary unless the factor is significantly unusual and it clearly cannot be explained by mere coincidence.

Accidental Cause Factors may include:

- Origin area clearly defined and searched.
- No reasonable accidental ignition source is found after a thorough search of origin.
- No reliable factors of incendiary cause.
- Witness statements support a specific cause.
- Video tape or photographic evidence supports a specific accidental cause.
- Data supports specific cause.
- Data supports a specific activity taking place just prior to the fires ignition and detection.

6. **Test the hypothesis**: For a hypothesis to be valid, it has to be able to be tested and withstand such tests without it being rejected. A hypothesis developed without supporting empirical data is not a valid hypothesis. Testing is conducted by comparing all the empirical data (facts) and applicable scientific research in an effort 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 empirical data (facts) and scientific knowledge associated with the specific phenomena (Deductive Reasoning).

Deductive Reasoning

Reasoning from a hypothesis to account for specific empirical data, research or experimental results.

- Must be supported by the facts.
- Testing may be either cognitive or experimental.
    - Many fire causes will be tested cognitively, for example, based on knowledge, research and experience.
    - Others will lend themselves to further experimental testing.

Key analysis to this process is what other hypothesis could be supported by the same set of facts?

- If there are alternative hypotheses that are supported by the same facts, then the wildland fire investigator may not have gathered sufficient data.
- Gather more data and re-test.

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

Typical analysis questions that should be considered:

- Does the hypothesis make sense in the context of all the facts?
- What facts support/contradict the hypothesis?
- Is there research that supports/contradicts the hypothesis?
- Can a peer review reject/support the hypothesis?
- What interpretation may an opposing 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 conducted will focus on issues concerning the origin and/or ignition source of the wildland fire. It is recognized that it is impossible to replicate the exact conditions present at the location of a specific fire at the time of ignition. It is also recognized that published scientific testing and experiments often address similar but not precise conditions as those 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 recreate those conditions. Therefore, the wildland fire investigator should strive to collect all useful data at the scene that is practicable in an effort to reconstruct the scene conditions for testing purposes.

Example: If there are pine needles, dry grass, duff, punky wood, and bark present at the origin of the fire, it should be recognized that each specific fuel can have a different ignition temperature/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, as far as possible, it is important for the wildland fire investigator to identify all the components of a fuel bed.

Knowledge and experience pertaining to wildland fuels and their ignition characteristics is one way to test these fuels in *thought experiments*. Ignition tests may be conducted specifically on each of these components as it is often impossible to say just which of these fuels was the first fuel ignited.

Testing by *thought experiments* may be augmented by various degrees of physical testing, at the same time or at a later date. Physical testing can, and often will, be conducted by the wildland fire investigator and/or others more qualified. For physical testing to be valid, it should closely represent the conditions and circumstances actually present and test all components of the item at issue.

Physical testing of a hypothesis may result in casting doubt upon a hypothesis but fall short of rejecting it. In such a case it is up to the wildland fire investigator to determine if the doubt is significant enough to change their level of confidence in their opinions. Testing which casts doubt upon 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 should be developed and tested. This development and testing may include the collection of new data or the reanalysis of existing data. All feasible hypotheses should be tested in this manner.

If no hypothesis withstands the testing process, the cause should be undetermined at that time. The development of additional data or analysis may provide for the determination of cause on a fire cause previously classified as undetermined.

7. **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 which is not rejected by the data or fits the data to the level of probable. There may remain hypotheses which 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 wildland fire investigator who must be able to support such an opinion with the known data.

When two or more hypotheses withstand testing, the wildland fire investigator must determine if the facts support one hypothesis to be probable, over others that are just reasonably possible. When all hypotheses not rejected by the data are considered to be reasonably possible and none rises to the level of probable, the cause of the fire should be listed as undetermined.

Level of Certainty: The wildland fire investigator is being asked for their opinion based on their confidence in the data, data analysis, and testing of the hypotheses. There are two levels of certainty, Possible and Probable.

Possible: Hypothesis is feasible but not to the level of probable.

Probable: Likelihood hypothesis is true is greater than 50%.

If two or more hypotheses are equally likely, then the level of certainty must be *possible* for both.

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

Select the hypothesis that best explains all of the known facts surrounding the origin and cause of the fire. This will then become the theory of the case that conclusions will be based upon.

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

Premature Assumptions: Wildland fire 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 wildland fire investigator to come to a final conclusion after all reasonably available pertinent information has been considered.

The wildland fire investigator should avoid presumption 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 without considering all relevant data, discounting data, or failing to seek data pertinent to the investigation. Data developed by a wildland fire investigator indicating certain activities or events does not necessarily indicate expectation bias.

For example, a witness providing a statement early in the investigation indicating a certain potential cause of the fire, does not of itself constitute expectation bias unless the wildland fire investigator ignores factual data that could indicate other potential causes.

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

Confirmation Bias: Using the data to prove a hypothesis rather than test it and attempt to disprove it. Test all hypotheses for which there is supporting data. A hypothesis without a basis in empirical data is not a valid hypothesis.

Methods

Arrival on Scene

The investigation begins at the time of dispatch. Certain investigative practices take place during the receipt of the dispatch and during the response to the fire which will be discussed in combination with documentation of such activities in Chapter 5, Documentation.

Record the date and time of your arrival at the fire. The conditions at each fire may be different and will dictate the order in which the following actions are taken, but they all should be completed shortly after arriving on scene. Make notes of your actions.

Upon arrival at the fire scene, many issues will be competing for the attention and time of the wildland fire investigator. Sizing up the needs and situation should lead to a plan of action. The investigative plan, discussed earlier in this chapter, will often initially be verbal in nature but may need to expand to a written document during extended investigations.

The need to plan investigations remains constant and ongoing.

Based on the number of tasks that need to be completed and the time and effort required to accomplish them, the lead wildland fire investigator should form a plan of investigation which identifies needs for additional resources such as additional wildland fire investigators, law enforcement, other experts, etc. Resource requests should be made in a timely fashion considering the time lag for response of such resources.

Additional resources may include specialized personnel who can provide technical assistance. A wildland fire investigator should never hesitate to call on another fire investigation expert who has more knowledge or experience in a particular aspect of the investigation.

Wildland fire investigation is a specialized field. Those individuals not specifically trained and experienced in wildland fire investigation will usually not be qualified to render opinions regarding fire origin and cause. They may, however, be able to give the qualified wildland fire investigator additional data which will aid in developing a sound theory of the origin and cause of the fire. A wildland fire investigator should know and follow agency policy when requesting specialized personnel or technical consultants.

The following descriptions are general and should not be considered all-inclusive.

Fire Behavior Analyst: A qualified wildland fire behavior analyst 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 wildland fire investigators in locating areas for collection of samples for laboratory analysis to identify the presence of ignitable liquids. Other very specialized canine/handler teams are capable of tracking the responsible person(s) to and from the general origin area of wildland fires. 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 needed legal assistance with regard to 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.

Geographic Information Systems (GIS) Specialist: With the increasing use of Global Positioning System (GPS) data and the accuracy of GIS mapping technology, consider including a GIS specialist on the investigative team to produce maps of the fire and diagrams of the origin scene.

Other Specialists: 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 make arrangements to have the additional resources respond to the incident. If there is evidence of non-fire related criminal activity, immediately notify the proper authorities. Considerations for determining the number of wildland fire investigators assigned include available staffing, complexity, number of witnesses, and the size of the area to be investigated.

A minimum of two wildland fire investigators is recommended when forming an *investigative team* for some wildland fires. However, on occasion, circumstance may dictate that one wildland fire investigator will be responsible for all investigative tasks.

When multiple wildland fire investigators are assigned to the investigation, each person should be clear about what their responsibilities are and what the reporting expectations are. It is up to the lead wildland fire investigator to communicate this information to each investigative team member.

Safety issues: Safety is the first priority. Safety issues should be identified and mitigations incorporated into the investigative plan. Conditions at a scene may prevent the immediate search for the origin of the fire. If this is the case, secure the general area or heel of the fire as best as possible. Other tasks such as taking weather, identifying and interviewing witnesses, evidence protection, etc. should continue in a timely fashion as conditions allow.

Establish fire behavior context: Note 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 your observations.

Record weather: Record temperature (wet and dry bulb), relative humidity, wind speed and direction in degrees, cloud cover, etc., and obtain fire weather readings taken by first responders. Weather readings taken as near to the general origin area as possible, and as soon after the fire's ignition are the most useful for understanding the initial ignition and fire spread. 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 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 weather station readings for the time of ignition may be of more value than on scene weather data taken hours after the ignition took place or from non-representative locations.

On-scene weather readings, even taken hours after the ignition, may help to validate the most representative remote automated weather stations (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 the general elevation, aspect, shading, and fuels as those at the actual fire scene. The nearest RAWS station may not be the most representative.

Preliminary area of protection: Protection of the scene from further damage and contamination is a priority item. Scenes which have already been damaged by suppression actions or other activities do not exclude the need to protect the scene once the wildland fire investigator arrives. In some cases, trained fire suppression personnel who understand the need to protect the general origin area will have already identified what they believe to be its location and taken steps to protect it.

The preliminary area to protect is generally identified based upon the fire behavior context, macroscale fire pattern indicators, and witness statements. Witness statements include information from first responders and where they located the heel of the fire, if they have done so. The wildland fire investigator should test the first responders' hypothesis as to the location of the heel of the fire by comparing it to other witness statements, the fire behavior context, and macroscale fire indicators.

Based on these factors, the heel of the fire should be identified and secured as well as possible. This area can be small, a tenth acre or less, or it can be of significant size, 5-50 acres or more, depending on the individual fire size 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 needs, and public interest. Barrier tape and flagging may not be reasonable on larger size fires where the heel area is in excess of an acre in size and verbal warnings may be needed to be given to suppression personal. Road blocks may need to be considered. If needed, post a security person at the area of protection and provide that person with clear instruction concerning access to the area.

Equipment and firefighters must be routed around this area. As much as possible, ensure that no one places any foreign materials in the area of protection. When appropriate, log the names and times that wildland fire investigators or any other persons enter and leave the secured area of protection. If the fire is such that an area of protection is not easy to locate quickly, as far as possible restrict access to a larger area that you believe contains the fire's general origin area.

Witnesses: Interviewing witnesses is a key component to establishing the initial area of protection and general origin area and is very important to the investigation overall. Witness statements should be analyzed for reliability and tested against the fire behavior context, fire pattern indicators, and other witness statements before using as part of the empirical data/factual information to form a working hypothesis. Note that multiple witnesses may have seen the same event from different perspectives and that their understanding of a complex incident may be skewed by their personal experience, education and location.

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

- Names and identifying information, such as date of birth, driver's license number, physical address, phone number.
- Make, license 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.

Civilian or suppression witnesses can provide information including:

- Size of fire on arrival.
- Specific fire behavior.
- Fire progression.
- Suppression strategy.
- Weather conditions.
- Evidence.
- Other witnesses.

Locating and Protecting Physical Evidence: Physical evidence can be almost anywhere. A reasonable search of the area in and around the heel of the fire and access routes or other areas of potential activity may produce physical evidence which will need to be protected and secured. This may include areas removed from the fire origin.

Evidence Protection Area: The area where a reasonable expectation that evidence may be found, based on experience, observation, location and specifics of that incident.

- Both outside and inside the burn.
  - Look up, down, and all around.
- Be cognizant of where you put your feet and where resources drive and park.
- Minimize the impact.

When walking around, look before you plant your feet inside and outside the black. Walk where you walked before when possible to minimize impact. Be mindful of where you and others park.

Minimize the impact of all activities whenever possible. While protecting the general origin area, look for such things as equipment, vehicles, tracks, discarded items, or any other objects or impressions that may have value as evidence. Do not disturb these objects until they have been properly documented. Flag or otherwise protect anything you find. Footwear impressions at or near the general origin should be protected and traffic should be re-routed around them.

Areas of the Fire

The *General Origin Area* may be anywhere from a few square yards to an acre or two in size. The wildland fire investigator should re-evaluate any area flagged by first responders to ensure that it includes the fire's likely Ignition Area.

Even with large areas, there is a systematic method for identifying the Ignition Area where the fire started. Fire behavior is controlled 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 various fire pattern indicators, when taken together, analyzed within the fire behavior context, and compared with witness statements, can lead the wildland fire investigator to the Ignition Area.

The origin area of a wildland fire is broken down into the following components; overall fire area, General Origin Area, Specific Origin Area, and Ignition Area.

Overall Fire Area: Also referred to as the heel of the fire. This is the area which surrounds the General Origin Area. This area should be large enough to be sure that the General Origin Area is contained within it. The overall fire area is formed by the first major advancing vector of fire and the associated lateral transition zones. This area is often visible from the air on a large scale in the form of a larger macroscale V or U pattern. It continues well into the area of macroscale backing fire pattern indicators. This is the area where the investigative team will begin its on-scene search for the General Origin Area.

General Origin Area: The area of the fire that the wildland fire investigator can narrow down based on macroscale indicators, witness statements and the fire behavior context. It may be a limited area or several acres in size but is typically less than one half acre in size.

The size of the General Origin Area is going to be dictated by what the indicators determine, not the potential ignition sources. Once the General Origin Area has been identified by use of macroscale indicators, witness statements, and the fire behavior context, a boundary may be determined and marked. The General Origin Area is recommended to be the smallest area to be protected during the scene investigation.

Specific Origin Area: 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. The Specific Origin Area is where the wildland fire investigator is primarily looking at microscale indicators and generally needs to be down on their hands and knees or stooping to observe the indicators and potential evidence.

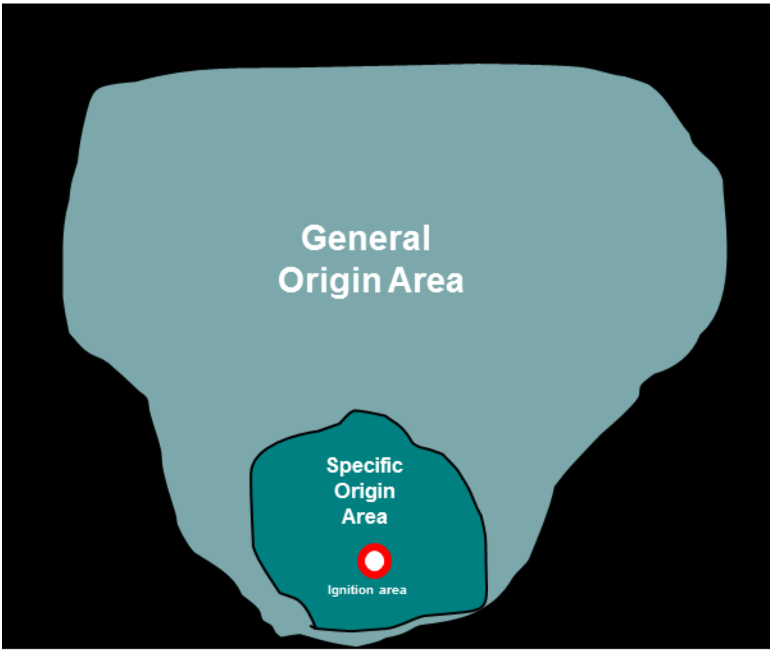
Generally this area is characterized by lower intensity burning and subtle microscale fire pattern indicators. It will usually be no smaller than about 5'x 5', and may be substantially larger, depending on indicators and other factors.

Ignition Area: Contained within the Specific Origin Area will be the smallest location which a wildland fire investigator can define, within the Specific Origin Area, in which a heat source and fuel interacted with each other and a fire began. This is the Ignition Area. The area near or in the Ignition Area is where the chances of any physical evidence of the actual ignition source increase. The Ignition Area should always be validated by fire pattern indicators no matter how obvious the ignition source is.

In most wildland fire investigations, an exact point where the first fuels ignited and came into contact with a heat source, a Point of Origin, cannot be determined. This is due to the fact that from the time that a fire originates, is ignited, to the time a wildland fire investigator arrives at the Specific Origin Area, decomposition of the fuels and other physical makeup of the scene has altered or destroyed portions of it, particularly on the microscale. Thus it is far more realistic to speak in terms of the smallest area able to be defined based on the fire pattern indicators.

Point of Origin: The exact physical location within the Ignition Area where a heat source and the fuel interact, resulting in a fire.

Figure 68. Drawing of an Ignition Area, Specific Origin Area, and General Origin Area.



Determining the General Origin Area

When working to identify the general origin area, it is recommended that the wildland fire investigator(s) first identify an advancing area of the fire consistent with witness statements and the fire behavior context. This is often identified by high intensity burning and higher consumption of fuels. Evaluating damage differential between areas of high fuel consumption and those of lower or low fuel consumption will assist in the identification of advancing, lateral, and backing fire spread on the large scale.

Frequently this will be the area which shows the cleanest burn, and may be characterized by a classic and larger scale V or U-shaped pattern. It is often bounded on both flanks by lateral fire pattern indicators showing less complete consumption of fuels.

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 towards its source.

Care should be exercised in not starting the search for the general origin area too close to the transition of advancing and backing vectors. Multiple ignitions that burned into one fire will have multiple advancing areas, some of which can be missed if the search for a single general origin area is started too close to the advancing and backing transition zone. If more than one advancing area is located within the heel area of the fire, all should be traced back to their source to determine if multiple ignitions took place or if all advancing areas can be tied through fire pattern indicators to a single origin. In the case of a single source of ignition, all advancing fire patterns should lead back to the same source, sometimes including areas of transition from advancing to lateral and/or backing fire spread.

General Origin Area Investigation Techniques

Once the general origin area has been narrowed down using macroscale indicators, considering the fire behavior context, and witness statements, it is then necessary to identify the actual general origin area boundaries. If other resources are there and available, for example, canine or man tracker, these other resources should be consulted about the plan of action and needs prior to entering the general origin area.

Walk the exterior perimeter. When transition zones, control lines, or other information indicates that it is safe to do so, walk the perimeter of the general origin area twice, once in each direction: once in a clockwise direction and once in a counter clockwise direction. Look at the unburned area as well as the burned area for evidence and comparison fuels. Examine and mark directional fire pattern indicators at the perimeter of the general origin with colored flags or other appropriate markers once they are located. If evidence is located, protect and mark it with white flags. Mark the boundary of the general origin area once it has been confirmed and re-assess security needs.

Identify advancing fire area. Identify the initial run that the fire made within the general origin area. Frequently, just as in the overall fire area, this will be the area which shows the cleanest burn, and may be characterized by a classic smaller scale V or U shaped pattern. This smaller scale V or U pattern may be part of the larger V or U pattern or a separate V or U pattern which leads towards the macroscale V or U pattern. It is often bounded 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 which produces the least scene disturbance possible. Photograph the general origin area prior to entering. Once the initial run has been identified, the general origin area should be entered from the head or advancing side of the run; this is the side generally furthest from the suspected ignition area. The reason to enter from the advancing side is that the fire pattern indicators are more obvious in this area and the wildland fire investigator is less likely to *overrun* the specific origin area than if the general origin area is entered from the heel or backing side of the fire.

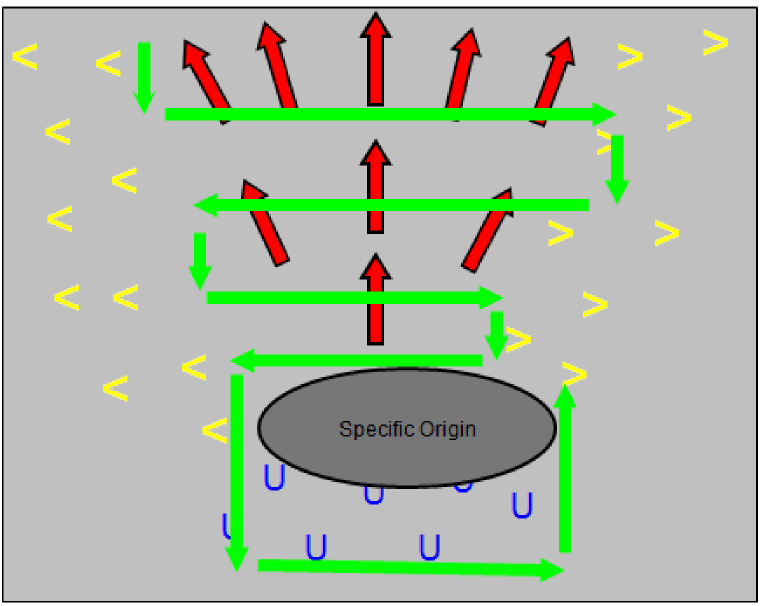
Each scene is unique. There may be exceptions to this recommendation such as fires that do not include advancing indicators. For example, a fire burning from a roadway into the wind or downhill may only demonstrate lateral and backing indicators; fires starting on a ridgetop or peak may only demonstrate 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. The recommended method for these situations is to follow the most demonstrative indicators back to where they come together. In addition, if the general origin area is on a steep slope where material and soil may be dislodged by the wildland fire investigator and roll down-hill and disturb the specific origin area, then the wildland fire investigator may choose to enter from the backing or heel side of the general origin area and work up-hill in an effort to protect the scene. Another example would be when features such as roads and other breaks in the fuel allow for access while still protecting the specific origin area. Wildland fire investigators are encouraged to use the technique which 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 wildland fire investigator should search a pattern from lateral transition zone to lateral transition zone while moving progressively closer to the location where the fire came from. Care should be used to inspect the ground where the wildland fire investigators place their feet prior to disturbance for the presence of evidence and or fire pattern indicators.

Work the General Origin Area

- Enter from the advancing area when appropriate.
- Work across the run until the lateral transition zone is reached.
- Move several feet closer towards the origin and re-cross the advancing run to the opposing lateral transition zone. Repeat above steps until specific origin area is reached (Figure 69).
- Walk around the specific origin area perimeter once in each direction taking care to stay well outside the initial backing area as shown in the figure below.

Figure 69. General Origin Area search pattern design to find the Specific Origin.



Identify fire pattern indicators: Mark the location of each fire pattern indicator located with a visible marker. Color-coded pin flags are the most visible and easiest markers to use (see Figure 70).

Recommended colors include:

- Red – advancing fire indicator.
- Yellow – lateral fire indicator.
- Blue – backing fire indicator.
- White – evidence only.
- Lime green – items or points of interest.

Use lime green flags for areas, items, or points of interest (for example, the four corners of the ignition area). Explain the lime green flags in the report. One suggested technique is to lean the indicator flags in the direction that the fire is spreading toward.

Figure 70. Example of general origin area with red, yellow, white, and blue pin flags identifying the fire pattern; and green pin flags identifying items of interest.

Work the Specific Origin Area

The manner in which you conduct the search of your specific origin area (SOA) will be dependent upon the specific conditions that exist on your scene. There are a number of suitable techniques available to conduct a search of a SOA. Whatever method is chosen should reflect a systematic approach that protects scene integrity as much as practical.

Three techniques for conducting a search will be discussed in this section that may or may not be applicable to your specific scene. There are common tools that may be employed as needed in all three of the search techniques which will be discussed following the description of the three techniques themselves.

Prior to applying any search technique to the SOA it is important that the wildland fire investigator(s) do the following:

Identify the specific origin area:

- Mark specific origin area boundary.
- Walk perimeter at least twice.
- Examine/photograph area prior to entering.
  - Indicators.
  - Visible potential ignition sources.
  - Other evidence.

The following three search techniques are not intended to limit or exclude the use of other applicable systematic search techniques:

- Perpendicular lane search technique.
- Parallel lane search technique.
- Grid search technique.

Perpendicular Lane Search Technique

- Walk the perimeter at least twice before entering and photo document prior to entry, being careful not to walk in the area of the backing fire transition. Consider using binoculars to identify and examine indicators, possible evidence, and visible potential ignition sources prior to entering the SOA.
- In most cases, start in the advancing area of the fire and work toward the ignition area.
- Establish lanes one at a time perpendicular to the fire run.
    - Use of colored twine and stakes recommended.
    - Uniform width: (12-18 inches apart).
    - Enter from the advancing side of the fire.
    - Continue to work towards origin.
- Systematically move twine and stakes forward to form the boundary of the next lane. Be careful to make sure that there is overlap in the examination of each lane to assure that gaps do not occur in the search coverage.
- When multiple wildland fire investigators work side by side searching each lane, make sure that there is overlap in search coverage between adjoining wildland fire investigators.

Figure 71. Perpendicular lane search technique.

Parallel Lane Search Technique

- Walk the perimeter at least twice before entering and photo document prior to entry 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 prior to entering the specific origin area.
- In most cases, start in the advancing area of the fire and systematically work toward the ignition area.
- Multiple lanes are laid out parallel to advancing fire progression, towards the suspected ignition area. Ensure that far lane ends are established in the green or well into the backing area. Do not disturb the specific origin area when laying out lanes.
- This technique works well with multiple wildland fire investigators and or when working a narrow specific origin area.
- When multiple wildland fire investigators are used to work side by side searching each lane, make sure that there is overlap in search coverage between adjoining lanes and wildland fire investigators.

Figure 72. Parallel lane search technique.

Grid Search Technique

- Walk the perimeter at least twice before entering and photo document prior to entry making sure not to walk in the backing indicator transition zone. Consider using binoculars to identify and examine indicators, possible evidence, and visible potential ignition sources prior to entering the specific origin area.
- Search process when using the grid will be dependent on the scene.
- Squares or rectangle size is dependent upon scene circumstances. Make sure that grids extend beyond the edges of the specific origin area. Use caution when laying out the grids to avoid disturbing the specific origin area prior to the search.
- This technique is useful when the locations of multiple pieces of evidence need to be documented or when you plan on collecting the debris for sifting/examination. Photo document the location of evidence within each grid and label by grid ID, such as “Grid 3A”.
- Grids should be numbered and lettered for documentation. Tie collected evidence and/or debris to each grid designation.

Figure 73. Grid search technique.

Tools for Searching a Specific Origin Area or Ignition Area

Whether using a perpendicular lane, parallel lane, or grid search technique, the following practices and tools may need to be applied.

Search each lane or grid as needed:

- Visually.
- Using magnification as necessary.
- Remove lightweight debris by brushing or blowing.
- Use straight edge to focus search pattern.
- Continue locating and marking indicators with flags.
- Employ magnet search for ferrous metals.
- Metal detector search for non-ferrous metals.
- Screen debris and/or bag debris for future analysis when appropriate.
- Continue until the ignition area is identified and/or ignition source is located.
- Document and secure any evidence.
- Continue searching past ignition area or evidence until clear backing indicators are encountered.
- Document the perimeter of the specific origin area.
- Document the location/perimeter of the ignition area.

In all cases, continue to work search pattern up to and through the ignition area.

Visual Search and Magnification: There are a variety of conditions that may exist at each specific origin area depending on the fire intensity, fuels present before and after the fire, and other possible variables. Variations within the fuel bed at the specific origin area may necessitate the use of magnification in some parts of the visual scan and not in others. Magnification can include a standard magnifying glass, high powered reading glasses, or other such devices.

Remove Lightweight Debris: There are many tools that can be used to carefully move lightweight debris during the visual examination. Gently blowing on the debris is often enough to move it and assist examination. Using a bulb syringe is another tool commonly used to carefully move lightweight debris. Hair picks and forceps can also be used along with any other tool which allows for the careful removal of the lightweight debris without causing contamination.

Straight Edge: The use of a straight edge or other such techniques to keep track of the area being visually searched, and in some instances to assist in focusing on an area, helps to conduct a complete visual search. The application of the straight edge or other technique should not disturb any area not already searched and should not cause any contamination of the scene.

Mark Microscale Indicators with Flags: During the systematic search of the specific origin area, the wildland fire investigator(s) will also be searching for microscale fire pattern indicators which will help to narrow the specific area down to the ignition area itself. Microscale indicators should be marked with pin flags according to their directional vector and documented.

Magnet: The use of a pull-release type magnet to search for ferrous metals is recommended. Note the name and model of the magnet used along with the pulling strength of the magnet. Move the magnet just above the surface of the debris in a systematic pattern which overlaps to assure that the entire area is covered. It is recommended that the magnet surface be visually checked after each pass to identify any objects collected and the approximate location of where it came from.

One option for using a magnet is to place a plastic zip lock bag over the magnet turned inside out, which can then be turned right side out when an object is picked up. Thus the object is captured within the zip lock bag as evidence. Another way to collect the objects from the face of the magnet is to place a clean piece of paper underneath it when the pull-release handle is pulled, dropping the object onto the paper for photographing and/or placing into an evidence container.

In any case, photo documenting of the objects collected should be done as soon as it can safely be done, and may be done a second time under conditions more favorable for better quality photographs.

Metal Detector: Use a commercial grade metal detector to search for non-ferrous metals as needed. Use a systematic search pattern which overlaps to assure full coverage.

Screen Debris or Collect Debris: If a decision is made to screen the debris in each search area, it 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 for conducting a search allows for more precise locating of where each bag of debris came from. Each grid can be marked and the debris in most cases from each grid put into a single bag. Grid sizes larger than 18 inches square are not recommended, and 1foot square grids are common. Photo documenting each grid prior to and after collection of debris is recommended.

Screening or collection of debris may be used as an option only in the ignition area as determined by the wildland fire investigator(s) dependent on each scene’s needs. It is better to screen/collect too large an area than too small an area.

Secondary Opinion: Consider the need for a secondary origin and cause investigation or second opinion. Situations which may indicate the need for a secondary origin and cause investigation include major cases and/or when no physical evidence of the cause is found.

If a secondary origin and cause investigation is planned, the origin should be kept secured and as undisturbed as possible. Scene integrity, contamination issues, level of security needed, and needs for long term security should be addressed depending on the individual circumstances.

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Chapter 3 - Fire Scene Evidence

Types of Evidence

Evidence is classified into two broad categories

Direct: Testimony of witness who sees the act. A witness observes the defendant at the scene, setting the fire. Other senses also apply.

Circumstantial: Tends to prove a fact in dispute indirectly. Tire prints that match the defendant's vehicle recovered at the scene, Deoxyribonucleic acid (DNA) recovered from an arson device, are both examples of circumstantial evidence. Eyewitnesses to the actual setting of a wildland fire are an infrequent occurrence and most cases will rest on circumstantial evidence.

Evidence is further categorized by type

- Testimonial: Testimonial evidence is that which is testified to by a witness having firsthand knowledge. This may be observed or experienced. For instance, a witness observed defendant light burn barrel, witness smelled smoke, witness heard fireworks, or witness saw tire tracks. Testimonials can be direct or circumstantial.
- Real: physical or documentary: Real physical or documentary evidence are tangible items which help to establish a fact. Examples of physical evidence could be footwear impressions found near the scene or remains of an ignition source. Examples of documentary evidence may include burning permits, ownership maps, and social media.
- Demonstrative and Judicial Notice: Models, charts and graphic aids are examples of demonstrative evidence. Judicial notice refers to certain facts which are already well established and are common and of verifiable knowledge.

Admissibility of Evidence

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 as reliable, it must be competent and authentication establishes that it is the same item as collected by the wildland fire investigator. Further, 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 chain of custody.

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

- Non-private 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 owner, not recommended, difficult to establish proof, consult with prosecutors.
- Warrant (Criminal or Administrative) - A court order directing the wildland fire investigator to search for and seize specific items. This is a preferred method. Some jurisdictions allow for an administrative warrant where legal justification needed is substantially less than a criminal warrant.

In most wildland fire investigations, the wildland fire investigator can expect to recover the majority of evidence from private areas under the Plain View Doctrine and/or exigent circumstances.

Legal References to Evidence

Michigan v. Tyler

In Michigan v. Tyler (U.S. Supreme Court, 1978) fire officials investigated a fire while it was still burning. They re-entered the building the following morning after temporary interruption due to safety and visibility concerns and found evidence of arson. They continued to re-enter over the next several weeks. The evidence was challenged on grounds that re-entry was unconstitutional. The court ruled that the first two mornings were legal entries. Subsequent entries were ruled illegal and evidence suppressed.

As a result, the U.S. Supreme Court established legal authority for wildland fire investigators to conduct a warrantless search for evidence of the origin and cause of a fire based on public safety concerns and exigent circumstances.

- Court held that while a fire is still burning and under control of fire department a warrantless entry to determine the cause of the fire is reasonable.
- Evidence in plain view may be seized.

- Temporary interruptions due to hazards, poor visibility, etc., allow for subsequent warrantless re-entry within "*a reasonable time period*" (no bright-line rule).
- Absent "*exigency of sufficient proportion*," re-entry must be by consent or warrant.

If a wildland fire investigator must come back the next day, it is recommended that you have the property owner sign a consent to enter form. Consult with local law enforcement or District Attorney regarding local practices and considerations concerning private and public lands, and curtilage issues.

Michigan v. Clifford

In Michigan v. Clifford (U.S. Supreme Court, 1984), investigators arrived five hours after fire suppression crews had left the scene of a fire in a private residence.

Investigators found evidence of arson at the origin area and additional evidence in an area well away from the origin. No warrant or consent to search was acquired by the investigators. The search was ruled unconstitutional and a motion to suppress was granted.

As a result of Michigan v. Clifford, the court further defined legal parameters regarding the legality of an origin and cause investigation conducted after an emergency or exigent circumstances cease. A search of a fire scene was ruled unconstitutional and motion to suppress granted when the court determined that exigent circumstances had no longer existed at the time that access to the scene was made.

Collection and Preservation Procedures

Whenever possible, clean latex gloves should be worn when handling or working with evidence items.

Non-fragile fire cause objects

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

- Metal fragments.
- Catalytic converter particles.
- Welding slag.
- Power line hardware.

Collection procedures

- Carefully pick up and place in folded paper bindle.
- Place into hard sided container.
- Pack in cotton to keep fragile edges from breaking off.
- Seal and tag.

Fragile fire cause objects

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

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

Collection procedures

Some items can be picked up carefully by hand.

- Place in a bed of cotton in a hard sided container.
- Seal and tag and hand-carry to lab.
- Consult with your laboratory if unsure how to properly package any item of evidence.

Basal area lift technique

Technique used to prevent damage to fragile items. Use clean shovel or trowel and thin piece of flexible sheet metal. Clean tools with approved cleaning materials between each collection.

- Score line through ash & duff, down to soil around the object
- Leave border of several inches surrounding the object.

- Work the shovel or trowel into the dirt, under the object, until the clod of dirt and ash with object has been freed.
- Slide sheet metal under it and lift the clod intact.
- Place the metal and clod into a cotton padded container of appropriate size.
- Seal, mark, and hand carry to lab.

Figure 74. Basal area lift technique.

Ignitable liquid residue

Indicators

- Obvious signs of trailers and pour patterns; puddling; deep seated burning; scorching and sooting.
- Strong odor of gasoline and/or diesel, but deodorized kerosene, lighter fluid, alcohol and others may not be detectable by smell.

Search techniques

- Search perimeter areas.
- Use a canine (K-9) trained team to detect ignitable liquids or a portable hydrocarbon detector.

Figure 75. Canine and handler.

Sampling locations

- Take samples where the K-9 or detector registers 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 and in areas where the liquid may have been shielded from the heat.
- Deep compacted duff, punky logs and stumps that have not consumed completely.
- Areas of sparse vegetation or bare soil.
- Detectable amounts of hydrocarbon residue may remain in the soil for lengthy periods after the fire; however, microbial action may degrade the sample quickly.

Collection procedures

- Pick up suspected charred wood, soil or vegetation and place in a clean metal can (no glass) or other approved container or wrapping material.
- Fill can no more than 2/3 full with material.
- Avoid direct and cross-contamination.
- Clean collection tools with approved cleaning materials between each sample.
- Have new, unused can or packaging materials available for comparison sample at lab.
- If delay of more than several hours in getting sample to lab, samples should be frozen.
- Any containers found near or at fire scene should be collected.
- If there is still liquid present, pour a small sample (203 ccs) into a clean container with an airtight, non-rubberized seal.
- Seal and mark the container and hand carry to lab. If it will be several hours, store in a cool environment.
- Most crime labs will be able to isolate ignitable liquids by means of gas chromatography/mass spectrometry (GC/MS) analysis and other tests.

Firearms

- Never submit a loaded firearm to a lab unless it is delivered in person and then with advance approval of the lab.

Projectile evidence

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

Cartridge cases

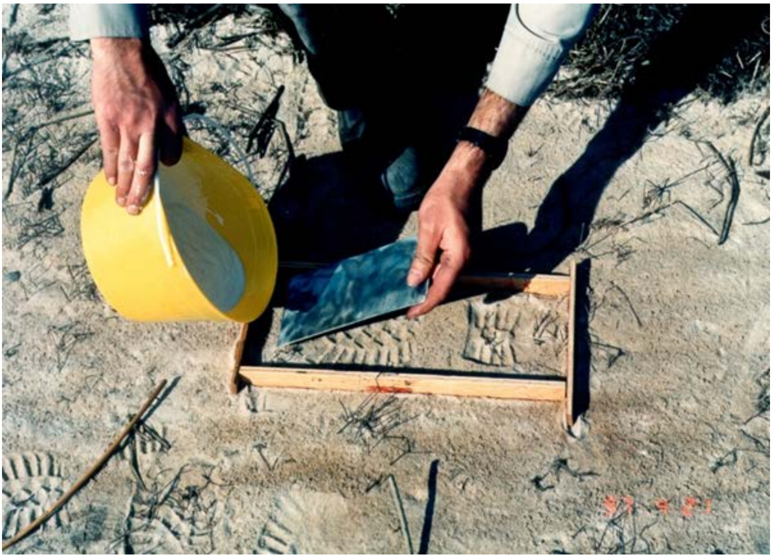
- Wrap each case in a separate paper bindle and seal in separate hard sided container.
- Seal and mark accordingly.
- If comparison to a firearm is necessary, submit both to lab.

Footwear & Tire Impression

Collection procedures:

- Photograph using a tripod to position the camera directly over the impression. Use a normal lens (50 mm).
- Place a linear scale next to and on the same plane as the impression.
- Set the f-stop on f/16 or f/22 for a greater depth of field.
- Photograph with the flash at different angles, between 15 and 45 degrees.
- Shoot several photos, move the flash two or more angles to the impression.
- Cast with dental stone.
- Once a cast is made, do not clean it off.
- Wrap it in tissue, dirt and all, and place in a cotton padded box, pack securely, seal and mark accordingly.
- **Shoe impressions should usually be cast.**
- **Casting of a tire impression is problematic:**
  - Difficult to match impressions to an individual tire.
  - Effort involved is significant.
  - Many crime labs prefer photographic documentation of tire impressions.

Figure 76. Casting of shoe impression using dental stone.



As with all types of evidence, collections that will be submitted to a lab for analysis, contact the lab prior to the need and get an understanding of their preferred methods.

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 (Deoxyribonucleic acid). from fingerprints. Do not assume that the fire has rendered latent print evidence unrecoverable.

Collection procedures:

- Handle object in such a manner as not to add extra prints to it; latex or nitrile gloves should be used.
- Package objects in a box in a manner that they will not break or roll around.
- Do not package fingerprint evidence in plastic bags.

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. Consider anything that may have been contacted, such as beverage containers, clothing, cigarette match device, or food.

Collection procedures:

- Collect items believed to contain DNA evidence with a gloved hand or clean tools, using fresh gloves and cleaned tool for each sample collected.
- If the item has wet blood, semen, or saliva, air dry the item prior to packaging.
- Package item in clean paper or envelopes with sealed corners: do not use plastic.
- Submit to local crime lab as soon as possible.
- If there are questions, contact your local crime lab for directions on correct collection and packaging procedure.

Miscellaneous evidence

Other types of evidence may include:

- Paint transfers.
- Blood stains.
- Hair and fibers.
- Glass fragments.
- Soil.
- Tool marks.
- Trace evidence.
- Trailing K-9 (scent evidence).

Trace evidence - found in small, but measurable amounts. Examples include hair, fibers, blood, or soil. Scent evidence includes where subjects have been at or around the scene.

Photography

Photographs provide visual representation of a fire scene.

Photographs must be a fair and accurate representation of the scene.

Photographs are the best method of reproducing any scene and can record facts more accurately than a word description. Photo documenting the scene will be further addressed in Chapter 5, Documentation. Photographs can provide the following advantages:

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

Camera Kit

- Digital Camera (back-up camera is recommended).
- Macro lens.
- Wide angle lens.
- Zoom lens.
- Tripod.
- Removable flash.

Photography Guidelines

Prior to moving: Evidence should be photo documented in place as it is found. This should include photos which show the location where the evidence is in relationship to other key features of the scene and close-up photographs that show the details of the item to be collected and the area immediately around it. The evidence should then be photographed with a scale in close proximity, being careful not to touch or contaminate the evidence item.

Figure 77. 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 both using photography and videography. This documentation may include the methods used for collection, the tools used, and the container used, including markings on the container identifying the evidence item.

After collection: When it is safe to do so, and when it is necessary, better quality photographs of an evidence item may be taken once the evidence has been moved to a safe location. Blue background paper may be used to place the evidence item on for better contrast. These photos may include comparison evidence items as long as cross contamination is avoided.

Photographs should appear natural to the eye by taking them at eye level for a general view of the whole scene; the camera should be positioned as an eyewitness would observe the scene. The photograph should give a fair and accurate representation of the scene or the subject matter. Unless taking close-up photographs of small evidence or of indicators, generally a 50mm lens, which is closest to the human eye, should be used. This is important if the photographs are later used in court proceedings.

- Begin photographing as soon as possible.
- Create a photo log.
- Record the type of equipment, film and/or storage medium used.
- Number and describe each photograph.
- Taking more pictures is better than not enough.
- Do not write on the pictures.

- Photos should be an accurate and fair representation of the scene.
- Establish the positional relationship between the wildland fire investigator taking the photo and item(s).
- Document photo points on a photo diagram with the appropriate symbols.

Types of photographs, photo logs, and general scene photography will be discussed in Chapter 5, Documentation.

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 you make during the video recording of any aspect of the investigation.

Subjects to be videotaped

- The fire in progress in early stages.
- Bystanders and vehicles at the fire area.
- Fire suppression activities relevant to the investigation.
- Aerial views documenting direction of fire spread from general origin area.
- Witness viewpoints.

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Chapter 4 - Witness Statements and Interviews

Overview

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

Poor interview techniques may compromise the investigation.

As a wildland fire investigator, you may interview witnesses.

Know your agency policy regarding the conducting of witness interviews.

The quality of the interview techniques govern the quality of the information that will be obtained. The interview can be an important tool in conducting the overall investigation. You may only get one chance to do it right, so do it right the first time! PLAN AND PREPARE FOR THE INTERVIEW. Additional classroom training specific to interviewing techniques should be sought by wildland fire investigators who conduct interviews.

Typically, poor or incomplete interviews will require a follow-up interview which requires finding and contacting the person to re-interview, and in the end, more work than if it is done right the first time.

The wildland fire investigator should develop and maintain a witness list. Follow agency guidelines and format. The witness list will provide information for inclusion into and formation of tasks for the overall investigative plan.

Interview vs. Interrogation

An interview can be described as "*a conversation with a purpose*". In the case of a wildland fire investigation, the purpose is the collection of factual data to assist in the formation and selection of a hypothesis which explains where the fire started (ignition area), what started it (ignition source), and how it started (ignition sequence), including identification of the responsible party or parties. Interviews are a detailed questioning of a subject which elicits statements concerning the investigation. Most witness interviews will not require an advisement regarding the right to avoid self-incrimination, such as a Miranda Warning.

The Miranda v. Arizona ruling generally defines interrogation as any direct questioning about the crime under investigation or any words or actions on the part of the police that the police should have known were reasonably likely to elicit an incriminating response from a person who is considered a suspect.

The legal requirements for Miranda include the questioning of a suspect by law enforcement regarding a crime they may have committed, AND the subject is or could reasonably perceive they are in custody.

Wildland fire investigators who are not peace officers are generally exempt from giving the Miranda Warning as long as they are not working at the direction of or as an agent for a peace officer.

Witnesses do not normally need to be given a Miranda Warning if they do not meet those conditions. Wildland fire investigators should follow their agency guidelines regarding the questioning and interrogation of subjects.

The main responsibility of a wildland fire investigator is to establish the origin, cause, and ignition sequence of the fire. The need for interrogation may arise during this process. Each wildland fire investigator should consider requesting a qualified law enforcement investigator when the situation dictates a higher level of expertise is needed. Consider the legal and strategic complexities involved that may fall beyond the scope of your training and experience.

If for various reasons you believe your witness is now a suspect, follow agency policy on referring this information to law enforcement for follow-up.

Witnesses

In most cases witnesses consist of:

- Voluntary witness (reports the incident).
- Unknowing & voluntary witness (saw/heard something but did not realize there was any offense).
- Reluctant witness (doesn't really want to be involved for variety of reasons).
- Hostile witness (won't speak to you).
- First responders (fire, medical, law enforcement).
- By-standers.
- Reporting party.
- Local residents.
- Property owners.
- Recreationists.
- Local resource users.
- Workers in area.
- Airborne personnel, lookouts.
- Dispatchers.

Witnesses are affected by numerous physical and emotional factors which can color and question the information given to the wildland fire investigator. Among these is the visual attraction of flames rather than the burned area to many witnesses. 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. Explore all the circumstances surrounding their evidence/recollection without leading and prompting the witness. Be aware that the witness may have seen something that they cannot explain since they do not know the precise terminology of a wildland fire 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. You want it to be their story not influenced by you.

Voluntary Statements

Generally, persons at the scene will give a written statement voluntarily, but may be reluctant to do so at a later date. In some instances they will make unprompted voluntary verbal statements. These should not be confused with an actual witness interview; the wildland fire investigator should ask these persons to record any observations or other knowledge they are willing to give in their own handwriting.

The wildland fire investigator may assist the subject in drafting the written statement. Have the witness review and acknowledge (initial) corrections. Include the start and end times of the interview. When writing or drafting a witness statement for them, make sure that they can read and write what you have written. Have the witness sign the written statement. Signing of a statement shows personal ownership. The original statement should be maintained in the lead wildland fire investigator's file.

The following guidelines can be used when obtaining voluntary statements:

- 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 statement should be read back to the witness.
- Have the person number, date, and sign each page.
- The wildland fire investigator should initial each page.
- Ensure that all identifying information is obtained from the witness.

Interviews

Definition: An interview is the consensual questioning of a witness. It differs from a voluntary statement in that the wildland fire investigator is asking the witness specific questions about the incident rather than having the witness write a voluntary statement. A pure version statement should be the first step in an actual interview.

A pure version statement is getting the witness' statement without contaminating them with your words. Let them tell their story without influence from the interviewer. The subject should be doing 70 – 90 percent of the talking during this information-gathering phase of the interview. This is the art of active listening.

The purpose of an interview is to establish in a non-accusatory way, a permanent record of the witness' recollection. This can come from witnesses, victims, informants (and sometimes suspects) or any person who may have evidence surrounding the circumstances of the fire with the ultimate objective being to elicit usable information. This is the Who? What? Why? Where? When? How? of the incident. This is an opportunity to find out what each witness has to contribute to the investigation.

Interviews can take place in a number of environments. In the field, in a vehicle, in an office, at the witnesses' home, all are potential sites for an interview. The wildland fire investigator should attempt to conduct interviews in private and in locations with the least amount of distractions and best conditions for recording if applicable. Discuss with the witness where the interview will take place to ensure it will meet his/her needs of privacy. You may in these cases phone ahead and decide to meet at a time and location where the witness's anonymity is ensured.

The witness should not be inconvenienced if at all possible. If the witness wants to have an early morning meeting because it suits them and their schedule, do so. This will also demonstrate that you are interested in their information and that you respect their wishes thereby establishing some trust and confidence. The end goal is to reinforce to the witness the importance of co-operating and the fact that he or she may have critical information that is important to solving the crime.

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 wildland fire investigator should take the time needed to get all the information that time will allow. Interviews should be conducted by wildland fire investigators who understand fire investigation and fire behavior, whenever possible, or in combination with other wildland fire investigators. The wildland fire investigator should brief interviewers that do not have a working knowledge of fire investigation as to what questions to ask, and key statements to listen for.

The wildland fire investigator should control the interview but avoid being authoritative or overbearing and should seek to reduce distractions. The wildland fire investigator should seek to establish rapport/trust, and avoid rushing when possible. Witnesses may provide estimates but should not be encouraged to guess.

Witnesses should be interviewed as soon as possible. If possible, prevent witnesses from discussing what they saw or heard with other witnesses.

Interview 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. Information obtained from witnesses should be recorded by:

- Notes of the interview made by the wildland fire investigator which are later reduced to a formal record of the interview, or
- A statement prepared by the witness or interviewer and signed by the witness and interviewer, or
- A tape or digital recording which is transcribed at a later date, or
- A combination of these methods is advisable in some situations.

Regardless of how the information is recorded, the final interview report should contain the name, address, identifying information, and phone number(s) of the witness. Follow your agency's policy regarding forms, format and use of recording devices.

If there is a need to interview minors, a parent or guardian should be present during the interview. The wildland fire investigator must follow the law in the jurisdiction and his/her agency policy regarding interviews of minors. It is also a good policy to have another person present as a witness during the interview of a minor.

Witnesses impaired by alcohol or drugs should be interviewed later. Angry or hostile subjects may escalate the interview into a more aggressive encounter. Have an additional wildland fire investigator or law enforcement officer accompany you during such contacts.

Non-English speaking subjects will require a translator. Mentally challenged individuals may require special interview techniques and assistance. Consider getting assistance.

Know your agency protocol for interviewing persons of the opposite gender. Generally for men interviewing a female witness, have another male or female investigator present.

Interview guidelines

- Identify yourself.
- Explain purpose of the interview.
- Record identification and contact information, physical and mailing address, contact phone number, use legal name.
- If they have no phone, ask if there is a person and phone number you can leave messages with.
- Ask the subject to tell you what they saw.
- Ask witness to mentally recreate circumstances, chronological timeline is best.
- Allow the subject to tell their story without interruption, from start to finish. Don’t take any notes and don’t ask any questions, just listen to the story and watch the witness.
- Do not lead the witness in any direction or force them to stay on one subject.
- If the witness gets off track of the investigation, short questions may be interjected to get them back on the subject.
- Ask the witness if they have photographs or video of the incident. (Particularly on their phone).
- Have the witness tell the story a second time.
- Take notes (even if you are recording the interview).
- Ask them to pause or repeat if you need to catch up in note taking or you did not understand a comment.
- Ask specific questions on key points the witness did not voluntarily provide or if you don’t understand a point.
- Use open ended questions.
- Avoid negative questioning, such as “*I don’t suppose you recall what he was wearing, do you*?”
- Do not lead the witness, such as “*Was he driving a red pickup*?”

- Questions may be interjected to get the witness back on track.
- Record visual and audible expressions.
- Make a note of questions the subject asks the interviewer.
- Summarize and review important points.
- Consider taking witness back to scene.
- If the witness is capable and willing, have them prepare a written statement.
- The wildland fire investigator may write the statement for the subject, if necessary.
- Have the witness review, correct, sign and date the statement. Assure that they can read.
- Make sure the witness initials any corrections.
- The wildland fire investigator should also initial each page.
- Where applicable, have witness draw a sketch showing where they were in relation to what they observed. Follow this up with witness viewpoint photographs.
- Thank the witness for their assistance.
- Give them contact information in case they remember any other important information.

Avoid

- Being in a rush.
- Being authoritative or overbearing.
- Using leading questions.
- Asking compound questions.
- Using questions that elicit short answers.
- Interrupting the subject.
- Negative questioning.
- Leading the witness in any direction or force them to stay on one subject.

If the witness saw the wildfire itself, ask specific details such as; fire behavior upon arrival, fire perimeter size, exact location, wind direction and any changes in direction, color of smoke and changes in color, material fire was burning in (for example, grass, brush, timber). Be aware that very often witnesses will tell you the location where they saw flames, and they'll strongly believe that's where the fire started. Keep in mind when questioning about fire size to be specific, otherwise witness will likely discuss smoke plume size, flame size. If there were multiple fires, question the size of the smoke columns to help determine sequence of ignition.

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?*" Summarize the statements of the witness for them, review, and re-affirm key responses. Ask specific questions on key points witness did not voluntarily provide. Leave your contact information and encourage them to call if they have further information.

The wildland fire investigator should summarize key points of each witness interview in field notebook and provide a briefing to the lead wildland fire investigator concerning the information gathered.

If for various reasons you believe your witness is now a suspect, follow agency policy on referring this information to Law Enforcement for follow-up.

Potential sources of information

Reporting parties: The reporting party may have seen the fire at an early stage and may be able to provide valuable information that will assist in determining the general origin area. Their observations are important because the origin investigation can be narrowed to the area burned at the time of the report. They may also be able to corroborate the information obtained from other witnesses. Keep in mind, however that occasionally, the reporting party may also be the person responsible for causing the fire.

Initial attack crew: The initial attack crew plays a vital role by making observations while en-route and upon arrival on the scene. Crew members may be able to provide valuable information pertaining to the general origin area, the area that had already burned prior to their arrival, fire behavior conditions, identification of people and vehicles in the area, weather, damaged locks and gates, items of potential physical evidence and other abnormal conditions. Also, initial attack resources can document initial suppression tactics, including water and retardant drops, hand line and/or hose lay locations and most importantly, any backfire or burn out operations. Anyone involved in the suppression of the fire may have a camera or phone/camera and may have taken photos or video. Contact initial attack resources early and ask for photos along with the actual time and date stamp for the photos. Note if the time and date stamp are accurate or what amount they are off.

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 air crew personnel often prove invaluable in showing areas burned, direction of spread, and intensity. Check with first responder air resources to see if they did take photographs.

Civilian witnesses: Witnesses can provide information about unfamiliar vehicles or people that may have been in the area. They can also provide information on the condition of the fire, such as smoke conditions, intensity, rate of spread, and weather. They may have also taken photographs.

In a situation where there is a need to conduct multiple interviews in a short period of time, for example, a fire has started adjacent to a full campground, strongly consider requesting additional resources to assist with the interviews. At a minimum, obtain basic identification and contact information before potential witnesses leave the area so that they may be interviewed at a later time.

Do not share your opinions of what you have seen at the fire or information about the person or thing that may have started it to anyone other than officials who need to have the information. Remember, your job is to gather information, not to give it.

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Chapter 5 - Documentation

The purpose of documentation during a wildland fire investigation is to produce a true and accurate representation of the investigation with sufficient detail to describe findings and explain conclusions. Simply put, it is memorializing the facts, allowing wildland fire investigators to recall and communicate their observations at a later date.

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 wildland fire investigators to refresh their memory and provide testimony. Documentation allows for subsequent wildland fire 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 of their actions in a case. Third party interests, including citizens who may have been damaged or harmed by 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.

Documentation - Terminology

It is recommended that wildland fire investigators use the terminology provided in this guide, such as General Origin Area, Specific Origin Area, and ignition area be consistent with the meanings taught in this guide, including in notes, sketches, diagrams, and reports. If a term is not being used in the recommended context, or if another term is being used which readers may not be familiar with, the wildland fire investigator should define the term in the report for clarity.

Forms of Documentation

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

- Written field notes.
- Interview/statements (recorded and written).
- Photographs/video/metadata/photo log.
- Sketches/diagrams.
- Written reports.

The wildland fire 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 is dependent upon the specifics of each fire scene.

All types of documentation used alone and in combination assist in tying the data and facts of the investigation together. Basic photography of all scenes is accomplished through the use of digital cameras widely available today. Photography includes the photos themselves, the attached metadata, and photo logs. Sketches are rough in nature and serve to orient the reader of the report and document locations of items of interest for later possible inclusion into a diagram. Sketch and diagram documentation can include photo points, directional fire patterns, fire progression vectors, evidence locations and measurements.

Measurements of features and items of interest can be documented by multiple methods including field notes, sketches, and photography. Field notes will form the basis for any final written report and can be supported through the use of photography, sketches, witness statements, etc. Evidence logs help to document details of evidence location, collection, and storage. Witness statements may be documented on agency specific forms.

Documentation – Field Notes

The taking of field notes is a continuous and ongoing process that includes information associated to all five categories of documentation. It begins with the receipt of the assignment and continues even past the field work itself, and may include a timeline of actions and events. Data collection generally begins at the point you receive your assignment.

Items that may be documented in field notes during the receipt of assignment include; when you were first called, who or how you were notified of the assignment and what they told you, when you responded, how long it took you to respond, what route you took in responding, and what the nature of your assignment was. Consider asking questions during this phase to begin the data collection process. For example, the time the fire was first reported, reporting party name and contact information, witness information, and first responder resources at the scene.

Notes should be:

- Readable. Notes need to be readable not only by you, but also by anyone else who may need to read them.
- They should contain complete words to avoid misunderstanding.
- Brief. Use short sentences or phrases. Avoid long, rambling sentences that could confuse a reader.
- Descriptive. Use words that actually describe what you see. For example, write *burned match* rather than *burned object*. Often sketches will be valuable in supplementing written descriptions.
- Accurate. Notes need to be accurate as to times, dates, names, addresses, weather conditions, scene description, and physical descriptions of vehicles and property, including serial numbers and license plates. They should also include map locations and measurements.
- Factual. You should keep your personal opinions or conclusions not based on the factual data to yourself. It is not advisable to include them in your notes.
- Complete. Answer the questions: Who? What? When? Where? Why? How?

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. The age of the scene may have an effect on the planning of the investigation. Identify the reporting party and contact information.

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

En-route to the scene: As practical, document radio traffic concerning fire location, access, behavior, size, direction of spread, and other pertinent data. Observations of suppression activity, condition of access and egress routes, gates, vehicles in the area, witnesses, activities in the area, smoke column, size of fire, color of the smoke, direction of smoke drift, wind conditions, evidence, and any changes that occur over time can be of importance to the investigation of the fire and should be documented. The wildland fire investigator may be questioned regarding initial observations and have to give testimony about them.

Upon arrival at the scene: There are several basic functions that are commonly performed in each wildland fire investigation. They include:

- Overall coordination of the investigation.
- Examining the fire pattern indicators.
- Searching the scene.
- Photography.
- Note taking.
- Mapping/diagramming.
- Interviewing witnesses.
- Evidence collection and preservation.

Each function may be assigned to an individual team member or a team member may be responsible for several functions, but everyone should be aware of who is performing each function. Functional assignments should be documented.

If an investigative team is established, a briefing that describes the objectives of the investigation and who will be responsible for completing the associated tasks should be held prior to the investigation. Personnel should be advised of the condition of the scene and safety precautions required. Safety of wildland fire investigators is paramount, document the safety briefings.

As soon as practical, the wildland fire investigator should document their arrival time and where the fire is actively burning, this may later help determine the general origin area. This may include the size, active fire area, location/boundary, suppression activities, direction of spread, fire intensity, fuels, topography, weather, and other observations which will assist the wildland fire investigator in establishing the fire behavior context needed to determine the general origin area.

Do not assume that someone else has taken down this information prior to your arrival. Don't rely on suppression crews to provide you with this information because most suppression resources will be focused upon their assignments and may not see the overall picture.

As soon as possible, the wildland fire investigator should take weather readings. The purpose of taking weather readings is to provide the most accurate weather conditions at or near the origin of the fire, nearest to the time of ignition. Readings should be taken as close to the origin time and location as possible. It may be helpful to also take wind and other weather readings along ridgelines near the origin to provide data for large scale progression of the fire and ridge wind conditions.

The wildland fire investigator should document the location where weather readings are taken using GPS or other means. The value of on scene weather readings may diminish as time passes after the fire's ignition.

However, the wildland fire 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 Remote Automated Weather Stations (RAWS) to determine which station may be most representative of conditions occurring at the scene.

Arrangements should be made to secure and preserve the scene until the scene is released. The wildland fire investigator should know his or her legal authority to access the scene if it is not on public property. There are a variety of scene security measures which can be utilized. The wildland fire investigator should select the method which best fits the specific conditions of each fire scene.

Field notes should include documentation of the measures employed to provide scene security. This should include any actions to protect an area larger than the general origin area and/or restricted access to an area larger than the general origin area. Various methods of securing the area may apply – dependent on the scene the wildland fire investigator may need to run barrier tape, position security personnel, or institute closures that restrict access. Each action should be documented as to time and location.

Once the wildland fire investigator, using fire patterns, the fire behavior context, and witness statements, has determined a reasonable area that likely has within its boundaries the general origin area, the wildland fire investigator should arrange for scene protection needs and document them in field notes. At the least, this documentation should include the method, time, and area secured. The wildland fire investigator, when appropriate, may want to maintain a scene log that records all personnel who enter the scene.

Determine and document what types of fire suppression actions and other activities have already taken place within the area to be protected to determine what alteration or disturbance exists or what influence fire suppression actions had on fire progression and fire patterns.

Once the general origin area has been identified, the methodology for examining it should be documented in field notes and may include details of precise procedures used to find indicators and search patterns used. 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. These notes should be complete enough to demonstrate that the indicators used were reliable and allow the wildland fire investigator to testify to them during later proceedings.

There is no set sequence of when the general origin area is to be documented. Some wildland fire 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 the indicators. This 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.

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 wildland fire investigator may also want to take into consideration the angle of the sun when taking photographs of indicators and time the sequence of photo documentation when the best sunlight is available or take more than one set of photographs.

When practical, start writing things down immediately rather than trying to recreate what happened.

Maintenance of field notes is an agency policy specific practice. Check with and follow your agency protocols for retention of notes.

Documentation – Interviews and Statements

Forms of documentation for interviews and/or statements include:

- Notes.
- Written statement (signed).
- Recorded interviews.
- Memorandum of Interview.
- Video tape.
- Supporting documents.

Notes pertaining to an interview, along with any audio and video should be maintained per agency policy.

Wildland fire investigators may take a written statement created by the subject, which can be combined with a Memorandum of Interview to document the wildland fire investigator's recollection of the interview.

Any or all of the items referenced above become part of the investigative case file.

Documentation – Sketches

Sketches are created in the field as part of the scene documentation. As appropriate, sketches may be the only *drawing* in your report. Sketches are used to enhance and illustrate field notes to better refresh the wildland fire investigator's memory when preparing the final report and when and if subsequent litigation or administrative processes take place. For that reason, the wildland fire investigator should be clear as to what they are portraying on the sketch and that it is reasonably accurate.

Multiple sketches are often appropriate and recommended. It can be difficult to capture all the data needed on one sketch without overcrowding the sketch. It is recommended to create separate sketches for the fire progression or fire pattern indicator map, or both, another for photo points, another for the general origin area, and a separate sketch for the specific origin area and/or ignition area. The complexity of the scene and investigation will influence the number of sketches which may need to be created in the field.

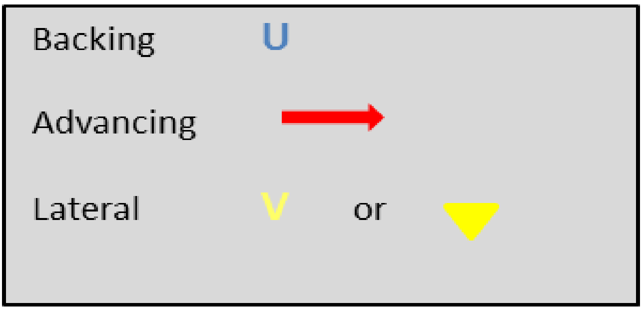
Diagrams (when needed) are created from the information in the field sketches and other data. Sketching is part of the field note and follow-up office process.

Sketches are not to scale and represent only a general overview of the area.

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

Sketching fire progression should include an outline of the General Origin Area, landmarks for orientation and to refresh memory, and a mapping of general fire progression using recommended symbols. The recommended symbols for showing fire progression are identified in Figure 78.

Figure 78. Fire progression symbols.



Sketching should be done while at the scene, during the investigation, not back at the office. Symbols do not necessarily need to be in color on the sketch.

Fire Progression Sketch

The field sketch does not need to have a symbol at each fire pattern indicator located, and symbols on a sketch map do not necessarily represent a specific fire pattern indicator on the ground, but rather portray a general progression of the fire spread. Orient the symbols as near as possible according to map compass orientation.

Indicate on a separate sketch where the General Origin Area boundary is. It is recommended that the boundary measurements of the specific origin area be shown on the fire progression sketch. Continue to show fire progression based on the fire pattern indicators, for example, microscale indicators. Locate and plot the boundaries of the ignition area. The ignition area boundary should be accompanied on the sketch with the dimensions of the area and be approximately the same shape and size as the ignition area on the ground.

Photo point sketch

Photo point symbols establish the positional relationship between the wildland fire investigator taking the photo and item(s) being documented. It is recommended that a separate photo point sketch be created to avoid crowding the fire progression sketch. The photo point sketch is often combined with the plotting of the representative fire pattern indicators to create a link between the photo points and the location and alignment of the fire pattern indicators.

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

Photo points may be portrayed using the following symbol on both sketches and diagrams.

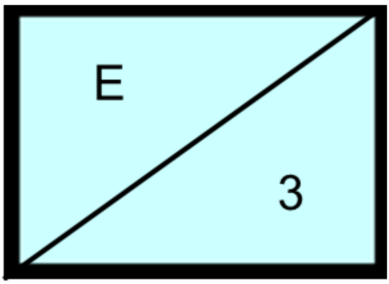
Figure 79. Photo point sketch/diagram symbol.

Photo numbering on sketches and the photo log should link digital photo metadata with the photo point number. On investigations which have multiple wildland fire investigators taking photographs, one option is to add the wildland fire investigator’s initials to the front of the photo number on the photo log and electronic title, to link photos to individual wildland fire investigators.

Evidence

Depending on the number of evidence items, there may be a need for a separate sketch just for evidence. Shooting range fires and roadside fires are examples of areas where multiple evidence items are likely to be present and which may require a separate sketch for evidence. The suggested symbol for evidence on sketches and diagrams is identified in Figure 80.

Figure 80. Evidence symbol.



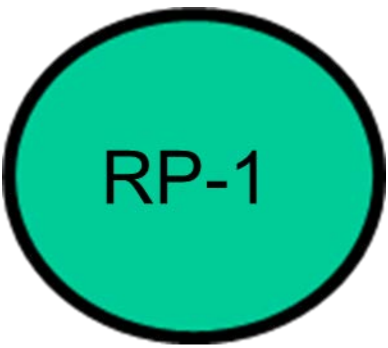
Document evidence locations both inside and outside the general origin area. Document relevant items, not just what you think started the fire. Ensure proper evidence handling both during the documentation phase and the collection phase. Whenever possible, document the evidence in place prior to collection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

Reference Points

Reference points should be documented on each sketch. Reference points are used in correlation to field measurements to show relationships between items of interest on the scene. They may also be used to recreate the scene at a later date.

Reference points should be marked in such a way that their location can be found at a later date. This can be done by taking a GPS reading and photograph for each reference point and placing a metal object, such as a large nail, into the ground which is less likely of being disturbed over time and can be detected later by the use of a metal detector. Figure 81 is the suggested symbol for reference points on sketches and diagrams.

Figure 81. Reference point symbol.



Measurement techniques – Sketch

There are three suggested basic methods of measurements

- Right angle transect.
- Azimuth.
- Intersecting arcs (triangulation).

The technique a wildland fire investigator uses will likely be case specific, dependent on slope, size of the area, vegetation, and obstacles. The measurements themselves may be printed right onto the sketch map or on a measurement log and keyed to a point on the sketch map. This process is often done with two tape measures but can be done with one tape measure and colored twine.

Consider placing the measurement method used on the legend of the sketch map for clarity and as a reminder later on.

Right Angle Transect

- Mark reference points on ground with locatable marker, for example nail, rebar, paint-mark.
- Recommend use of N/S and E/W bearings.
- Utilize the units shown on your measuring tape, for example feet/inches, meters/centimeters.
- Use multiple steel tapes.
- Can use multiple reference points.

Step 1. Select and mark two reference points on either a north-south, or east-west axis. 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, take and record 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 bearing. You may also elect to run a piece of colored twine between the two reference points.

Step 5. Deploy a second tape measure from the object to be plotted 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.) If you are using twine between the two reference points, measure from the object to be plotted to the nearest point on the twine and mark that location.

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. When using twine between the reference points, measure along the twine to the point marked in step 2.

Step 7. Document the direction the measurement is taken. For instance, using two reference points on an E/W axis, with RP-1 being at the east end and RP-2 being at the west end, a measurement from RP-1 towards RP-2 of 18 feet 4 inches would be recorded as 18’ 4” W. If RP-2 were used, the measurement may look something like 5’ 6” E. Only one measurement on this axis is necessary.

Step 8. Document what side of the east-west axis the object is on in relationship to the transect between the two reference points. In the case of reference points on an east-west axis, the two sides can only be north or south. In the case of this example, it is on the south side of the east-west axis between the reference points.

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 this coordinates on a measurement log may include the following information and look like:

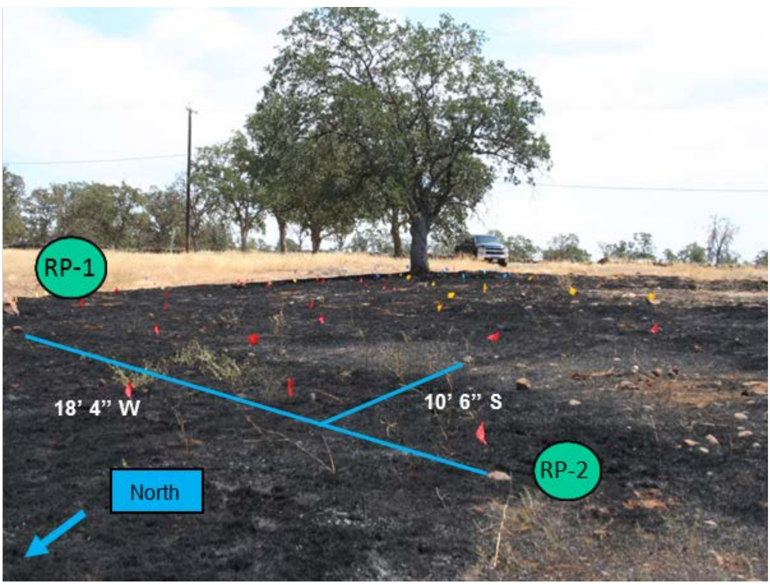
Indicator 12   Right Angle Transect   RP-1   18’4”W/10’6”S

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

Compass declination – you can set your compass to the scene declination or to zero declination, just record in your field notes the declination of your compass.

Measurement detail should be to the increment of your tape measure. If your tape is divided only to ¼ inch marks, measure to the nearest ¼ inch (not smaller to the 1/8 inch).

Figure 82. Example of a right angle transect.



Azimuth

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

A single reference point is used in this method and should be marked in a way that it can be identified and located years later, for example nail, rebar, or paint. The wildland fire investigator will need to record the compass declination used. Utilize the units shown on your measuring tape, for example feet/inches, meters/centimeters. This method relies upon the ability of the wildland fire investigator to take generally accurate compass bearings. If the needs of the investigation require higher accuracy, another measurement method may be more appropriate.

Step 1. Select and mark reference point to be used. More than one can be used as long as they are clearly identified. Note the reference point used in your notes. Example: RP-2.

Step 2. Measure and document the distance between the reference points.

Step 3. Standing at RP-1, take and record the compass bearings to the other reference point(s).

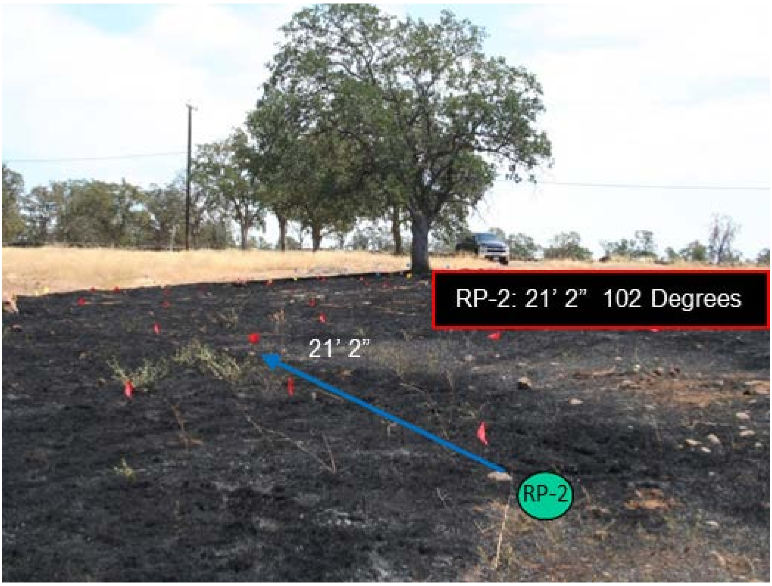
Step 4. Set your compass declination or set at zero and so note the declination used in your field notes.

Step 5. Take a position over the reference point to be used.

Step 6. Take and record the compass bearing from the reference point to the point being documented, for example: 102^{o}.

Step 7. Measure from the reference point to the point being documented and enter measurement into field notes, for example: RP-2: 21’ 2”, 102^{o}.

Figure 83. Example of a measurement taken using the azimuth method.



Intersecting Arcs (Triangulation)

The intersecting arcs method can be difficult on steep ground and in heavy brush or timber. It can be done with a single tape measure.

As with the other two methods, the wildland fire investigator should utilize the units shown on their measuring tape, for example, feet and inches, meters and centimeters.

The method relies upon 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. Therefore, it is important that the wildland fire investigator specify the cardinal side of the reference point axis.

Step 1. Select and mark, with nail, rebar, paint-mark, two reference points on either a north-south, or east-west axis. Label them RP-1, and RP-2 as appropriate.

Step 2. Measure and document the distance between the two reference points.

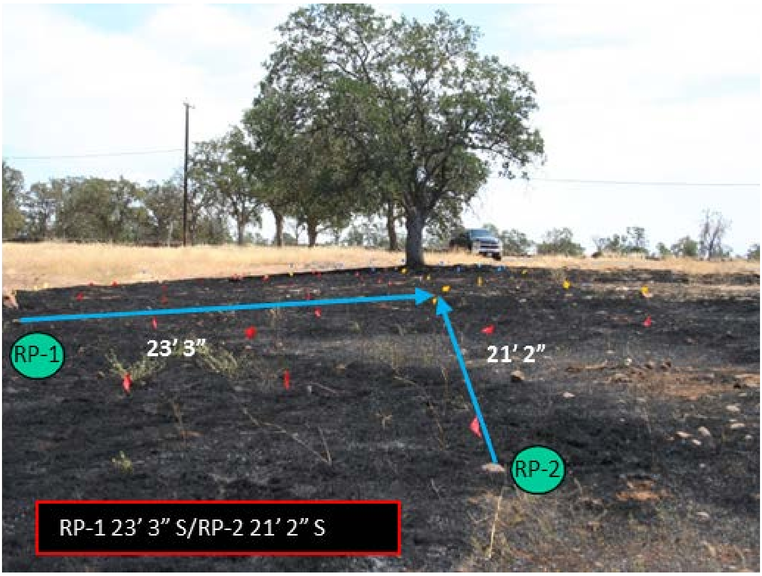
Step 3. Standing at RP-1, record the compass bearings to other reference point(s).

Step 4. Measure from one of the reference points to the point of interest and document the distance in your notes, for example, RP-1 23’ 3”.

Step 5. Measure from the second reference point to the point of interest and document the distance in your notes, for example, RP-2 21’ 2”.

Step 6. Document which side of the reference point axis the point of interest is located. Example: If the reference point axis runs from east to west and the point of interest is located to the south side of that axis, enter S behind the measurements in your notes.

Figure 84. Measurement taken using transecting arcs.



Documentation - Diagrams

Not every fire investigation requires a formal diagram(s). It is up to each wildland fire investigator and agency practice to determine if and when a diagram is needed in support of an investigation.

Diagrams may contain some or all components of the sketch:

- Final diagram is to *near* scale.
- Contains a legend.
- Can be hand drafted or computer generated.
- Has a scale.
- Orientation to north.
- Signature of person who created it.
- Date it was created.
- Incident name or other reference.
- Symbols and their meaning.

Separate diagrams may be created as necessary, such as one for fire progression, one for photo points, one for evidence.

Diagrams can be created using software available to the wildland fire investigator or may be created by experts in the area of surveying and mapping. The wildland fire investigator should be aware of the diagramming resources available to them and the appropriate resource request process.

It is suggested that the representative fire pattern indicators (those documented by photographs and measurements) located within the diagramed area be accurately plotted and direction of fire spread symbols used to establish actual rather than approximate fire direction spread.

Documentation – Global Positioning Satellite

Global Positioning Satellite (GPS) technology and accuracy has greatly improved in the last ten years and may be considered for recording certain types of data. This improvement includes both the accuracy of professional models and those hand held models used by many wildland fire investigators.

Positional accuracy of hand held models is affected by such things as model, post processing of data, satellite availability, and canopy cover. The range of accuracy on a typical hand held GPS model can vary from +/– 9 feet to over +/– 20 feet. Most newer hand held models will provide an accuracy reading for each position. It is recommended that these accuracy readings and the datum setting be documented.

When considering the use of a hand held GPS unit, the following recommendations should be considered:

- Specific Origin Area: GPS units with accuracy of more than + or - 1 foot are generally not recommended.
- General Origin Area: GPS units with accuracy of more than + or – 5 feet are generally not recommended.
- General Fire Area: The use of GPS units in the area outside the General Origin Area, to position macroscale indicators, transition zones, etc. may be an effective tool for plotting those features on the larger scale.

The use of hand held GPS units (those with error rates of + or – 5 feet or more is generally not accurate enough in the smaller areas of the general origin area and the specific origin area. Based on the specific conditions and need for accurate plotting of key features, the wildland fire investigator may use a hand held GPS unit within these areas. In that case, it is recommended that the GPS readings be backed up with measurements to points for validation and orientation.

Exception: The use of a reasonably accurate GPS unit (+ or – 20 feet) for taking coordinates for photo points is generally appropriate for helping someone to go back to the same location using both the GPS reading and the photo to compare to on the ground and for photo diagram preparation.

In this case, the photo diagram legend or attached spreadsheet should provide such information on how accurate the coordinates are, including the possible deviation for each coordinates, for example, Photo AWC1056, N45 168.124, W170 152.344 + or – 9 feet.

Hand held or other models of GPS units with accuracies of less than + or – 5 feet may be available through agency or contract resources.

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

Documentation – Photography

It is recommended that wildland fire investigators take additional training in photography; you will need to understand the operations and limitations of your photography equipment.

Recommendations:

- Consider formatting the secure digital (SD) card before beginning investigation photos. Formatting the SD card eliminates the possibility of unrelated photos being on the card and causes the first photo to be *0001* rather than *0023* etc., and ensures the SD card is compatible with the camera sd card.
- Confirm the correct date and time on the camera(s) used. Consider taking the first photograph of your cell phone showing the correct time and date. Note any difference in time settings, particularly if you have traveled across time zones. (PST, MST, CST, etc.) Check the dates and times of other team member cameras to be used.
- Check the picture format (jpeg, RAW, etc.) It is recommended that jpeg or RAW format be used for picture quality, file size, ability to enlarge and show sufficient detail. Be aware that RAW formats will take considerable more memory space and can only be viewed with proprietary software.
- With digital photography, it is easy to take lots of photographs. Make sure that you carry enough secure digital (SD) cards and batteries to get the job done.
- It is suggested that wildland fire investigators carry more than one camera with them. In the event that one fails, is lost, or is damaged, the backup camera may save the day.

Consider adding your initials to the photo number to reduce the confusion of multiple wildland fire investigators taking photographs starting with the photo number of 0001. This typically can be done as a batch process during downloading of images. Example *0001* would become *AWC0001*. Using this systematically will facilitate explaining how the photos were tracked during later testimony. The lead wildland fire investigator should make it clear to assisting resources what systematic numbering system is expected in order to track photos from multiple sources.

Storing Digital Photos to CD or DVD

- Be aware of *Auto-load* software effects on the image files.
- Do not open or delete original photo files.
- If possible, copy files directly from camera card to CD or DVD.
- Mark and secure 1st downloaded copy.
- When appropriate, store a 2nd copy as your backup.
- Copy a set of working files to PC hard drive.

Secure an untouched image file on a CD or DVD. This can be done by copying and pasting the entire image folder from the camera card directly to the CD or DVD without opening any specific file/image. Then a second working copy can be created and used during the investigation.

Do not delete any photo files taken during the investigation, even if they are of poor quality. Work off copy on your hard drive.

Marking Photo CD or DVDs:

- Permanent marker.
- Write in spindle area.
- Labeling.
- Case/incident number.
- Date photos taken.
- Brief identifier or fire name.
- Name of photographer.

Be careful about writing on the silver or gold face of a CD or DVD, even with markers that are supposed to be safe for CD or DVDs. Eventually the dyes and chemicals from the marker will deteriorate the coating and corrupt the data on the disk.

Photo Log – start a photo log early.

- Use an image (photo) numbering system you can understand when you download the images later.
- May use image number.
- Include a description of each photo in your log.
- Can be brief in your notes, more detailed on final log.
- Photo number is documented on sketch with photo points.

Fire Direction - Photo log components.

- Incident identifying information.
- Camera used and time stamp corrections.
- Photo identification number.
- Date photo taken.
- View direction (N, NW, ENE, etc.).
- Person taking the photo.
- Vector (advancing, lateral, backing) If more than one vector is present in a photo, explain.
- Category of indicator (staining, angle of char, protection, etc.).
- Direction of fire travel in the photograph. The direction that the fire is traveling in the photograph will help others to understand the progression of the fire in the photographs. For example, fire is moving left to right in photo. Or, fire is moving from lower right corner to upper left corner in photo.
- Photo point coordinates are needed if a reasonably reliable point diagram is to be created. With rare exception, these coordinates need not be precise and the use of a GPS device with accuracy better than + or – 20 feet may be acceptable. This may need to be reconsidered as the photo points get closer together, such as near the specific origin area.
- The general description of what is shown by the photo will assist the wildland fire investigator, sometimes years later, to recall why the photo was taken and what was being portrayed. Be as complete as possible. If multiple photos in series have the same subject matter, repetitive photos can be described by referring to the description in the first photo of the series. Example: Same as photo AWC1056, etc.

Investigative Photographic Documentation:

The demands of each individual fire scene will dictate to some extent when photographs can or should be taken. The important thing to remember is that some opportunities may be lost while others can be put off until later. Prioritizing and staffing is the responsibility of the wildland fire investigator.

As each fire investigation is unique, there will be opportunities for taking a variety of photographs or video during various times, this includes:

- En-route.
- Arrival.
- Scene orientation/overview.
- Relationship.
- Identification.
- Examination.
- Other considerations, for example witness perspective.

En-route photographs: Wildland fire investigators should consider the need to take photos while en-route, this may be dependent on the time of response and purpose of the photograph. For example, if the wildland fire 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 photographs: Persons and man-made objects in the area of the fire scene are generally mobile in nature. Powerline equipment can be burned up or removed by power company crews. Heavy equipment can be moved to other sites or parts removed from them. Witnesses may walk or drive away. Photos may assist the wildland fire investigator in quickly documenting the presence of certain persons and things during a period when time is short and workload is heavy. Identifying the presence of equipment, persons, and actions during the first arrival on scene is part of the data collection process that will be used later to develop hypotheses.

Upon the arrival of the wildland fire investigator, he/she may need to document current fire behavior, both near the heel of the fire and overall. Macroscale fire pattern indicators may be photo documented. Suppression actions taking place may be photographed. Physical evidence subject to degradation should be photo documented upon arrival as they are observed.

Scene Orientation/ Overview: These types of photographs 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 are meant to portray the integrity and relationship of the scene to the overall environment and terrain.

These overview photographs can be used during testimony either unchanged or with explanatory symbols as exhibits. 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.

These types of photographs are often overlooked but are generally easy to take.

In addition to documenting the overall scene orientation, general orientation photographs of the general origin area should be taken.

When the general origin area has been identified, photo document the area immediately surrounding it and the general origin area itself looking in from the outside, prior to entry.

This process may be incorporated into the walk around and may include multiple views of the entire surrounding area and views into the general origin area from the perimeter. This will also serve to document the date and time of the walk around through the camera metadata.

The wildland fire 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: Relationship photographs show the relationship between various items, normally taken at medium range, and show specific views of the subject matter. This is just as the wildland fire investigator is beginning to focus on specific portions or objects in the area of the fire scene.

As the wildland fire investigator is working the scene, he or she should take relational photographs to document features and activities that are near to the general origin area. This can include the location of highways, railroads, trails, dirt roads, skid trails, structures, lookouts, etc. A single photo which shows train tracks and the fire near the tracks would be preferable to two photos, one showing the tracks and the other showing the fire. Remember, you are trying to show the relationship between the two subjects.

The wildland fire investigator should photo document fuels in and outside the burn area. If possible, get photos which portray both the burned and unburned fuels in a single photograph. Taking photos of actively burning areas which are representative of the general origin area is also helpful. Remember, you are trying to document a representation of the fuels in the specific origin area, general origin area, and the heel of the fire. This may require multiple photographs and some analysis to do properly. If the general origin area is well within the burned area, photos of representative fuels may be taken at a distant location which has similar vegetation type, vegetation density, aspect, and slope.

Consider using evidence markers to show locations of evidence and other important items in relationship to the overall scene and other items. Evidence markers provide better visibility of smaller items when taking orientation photos of the area. Further detailed close-ups should follow.

Take a photo both with and without evidence markers. Be careful that the evidence markers are correctly documented with the feature being portrayed and the marker does not disturb or place a shadow on the item being photographed.

Identification Photos: Shows the details of a specific item of evidence, such as tire or shoe impressions, sources of ignition, samples and comparison samples (controls), fire pattern indicators, or other important item. These photographs are taken close up for detail and are supported by the orientation photographs of the same items.

Documentation and collection of samples and comparison samples should be clearly documented in writing and photographs.

> **A sample is**: A portion of an item which is suspected of being contaminated with an additional substance, (typically an ignitable liquid) which has been collected for testing in an effort to identify its component parts and any contaminating substances.
>
> **A comparison sample**: Taken from the same type of material that it will be compared to and is recovered from an area where the wildland fire investigator believes there is no contamination relevant to the testing, and testing shows no relevant contamination, only its base components.
>
> A control sample, also known as a check sample or comparison sample, is an item of known composition used to check the samples themselves. This often requires that the actual control sample itself be tested to determine its components. The components of the control sample are then compared to the samples taken from known locations or items of evidence.
>
> **Exemplar sample**: When dealing with items such as rocks, fuel, or other items needed to compare by testing to a sample taken from a scene. Items are referred to as exemplar samples and should be taken from as near the same location as the sample being tested against for which the wildland fire investigator does not suspect relevant contamination. Effort should be made to make the exemplar sample consistent with the specific sample or area to be compared. Exemplar samples are collected specifically for the purpose of having samples on which testing can be conducted without the dangers of conducting destructive testing on actual evidence samples collected. Exemplar samples may be analyzed for comparison properties to the sample being tested against, but generally are not used to determine contamination issues, but rather ignition probability issues.

Documentation – Fire Pattern Indicators

As with any area of the fire, potential directional fire pattern indicators within the general origin area may number into the thousands. The job of the wildland fire investigator is to identify and document enough of these indicators to provide for reliable and consistent vector data which establishes the progression of the fire.

While the wildland fire investigator may observe many fire pattern indicators within a small area, selection of the best of these indicators for documentation through flagging/marking will include a selection based on 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 those that you mark/flag. There is no minimum or maximum number of representative samples required to be documented. It is however recommended that at least one of each category of fire pattern indicator used in a given area be documented.

For example, the wildland fire investigator may have placed pin flags on 250 individual fire pattern indicators. Clearly, documenting all of these indicators is unnecessary; however, a representative sampling sufficient to illustrate overall fire progression should be documented. Of the 250 fire pattern indicators flagged, they may represent 6 of the 11 indicator categories. Document at least one representative indicator from each of the available indicator categories. It is further recommended that these indicators include examples within each of the fire progression vector zones, starting in the advancing zone within the general origin area, working across into the lateral zones and moving in towards the specific origin area and ultimately, if possible, the ignition area. Following this methodology typically results in the documentation of 10-25 total indicators, however it can be less or more, depending upon the circumstances. It is always better to document too many representative samples of fire pattern indicators rather than too few.

The wildland fire investigator should use their experience and judgment to determine how many fire pattern indicators need to be documented to reflect the methodology relied on and illustrate the scene for others at a later date. Ultimately, 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 wildland fire investigator was appropriately interpreting each indicator. While there will always be times when indicators are very subtle and need an expert to explain them, most of the indicators documented should be easily identified once the wildland fire investigator has documented them and explained them in the notes.

Documentation of Fire Progression: Photographs of fire pattern indicators showing fire progression are enhanced through the use of visual aids including flags and vector symbols. There are additional aids available on the market or that can be made at home which can help to present the message in each photograph. Many of these aids assist in the photo documenting of fire pattern indicators and can provide information such as direction of advancing, lateral, backing fire spread, the orientation of north in each photo, the fire pattern indicator evidence reference number.

There are a number of ways wildland fire investigators have shown vector direction in their photographs. No matter which method is used, consistency is critical and the wildland fire investigator should explain the method used and/or meaning in their report or attachments. Any method should visually identify the vector of the individual fire pattern indicator being relied upon. The wildland fire investigator should avoid using symbols or methods which may contaminate or damage the fire pattern indicator.

This guide recommends the use of colored pin flags, a method which is designed to provide an educated and trained reader of the report with graphic information documenting the progression of the fire.

Photo documenting fire pattern indicators: Identification photographs show the detail of the specific fire pattern indicator. They are generally close up photographs, with the possible exception of macroscale indicators. When taking identification photographs of fire pattern indicators, it is recommended that the wildland fire investigator choose the most reliable and clearly discernible indicators to document within each category.

Sometimes, a single photograph may be sufficient to document a fire pattern indicator, for example, in Figure 85. It is always a good idea to confirm the fire pattern indicator reliability prior to photo documentation. In Figure 85 the gourd may have rolled or moved. However, the area of protection in the lower right corner of the photograph is consistent with the fire vector indicated by the gourd and therefore both indicators support the reliability of the indicator.

Figure 85. Detailed photograph which indicates fire pattern.

Some indicators will take two or more views to properly document photographically. Any indicator which is based on *compare and contrast* of burn damage should be considered for multiple views and focal length. Exceptions to this rule may be small objects which are lying in such a position that the two sides can clearly be documented with one overhead photograph. Any other time, multiple views, contrasting opposing sides, may need to be taken.

Examination Photos: When done correctly, examination photographs will assist the wildland fire investigator by providing detailed images of items that many times are packaged and stored in an evidence facility. The ability to examine good quality images may prevent the need for opening evidence packages, documentation of chain of custody, and repackaging.

Examination photos are taken close-up, with a scale that is designed for evidence photography.

After taking examination photographs of evidence in place, the evidence should be collected, packaged, marked, and secured. Due to the risk of contamination and or loss of the evidence, further detailed photographic documentation and measurement of these evidence items should be saved for a safe environment. Comparison photographs may be taken, but care should be exercised to avoid cross contamination of the evidence or mixing of different evidence items. Consider having blue background paper for high contrast photographs of ignition evidence or other important items.

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

Photo documentation – Origin Areas: The wildland fire investigator will often be asked to describe the Ignition Area, Specific Origin Area, or General Origin Area boundaries. The simple use of flagging or other reference material can enhance photographs of such boundaries and save a lot of time during testimony.

Photo documentation – Exhibits: Photo exhibits can play an important part in the documentation and presentation of the fire investigation. When taking photographs, think long term needs. Such as, *What photographs could I use during my testimony to better explain the investigation*? Thinking about this ahead of time allows for the taking of deliberate photographs for use as exhibits rather than settling for a photo taken for another purpose that may not completely serve your needs.

There are a wide range of subjects which can be documented through photo exhibits. Typically, the best time to take photographs for use as exhibits is when the scene is fresh. Larger scale photographs and aerial photos should be taken as soon as someone is available to take them.

Aerial photos may be taken to document both the larger scale origin scene and fire damages and threats to homes or other property. These photos 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. These photos may come from the wildland fire investigators themselves or may be collected from others who have taken photographs of the area.

Documentation – Report

As a Wildland Fire Investigator (INVF), your job may include only the issues directly related to the origin and cause of the fire. This may be focused primarily on reading and following fire pattern indicators, documenting the scene, on scene interviews, weather data, and photographs. You will gather and document this data and provide it to the case agent or case manager. The INVF prepares an *origin and cause* report containing this data, that often becomes the lynch pin to the final fire investigation report.

The role of the INVF is agency dependent and may change by incident. Make sure you are clear about your responsibility and authority for each assignment.

The role of an INVF during an investigation may change over time. Ask questions and get clear instructions. The INVF is the first line of investigation.

Regardless of your role, you will generally have an investigative case file which includes both hard and electronic copies. The contents and extent of the file will be role dependent. The file may include, but is not limited to:

- Origin and Cause report(s).
- Reports of interview.
- Sketches, diagrams, measurements.
- Maps.
- Weather data.
- Miscellaneous reports and documents; for example forensic, expert, other agency.

Evidence logs should be up to date at the time of inclusion into the case file and/or report. Investigative notes should be included into the case file or report per agency policy. Correspondence, including emails, should be retained per agency policy and included into the case file for later discovery. Supporting documents which assist in the understanding of the investigation, origin location, cause, or other important facts of the case should be attached to the case file by reference and copy, including all photographs, videos, recordings, etc.

Origin and Cause Report: The format of origin and cause reports is agency or prosecutor specific. It forms the basis for INVF testimony and becomes an attachment to the final case report.

All wildland fire investigators should remain open to any new pertinent data that is subsequently developed, even after the investigation report is submitted. This new data may change your opinion or it may not. The new data may strengthen the final hypothesis or it may call it into question. You as a wildland fire investigator are providing opinions based on the data that you have at the time you write your report. With new data, you will need the latitude to adjust your opinions based on your review of it.

The placement of a disclaimer into a report is common practice by many experts. It simply reflects the realities of a systematic scientific investigation. Check with your agency legal staff if you have any questions about the inclusion of such a disclaimer or the preferred wording for such a disclaimer. The example shown below is a common version of such a disclaimer. (However, the utilization of the scientific method will innately have as part of the methodology the same *unwritten* disclaimer. Opinions are developed with only the data available at the time the opinion was developed tested and concluded.)

I reserve the right to change my opinion or conclusions based on any additional data received.

The origin and cause report is recommended to:

- Use a narrative format.
- Proceed in a chronological order of the fire event.
- 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 narrative section explains:

- Facts from witnesses and other data sources.
- How data was used to develop hypothesis(es).
- How each hypothesis was tested and final hypothesis was selected.
- Conclusions.
- Attachments and supporting documents/photos.

The wildland fire investigator is documenting in the narrative report the basis for his/her expressed opinions. By the time the reader gets to the end of the narrative, he/she should have a good foundation of what the opinions expressed are based on.

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

1. Call and Response.
2. Arrival on Scene.
3. Methodology/Data Collection.
4. Data Analysis and Application.
5. Working Hypotheses Development.
6. Hypotheses Testing.
7. Conclusion/Selection of Final Hypothesis.

This is the section of the report where the INVF articulates the methods used within the framework of the scientific method resulting in the overall *methodology* applied for the specific conditions of the specific investigation.

Wildland fire investigators are cautioned against using cut and paste language within their report which detracts from the uniqueness of each fire investigation and report.

1. Call and Response.

    - Time of call, time of response, who requested you, information/data gained.
    - Assignment/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 section serves to introduce the reader to how and when the wildland fire investigator became involved in the specific fire investigation and the responsibility and authority of the wildland fire investigator. It also provides initial information about the fire received during the dispatch and/or response which can include the size of the fire, location of the fire, other resources being assigned, initial reports from the reporting party and first arriving responders, etc.

2. Arrival at Scene.

    - Describe the scene on your arrival:
        - Time of arrival and location.
        - Location and perimeter of fire.
        - Surrounding area.
        - Activities taking place.
        - Observed fire behavior.
        - Security in place (or not).
        - Witnesses, reporting party present.
        - Data collected (weather, statements etc.).

    Defining the problem more specifically allows for the construction of a more specific investigative plan and thus more organized efforts at data collection leading to a more complete narrative report. Once the wildland fire investigator has arrived at the fire scene more data becomes available upon which an investigative plan can be further established. It is recommended that this data be documented in the narrative report in the chronological order it occurs. Tasks completed will generate more data which should be documented for the report in field notes and then transferred to the narrative section of the report.

    This process of developing an investigative plan and the tasks which are accomplished through it will provide the data which will allow the wildland fire investigator to compose a complete narrative report. Poor narrative reports are often the result of poor planning and data collection.

3. Methodology or Data Collection.

- Witness statements and interviews.
  - Suppression personnel, Law Enforcement personnel, reporting party, civilian witnesses.
- Fire behavior context.
- General Origin - describe your actions in detail.
- Specific Origin - describe your actions in detail.
- Ignition Area – potential ignition sources.
- Documentation – evidence, sketches & photographs.
- Other observations and sources of information.
  - Weather, lightning data, 911 call logs, etc.

Both the process (methodology) for carrying out the tasks of the investigative plan, and the data collected should be documented in the narrative report.

Because witness observations and the fire behavior context are often key components to establishing the general origin area, data collected during initial witness interviews and a description of the fire behavior context as observed by the wildland fire investigator will often be the next items to be documented in the narrative section.

Once any initial witness information has been gathered, and the fire behavior context is understood and described in the report, the reader of the report is prepared for the description of how the wildland fire investigator found and determined the general origin area. Typically the logical progression of the narrative section will include the establishment of an advancing area, identification of lateral transition zones, and the subsequent reading of macroscale indicators within the fire behavior context.

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

The narrative section should describe the methodology used and data collected in searching the specific origin area and the ignition area. Describing both in the narrative section in reasonable detail so that the reader may understand what took place and what was found.

During the search for the General Origin Area, specific origin area, and ignition area, the wildland fire investigator may be provided with an opportunity to gather additional witness information or other data which may decay over time. There is nothing wrong with putting the search for the ignition area on hold while such additional data is gathered. Such information may include data which will assist in the location of the ignition area, or shed light on potential activities and causes in the area. If the wildland fire investigator needed to leave the scene for any reason, the narrative section of the report should reflect the time period of absence along with an explanation as to how the scene was secured in their absence and why.

4. Data Analysis and Application.

At this point in the narrative report, most if not all of the pertinent available data has been documented and the process of analysis has begun.

- Document why certain data was rejected.
- Document why certain data was relied upon.
- Describe the meaning applied to the data during the analysis process.

Once the methodology and pertinent data has been documented in the narrative section as it was chronologically collected, the wildland fire investigator should now describe the process and result of data analysis. This will include the validating of data as reliable; not rumor, conjecture, or speculation, and providing 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 report may document at this point the meaning applied to the data. For example, data indicating a wind out of the northwest at 5 mph and a slope aspect facing southwest would indicate that both the wind and slope combined to influence the spread of the fire. Another example may include a macroscale U fire pattern indicator which when analyzed indicated a general fire spread from the northwest to the southeast.

In the example above, there may or may not have been other ignition sources. If other ignition sources were present and analysis of the pertinent and reliable data indicated that they were reasonably possible sources of the fire ignition, an alternate working hypothesis should be described in the narrative section. This documentation should be repeated for all reasonably possible hypotheses based on the pertinent and reliable data.

5. Working Hypotheses Development.

   Document a hypothesis for each reasonably possible origin/cause supported by the data/fact analysis.

   EXAMPLE:

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

   At this point, the wildland fire investigator should be able to describe the working hypothesis or hypotheses which were developed based on the meaning applied to the reliable data.

6. Hypotheses testing

   Describe how you *tested* each hypothesis.

   EXAMPLE:

   Smoking: The relative humidity measured at the scene at the time of the fire was 37%. Scientific research has shown that discarded cigarettes will not ignite dry grass at humidity levels above 22 to 25% (Countryman, 1983). Therefore, smoking is excluded as a potential cause of the North Fork fire.

   Once the working hypotheses that can reasonably be proposed, based on the data/facts available at the time, have been identified in the report, the narrative section should reflect the process, including the specific data/facts which rejects each hypothesis and which hypothesis is best supported by all the data or facts.

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

   If the lone working hypothesis does not explain all of the pertinent data or facts, the report may reflect the data or facts which resulted in a finding of undetermined, or actions taken, to gather further data or facts for consideration of other alternative hypotheses.

   While the wildland fire investigator or investigative team may conduct initial testing of the working hypotheses, further documentation of additional hypotheses testing may be included into the case file at a later date when appropriate. In that case, the wildland fire 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 upon which raises one of the hypotheses to the level of probable over other alternative hypotheses which 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 hypothesis 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 or Select Final Hypothesis.

   Describe in the conclusion section, the ignition source, material first ignited, and the ignition sequence.

   EXAMPLE:

   On August 14th, 2011 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 he 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 lofted out of the burn barrel by hot gasses 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 upon the data which has been articulated in the previous narrative, including references to attachments and supporting documentation. Once the wildland fire investigator writes his/her conclusion in the narrative report, he/she should review the narrative report to see that by the time the conclusion is reached, the reader has an understanding of the methodology used, data/facts collected and analyzed, working hypotheses considered, and the data or facts which support the conclusion and opinion of the wildland fire investigator(s).

   Remember, the wildland fire investigator is being asked for their opinion based on the data or facts of the investigation and that data/facts should be understood by the reader of the report by the time the conclusion is reached.

Summary

The person responsible for the case file will include the Origin and Cause report into 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 6 - Ignition Factors and Sources

Fire Cause Determination - General

The objective of every fire investigation is to establish the cause of the fire and determine the ignition sequence of how the fire started.

Because the investigator will be looking for something that is usually very small, and black, and is located in the middle of a lot of other black material, a systematic approach as recommended in Chapter 2, Methodology, of this guide is very important for success.

Meeting the challenge can be difficult if the origin has been incorrectly identified or the ignition source has been destroyed by suppression activities. If the ignition source is small and not readily visible or buried under ash and debris, a thorough examination will be necessary to locate it. Ignition sources can also be unfamiliar and therefore overlooked by the wildland fire investigator if a systematic method is not applied. An arson *hot set* with the ignition device removed or if the remains of the ignition device are consumed by the fire will make it a tougher job to determine a cause, but not an impossible one.

Under normal conditions, forest fuels will ignite and burn when exposed to a heat source that is capable of raising them to a temperature of between 451 and 750 °F. Research places the average ignition temperature at about 500-600 °F. This relatively low ignition temperature creates an extensive list of potential **competent ignition sources**.

A **competent ignition source** is any item which can produce sufficient heat over a sufficient duration of time capable of bringing forest fuels, 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.

Figure 86. 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:

- Competent Ignition source.
- The type and form of first fuel ignited.
- The circumstances or human actions or natural events that allowed the factors to come together.

For example, in Figure 87, 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 87. Photograph of a burn barrel ignition source.

Ignition Source Location

Ignition sources may tend to rest on top of the ash surface or burrow and/or settle due to weight, temperature, velocity, or degradation of the fuel bed. Typically but not always, ignition sources such as matches, cigarette remains, and flat metal fragments will 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 that the ignition source first comes into contact with and sustains combustion in the ground or surface fuels. These are generally made up of one hour fine dead fuel moisture

(FDFM) category fuels (0-1/4 inch diameter) with high surface area-to-volume ratio (for example, duff, grass, chaffs, etc.)

Fire Cause Categories

General cause: Classify the fire cause according to the ignition source or to the general human related activity which started the fire. The following categories are used to describe various causes. If applicable, use the agency's cause category as appropriate.

- Lightning.
- Campfire.
- Smoking.
- Debris burning.
- Incendiary (arson).
- Equipment use.
- Railroad.
- Children.
- Miscellaneous.
    - Power lines.
    - Fireworks.
    - Cutting, welding, and grinding.
    - Firearms use.
    - Blasting.
    - Structures.
    - Glass refraction/magnification.
    - Spontaneous combustion.
    - Flare stack/pit fires.

Categories may vary by agency. Wildland fire investigators should be familiar with their agency cause categories.

This section of the guide will cover these fire cause categories and include a discussion on:

- **Ignition sequence**: The conditions, actions and events.
- **Circumstances**: Evidence or things typically associated with the cause, including potential ignition source remains.
- **Investigation techniques**: Specific investigation methods that may assist in establishing evidence of the cause.

Lightning

Definition: Any wildland fire started as a result of lightning activity. Lightning occurrence maps are a significant tool to be utilized in suspected lightning caused fires.

Ignition Factors: Lightning is discharged static electricity associated with thunderstorm activity. Lightning is typically a series of short bursts approximately two inches in diameter, lasting for about one-half second. These lightning discharges include cloud-to-ground strikes which are in the range of 100 million volts, 200,000 amperes, and 54,000 °F.

Lightning strikes can possess either positive or negative charges with positive charges making up 10% of all strikes and negative charges making up 90% of all strikes. It is recommended that when checking lightning data that the different positive and negative strokes be noted in the investigation report. Positively charged strokes have greater fire starting potential creating long single strokes with continuing current. Damage on the ground is the result of electrical resistance. Stroke duration influences the likelihood of ignition in forest fuels.

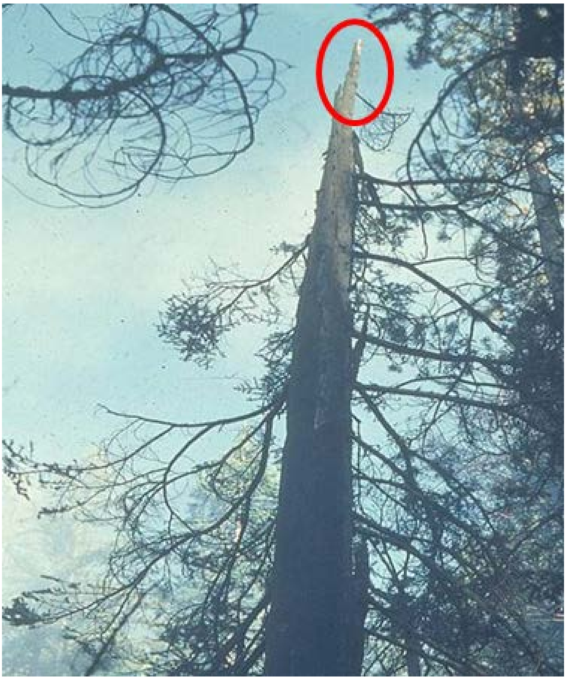
Circumstances: The circumstances indicating a possible lightning strike as a cause includes recent electrical storm (hours/days/weeks) activity in the area, the presence of indicators of *sleepers* and *holdovers*, scarring on trees or snags, precipitated sap, *needle shower*, ballistic penetration of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

Figure 88. Examples of lightning activity as possible ignition source.

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

Indications of a lightning strike in the tops of a tree include a spike top or blunted snags with no visible scar, tops of trees which are blown off and scattered, and charring in the top of the tree or other visible damage. In some instances, some or most of these remains will be consumed in the fire.

Figure 89. Example of lightning strike in the top of a tree.



Lightning striking low vegetation and small trees can result in splintered limbs such as in Figure 90. Strikes directly into the ground may result in blowholes and fulgurite formation.

Evidence of a lightning strike on the ground may include needle showers, disturbed soil, and shattered rocks.

Figure 90. Example of lightning strike on low vegetation.

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

Look for blowholes or disturbed soil at the base of trees such as in Figure 91.

Figure 91. Example of lightning caused blowholes or disturbed soil.

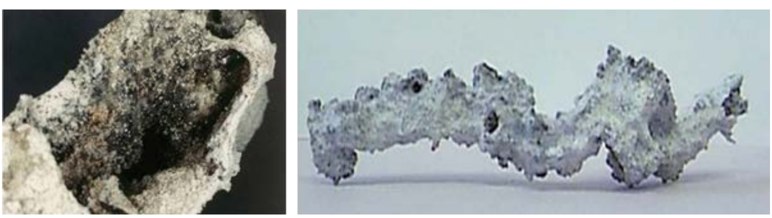
Fulgurites generally take place in soils with a sandy component to them. There is some evidence of them forming in sandstone rock. They can be created both by electrical discharges during a lightning strike or through contact between an electrical conductor and the ground or rock. Much like the process of using heat to make glass out of sand, the heat of the lightning strike heats the sandy particles and fuses the soil or rock at the location that the strike discharges to the ground.

Fulgurites generally resemble fused glass but may have a sandy or rough exterior. Fulgurites are usually hollow and branch like. Careful recovery is necessary, as they can be fragile.

Figure 92. Size of fulgurates compared to a quarter.

Fulgurites generally resemble fused glass, but may have a sandy or rough exterior. They are usually hollow, branch like and fragile.

Figure 93. More examples of fulgurates.



Investigation Techniques

- Lightning should only be considered as a working hypothesis, when you have data that supports it. Data should be collected and analyzed to determine if a working hypothesis of lightning can be formed. Document how the investigation tested lightning against the facts of the case and eliminated it or did not eliminate it.
- Interview available local area witnesses as to whether they 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 for the last 15 days. Extend this analysis to 30 or more days if weather or fuel conditions warrant. Obtain data through dispatcher. Lightning data should not be completely relied upon. Accuracy is approximately to 500 meters with an 80% to 90% detection rate.

  Sources of lightning detection networks include:
  National Lightning Detection Network, Vaisala:
    - www.vaisala.com, 520-806-7300.

  Total Lightning Network, Earth Networks:
    - www.earthnetworks.com, 800-544-4429.

  US Precision Lightning Network, WSI:
    - http://www.uspln.com/, 978-983-6648.
- Examine physical evidence within or close to the origin area that may support witness statements or be suspect as a source of electrical contact.
- Use binoculars or spotting scope to examine tops of tall trees.
- Examine all old lightning damage pathways for signs of recent pathway activity. Charred or discolored surface splinters in the old pathway may indicate recent activity.
- Conduct searches for macro effects and micro effects of lighting pathway activity, for example, spiral bark rips, freshly precipitated sap, and needle showers.
- Examine tree species that are prone to center-rot decay and subsequent lightning pathway effects, for example, white fir. If necessary, fell and open suspect tree boles. Follow evidence procedures and avoid unnecessary cutting of trees.
- On suspect trees, inspect the root collar area and the integrity of roots near the surface and in shallow soil. 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 and locate lightning damage by photographs, sketches and diagrams, as appropriate.

Campfires

Definition: Any fire kindled for warmth, cooking, light, religious or ceremonial purpose. Campfires may occur at any location. Responsible parties may include hunters, campers, anglers, hikers or transients (homeless). Regulations often address attendance, clearance, and periods of use, suppression tools, and proper extinguishment. Violations of these regulations often result in escaped fires.

Ignition Factors: Campfire escapes can be caused by a number of factors, here are a few of them:

- Failure to properly extinguish.
- Lack of attendance.
- Improper clearance or construction.
- Careless placement.
- Fire play.
- Improper discarding of coals/ash.
- Improper use of accelerants.
- Careless discarding of matches.
- Camp stove malfunction.

The primary ignition mechanisms for an escaped campfire can include direct flame impingement due to construction of too large of a fire or addition of too much fuel, aerial sparks or rolling materials leaving the campfire pit or area, creeping fire under or around campfire barriers if they exist, overly heated rocks which contain moisture shatter (explode) blowing burning wood embers out of the fire pit area.

Sparks or rolling material typically result in an origin downwind/downhill of the campfire and are typically fairly close to it. Paper or cardboard is a prime aerial firebrand material which may still be present in the remains. The fire origin may be in punky material or fine fuels. Origins from sparks that emanate from rapid vapor expansion in wood will be close to the campfire.

Creeping campfire escapes may result from un-cleared duff around the edge of the campfire often resulting in a smoldering type escape. This type of campfire escape may appear as a *finger* or *fingers* fire pattern. Underground root systems may transmit smoldering or creeping fire to the exterior of the campfire. Unattended, abandoned or improperly extinguished fires are common factors in creeping campfire escapes.

Discarded coals or ash placed on forest fuels prior to total extinguishment will generally result in an origin near the original campfire. Coals and/or ash will be present at the origin. 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. Ashes discarded from home woodstoves, outdoor wood burners, or home heating furnaces would have similar ignition factors to discarded coals or ash at campfires.

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 origin, if recent in nature, may help to determine the sequence of events which took place. Residual heat in the campfire may remain for days. It should be noted that not all campfires will be within rock rings.

Circles of rocks or pits with a large amount of ash and coals, or a pile of wood are good indicators of a campfire. Signs of recent camping activity, including discarded food containers, and the presence of metal tent stakes or metal grommets from a tent may indicate the possibility of a campfire nearby. Wet ash and/or ash mixed with soil in a failed effort to extinguish the fire may be present.

Figure 94. Campfire escape.

Improper extinguishment of a campfire may be due to inadequate amounts of water used to put the campfire out. Fresh campfires will form white ash on the surface if not disturbed by extinguishment efforts. Campfires will form a crust of ash on top when mixed with water. Fire will sometimes smolder under the crust and the residual heat will be insulated from the cooling exterior environment. Hot embers insulated by the crust of ash may burn their way to the edge of the campfire and beyond or become exposed to surface winds and blow out of the campfire area.

Campfires smothered with soil/rocks may smolder for hours or days under an insulating layer of the soil and rock. Look for the presence of hot coals and vent fumaroles (a fumarole is a hole in the ash in which hot gases and vapors have escaped) on the surface of the ash. Organic matter may contribute to smoldering and should be looked for and documented. Soil moisture and mineral content may extend the smoldering period and should be noted.

No extinguishment efforts may be an indication that the campfire has been abandoned. When no extinguishment efforts take place, fine, and fluffy white ash may be present on the surface with a fragile appearance. An odor of fresh burning may be detectable.

Wildfires burning over old campfire rings will not likely re-ignite coals.

Investigative Techniques: During the investigation and documentation of an escaped campfire, factors will center on the origin determination itself, construction of the campfire, violations of regulations and failure to extinguish the campfire.

- Determine if the use of the campfire was in violation of any fire regulation and document what enforcement action and subsequent disposition took place.
- 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. Take pictures of the fire ring up close and from a distance, showing proximity to ignition area and spread direction.
- 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. Measure the ring dimensions, including the average ash depth, making note of color, size and condition of ash/charcoal.
- Determine what actions, if any, were taken to extinguish the campfire. Be specific with details and persons that took such actions. 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 and 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.
- Review weather records for conditions that would be consistent with holdover of smoldering material in the campfire bed.
- Thoroughly examine the ashes in the campfire bed for signs of proper extinguishment or material involved with slow smoldering combustion.
- Determine if the campfire users left the fire unattended at any time or allowed it to spread from the fire ring at any time, regardless of whether the escape took place at that time or not.

- Document the purpose of having the campfire and include identification information of all persons at or near the campfire during its use.
- Interview witnesses who observed people at the campfire and their actions.
- Contact the landowner to verify the campfire user had permission to have a campfire on the property.
- Campfire site - search for and note:
  - Bottles, cans or other consumer debris.
  - Circle of rocks (fire retainer) within burned area.
  - Seating, such as logs around *circle of rocks*.
  - Pile of unused firewood.
  - Campsite registration information.
  - Accessibility.
  - Ashes from firewood in definite pattern.
  - Abandoned camping equipment.
- Exclude or analyze other reasonable potential causes.
- If hot ash or coals are present, use a high temperature thermometer or other method to establish residual heat levels. Do not introduce paper or other flammable materials to the ash/coals to demonstrate their ignition potential as this will contaminate the remains of the campfire.
- Check trail registers, campfire permits, campground logs, and registration.

Smoking

Definition: Wildfires caused by smoking activities or accoutrements, including matches, cigarettes, cigars, pipes, illegal substances, etc.

Cigarette remains may be hard to see as shown in Figure 95.

Figure 95. Burned remains of cigarette and match.

Redsicker and O'Connor observed in *Practical Fire and Arson Investigation*, "*Cigarettes have long been the scapegoat in cases where no other cause could be determined*" (Redsicker, 1997). 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.

The physical characteristics of manufactured cigarettes generally include:

- Chemically treated tobacco wrapped in paper.
- Cellulon, plastic or charcoal filter.
- Weight: 2/3 gram.
- Length: 45-90 mm.
- Interior core temp. of 1361-1541 ^{o}F.
- Exterior tip temp. of 572-1200 ^{o}F.

Fire Safe cigarettes are designed primarily for safety with interior upholstery. Informal research shows they may continue to burn in a wildland environment. The tobacco itself is not chemically treated; however, the paper has two thicker bands to retard burning unless actively being smoked. Even if the cigarette is considered a *fire safe cigarette* (FSC), in testing 30% are allowed to fail and the cigarette can still meet the safety standard.

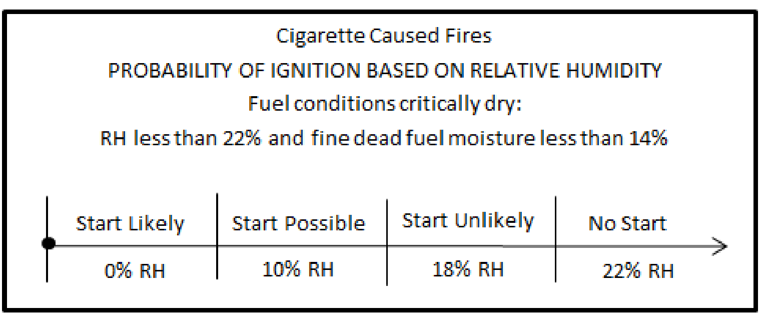
Ash content in cigarettes varies and will affect the exterior temperature of the tip. There is up to 20% shrinkage of the tobacco during burning. As the tip burns, it lifts up and away from the fuel bed. Heat transfer is primarily by conduction and radiation unless suspended in fuel.

Linear burning progression limits exposure to any one point to one to two minutes.

Total burn time of a cigarette is approximately 12-15 minutes (1 inch in four minutes). Most people discard a cigarette that is almost totally consumed, therefore, the fuel bed's typical exposure to heat is approximately one to two minutes.

Ignition Factors:

Figure 96. Cigarette ignition factors.



Environmental factors include:

- Finely particulated fuel bed.
- Loose fuel arrangement.
- Fine dead fuel moisture (FDFM) less than 14%.
- 80 ^{o}F + ambient temperature
- Microclimate location (temperature at ground level vs. temperature at higher level).
- Relative Humidity (RH) of 22% or less.

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.

Circumstances: Physical placement of the cigarette is an important factor. It should be noted that what is important is 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, 30% + of 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 downslope of the non-burning end.

Smokers normally do not discard full-length cigarettes. The length of the ash remains should be examined and consideration given to being part of a time delay incendiary device. Consider altered cigarettes such as a matchhead device, cut back behind suppressant rings.

Figure 97. Cigarette evidence.

When considering the circumstances related to a possible cigarette caused fire, the weather and fuel bed conditions should be compared to the requirements provided in this field guide. Besides the physical placement of the cigarette remains, signs of human activity may be present in or near the origin area.

Rounded or pointed tips may indicate active smoking. A flat tip may indicate extinguishment prior to being placed. Exploded appearance on ash column may indicate a lit cigarette. Old remains may have a bent, weathered or mangled appearance.

Figure 98. Examples of cigarette tips.

Investigative Techniques:

- Carefully examine all cigarette butts located at or near the Point of Origin 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 a fuse component in a time delay incendiary device. If so, proceed with the investigation as a suspected arson.
- 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 product is hand rolled. Examine condition of remains for indications of crushing. Photograph and collect the cigarette residue and butt from the origin using a basal-area lift technique.
- Carefully 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.
- Package, label and store the sample for future use as evidence.
- Determine the specific weather conditions at the suspected time the cigarette butt was delivered to the fuel bed. Document wind speed and direction, relative humidity, temperature and state of weather (percent sunshine).
- Determine what the fine dead fuel moisture would have been at ignition time.
- Determine what the depth, arrangement and cure state of the *fine* (1 hour time lag) fuel bed would have been at time of ignition. Examination of unburned fuels near the general origin area may give you an idea of the fine fuel factors.

- Contact witnesses who may have been near the ignition area at the time the cigarette may have been discarded. Do not overlook residents that may have observed someone walking or driving by at the time. Generally, focus on the time period from one hour before ignition up to the time the fire was reported. (Extend this time as needed based on fire behavior conditions).
- Using interview and scene information, attempt to estimate the source from which the cigarette butt came and the estimated trajectory it may have taken when discarded.
- Determine if any fire prevention regulation was violated and what enforcement action and subsequent disposition took place.
- Exclude or analyze other reasonable potential causes.

Debris Burning

Definition: Wildland fires caused by debris burning activities including residential (pile, barrel, hazard reduction) and industrial (logging operations, land clearing, agricultural, forestry, right-of-way hazard reduction, or other controlled burning). Debris burn escapes are one of the leading specific causes of wildland fires.

Ignition Factors: Factors are similar to escaped campfires. Windblown embers or fire creeping from the control burn area into un-cleared vegetation are the primary ignition mechanisms.

Circumstances: Discernible spread pattern originating from the perimeter of the debris burn. Windblown embers generally land within 40 feet of their source. Cardboard and paper form competent aerial firebrands and are often present in residential debris burning activities. The debris pile or burn barrel will be present and discernible at or upwind of the ignition area. When burning is being done in a barrel, defective screens (burnt out, too small for size of barrel, or mesh that is too large) or no screen is present. The barrel itself may be defective and have holes not covered by a screen either deliberately cut into the barrel or simply from rust or burn through. Inadequate clearance is often a primary circumstance associated to 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 99. Debris burning burn barrel escaped fire.

Lack of attendance is a common circumstance in debris burning escapes. This includes both residential and industrial debris burning activities. Failure to attend a residential debris burn typically can result in a delayed escape of minutes to days.

Escaped fires originating from large slash burning operations should be treated generally the same as other debris burns. Their size, and the fact that they may hold over for an entire winter do create additional considerations. Industrial debris burning, such as logging slash or other forest industry pile burning, can develop ash crusts similar to that described in the section on campfires, creating residual heat for months. Often, by the time these larger industrial burn piles are exposed and become active again, forest debris such as leaves and needles have covered any attempts at control lines around the piles, allowing the fire a path of escape by direct burning or windblown ember.

Fires may surface from clearing and brushing activity well after the original materials were burned. They may also surface from burning in the ground where no brush pile exists. There are numerous documented instances where these fires having escaped the following spring after being originally burned the preceding fall. This may be due to a mixture of dirt and ash which insulates the hot embers within the debris that is piled by these activities.

Investigative Techniques - General

- Determine if the ignition area or source of ignition is the burn pile, and if burn patterns support the determination.
- Conduct thorough interviews of subjects that may have observed the burning or were involved in the burning.
- Examine the residual pile material for size, depth and composition. Fully document what materials were burned and if any residual heat was retained in the pile.
- Determine what control barriers were constructed, what tools and water source were relied on, and if the subject attended the burn at all times. Fully document all conditions and deficiencies that existed.
- Determine the time frame from ignition of the pile to escape; often this is measured in days. Be specific on dates and times.
- Determine what the weather conditions were during the entire burn time and specifically at time of escape.
- Determine the proximity of the burn pile to surrounding fuels or near-by fuel hazards. Include slope, aspect and proximity to fuels.
- If an incinerator or burn barrel was used, document the amount of vegetative clearance around the unit, integrity of the screen and barrel container, proximity of the unit to near-by fuel hazards, and whether the user monitored the burning and had sufficient tools on hand.
- If juveniles were involved, determine if they acted as the parents' agent to burn the material.
- Was burning conducted during times of restriction or closure? Document any permit or prevention violations that were involved, enforcement actions taken and subsequent dispositions.
- Collect samples of burn material, if necessary, and always take several photos of 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.
- Summarize all refuse or yard debris burning evidence, validated and/or eliminated, in the investigation.
- Exclude or analyze other reasonable potential causes.

Investigative Techniques – Slash Piles

- Document the type and extent of fuel material burned, expressed in species, fuels, sizes, acreage, pile sizes or tons per acre.
- Determine the extent of broadcast and pile burning, and diagram perimeters of burn areas. Transcribe this information on to topographic maps. Take aerial photos when necessary.

- Document the extent of pre-planning, site preparation and proper burn execution for the burn operation. Extent of control barriers planned and appropriately constructed, fuel hazard reduction near control lines (both sides), personnel and equipment for control, emergency contingencies, weather monitoring, ignition and lighting equipment and techniques, communications, supervision and training. Fully document all commendations and deficiencies.
- Document the ignition method employed and its sequence. Document any situations where ignition sequences failed or were partially successful. Record the extent of unburned fuel from these actions and the extent of subsequent re-burn, follow-up actions as they related to escape or hampering control efforts.
- Document the extent of agency involvement in the approval of burn plans, pre-burn, burn and post-burn inspections, follow-up on non-compliance issues, permits, record of fire and district control actions. Fully document all conditions and deficiencies.
- Document weather information 30 days in advance of the fire, during the escape and the suppression period. Determine fuel moistures for all size classes of fuels involved. Obtain copies of any pre-planned fire behavior prediction estimates.
- Document the areas or points of fire escape and any situations where spotting may have occurred. Document all physical evidence and relevant human actions related to the escape or ignitions.
- Document all relevant human actions that took place after the escape was discovered. Document the extent of control resources available and the extent of which it was effectively used.
- Document the timeline of large piles burned or broadcast burns that included piles. Include time of year ignition took place, extent of monitoring, patrol or mop-up efforts. Fully document all conditions and deficiencies.

Investigative Techniques – Holdover fires

The investigation should include (if the brush pile has not been scattered during suppression):

- Photograph, video, and measure the brush pile and commence sketch initially during examination.
- Probe the pile to identify hot spots.
- Obtain a detailed statement from the landowner or property holder, including the date the location was brushed, burned, and re-piled.
- Commence examination at an identified location of the brush pile.
- Have the landowner present if possible.
- Use a skidder, tractor, or cat to dissect the pile.
- Measure each *cut* into the brush pile.

- When dissecting the pile, examine and document not only the *hot* core of the pile, but look for areas of cold charcoal and determine if they connect to the burning core. Debris color as this can determine intensity of heat.
- Video and photograph the procedure.
- Sketch the scene with appropriate measurements.
- If initial burn was within the fire season, obtain a copy of the fire permit.
- Confirm the permit conditions with the issuing agency.
- If a ground fire, a careful examination of the area to determine depth of burn and fire movement will be necessary to confirm cause.

Arson/Incendiary

Definition: Wildfires deliberately or maliciously set with the intent to damage or defraud. Refer to your jurisdiction's legal definition of arson.

Arson/Incendiary caused fires will be addressed in Chapter 7.

Equipment Use

Definition: Wildland fires resulting from the operation of mechanical equipment excluding railroads. Types of mechanical equipment range from heavy construction to small portable engines. Equipment use caused fires will be discussed in this section in five parts:

1. Exhaust system particles.
2. Friction and sparks.
3. Fuel, lubricant, fluids.
4. Mechanical breakdown or other malfunction.
5. Radiant or conductive heat transfer.

1. Exhaust System Particles: Ignition Factors

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.

An exhaust system is made up of components, including a header, converter, exhaust pipe or pipes, muffler, and tail pipe.

Exhaust carbon particles are materials that are created by incomplete combustion of hydrocarbon fuels. They are made up of engine carbon, trace metals, and lubricants as a binder. Carbon particles can have the heat content equivalent to a similar sized piece of hardwood. 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 generally more prone to ejecting competent ignition sources than are gasoline engines.

Figure 100. Examples of carbon exhaust particles.

Gasoline carbon particles generally come in smaller particles than diesel carbon particles. Gasoline carbon is typically granular or in flakes, and may be either 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. Diesel carbon particles may appear shiny or dull but are usually black and sooty. Experience has shown that they are rarely recoverable with a magnet.

Diesel carbon particles pictured below are generally larger than gasoline carbon particles. Note the black sooty appearance.

Figure 101. Examples of diesel carbon exhaust particles.

Exhaust system particles originate from the combustion chamber where temperatures are commonly 3,000 ^{o}F, and ports or manifolds which reach temperatures of 1,600 ^{o}F. Generally, the maximum horizontal flight distance from the exhaust source to the ground is about 45 feet. Most fires ignited by exhaust particles will be much closer to the source of the particle.

Exhaust particles are considered a competent ignition source when they are a minimum of .023 inch particle size (Fairbanks, July 1934). Particles which ignite fires are usually in the range of 0.06 to 0.08 inch or larger (Countryman, 1983). Particles up to 0.5 inch or larger are not uncommon when associated with diesel locomotives.

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

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

The two categories of spark arresters and turbo-chargers:

- Attrition.
- Retention.

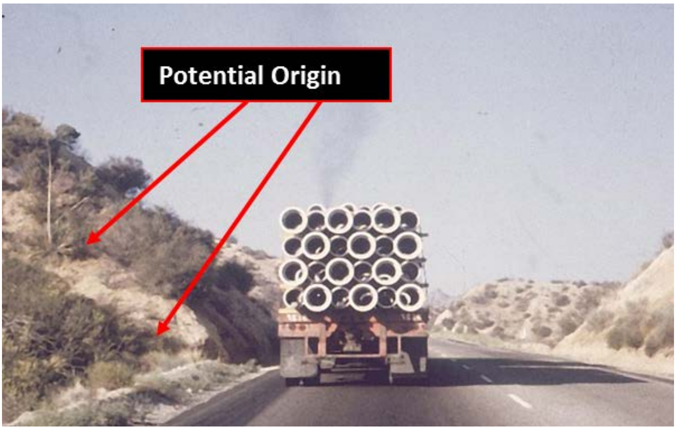
Spark arresters and turbo-chargers must meet pertinent standards. Spark arrester guides can be found at the Forest Service Technology & Development Program Web page at http://www.fs.fed.us/t-d/programs/fire/spark_arrester_guides.

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.

Conditions: Exhaust carbon particles are more likely to ignite fires in conditions which include low RH and high temperatures. Variations in particle size make establishing minimums difficult and large particles have been known to start fires in up to 80% RH (DeBernardo, 1980). The host fuel bed is typically finely particulated one hour fuels. Fine dead fuel moisture (FDFM) is generally low, but no known upper threshold has been established.

Locations where exhaust carbon particles may originate include cutbanks, slopes, tunnel portals, downgrades and at shift points on upgrades. Road conditions that contribute to thermal or mechanical stress can increase the potential for exhaust carbon particle ejection.

Figure 102. Vegetated cutbanks can form receptive fuel beds for exhaust particle fires.



Where small equipment is suspected as having been in use, such as chainsaws, ATV, lawn equipment, portable power equipment, evidence of use near the ignition area may be present.

Figure 103. Several types of small engine exhaust systems.

Heavy equipment, such as dozers, dump trucks, logging trucks, tractors, graders, skidders, etc., of more recent manufacture will typically be turbo-charged but may still pose a threat if the system is damaged. The conditions may be obvious.

Figure 104. Damaged exhaust systems.

Generally, conditions which apply to a fire scene that can be 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, etc.

Ignition mechanisms include: exhaust system particles, friction, fuel, lubricant, fluids, mechanical breakdown or other malfunction, rock strike, vegetation buildup on hot surfaces and radiant or conductive heat transfer. Charred material on the exhaust or other hot surfaces may be present and should be looked for.

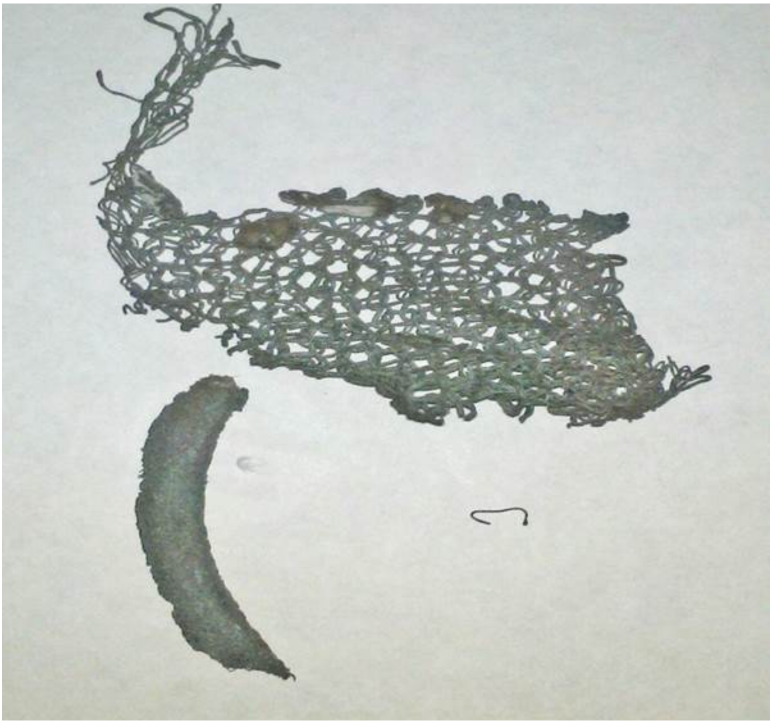
Catalytic Converter Particles

Catalytic converter particles are composed of a ceramic matrix and honeycomb monolith with small ceramic beads common in older vintage vehicles. The particles are generally grey in color, dull or have a metallic sheen. They may be scorched.

Figure 105. Catalytic converter particles.

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

Figure 106. Wire mesh from catalytic converters.



Normally operating catalytic converters can reach up to 1,380 °F. Malfunctions are usually caused by an electronic ignition failure. During a malfunction, the converter overheats and the matrix degrades and breaks apart at temperatures of 2,400 to 2,800 °F. Hot ceramic particles discharge from the exhaust system either through the tail pipe or through failures in the outer shell of the converter itself.

Conditions: Fires ignited from the ejection of catalytic converter particles generally have a maximum horizontal trajectory of approximately 35 feet. The tailpipe height limits the trajectory.

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 or multiple fires along the same road system are common.

The ignition area of each fire will typically have a particle(s) within it which may vary in size, up to the diameter of the tailpipe, or the hole in the catalytic converter shell. Catalytic converter particles are considered lightweight ignition sources and most often rest on top of the ash. The particles are non-magnetic and resemble melted plastic. A ricochet effect set up by particles exiting a low exhaust pipe may cause the particle to bounce at odd angles, but most particles come to rest in the general direction that the exhaust pipe is angled.

Figure 107. Catalytic converter particle.

Investigative Techniques: Catalytic Converter

Look for multiple ignition areas. Walk the roadside and look for additional particles which did not start fires. Search up and down the road for a disabled vehicle. Experience has shown that approximately 33% of vehicles with catalytic converter problems will stop running within a few miles of the fire(s). Inspect the converter looking for holes, rust, cracks, and loose mounts. Tap on the shell and listen for the sound of loose particle within the shell. Consider having a mechanical or automotive engineer examine the system to determine if there has been tampering or illegal modifications.

2. Friction: Ignition Factors

Heat generated by moving object(s) may cause sparks or high temperature particles (or both) and can be associated with mechanical malfunctions. This heat may be created as a result of objects rubbing together or as a result of one object impacting another.

Figure 108. Examples of rubbing and impact friction ignition.

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 which have been heated to their ignition temperature and are actually combusting. Heated metal particles are those which have not generally reached their ignition temperature but have absorbed heat which may be sufficient to ignite the forest fuels nearby. The spark or heated metal fragment temperature may reach several thousand degrees. Larger particles shear off and can be 700 to 1500 °F or higher. The ignition potential of each particle is dependent upon its total heat energy, the actual temperature of the particle, the ignition temperature and conditions of the specific fine fuel which the particle comes into contact with.

Examples of potential friction ignition sources include cable rub, tracked equipment, roller pins binding, slip or spin on rock(s), grader blade strikes, rotary saws, hydro axes, lawn mower and metal blade weed trimmer blade strikes, misaligned shafts, and vegetation buildup.

Rock strikes by heavy equipment and or by rotating metal blades or discs are common sources of friction sparks and heated metal particles. Testing of metal blade equipped weed trimmers has shown that the metal blade contacting rock can ignite both cured and partially cured annual grass.

Figure 109 is an example of a rock strike by heavy equipment. Notice the fresh chalky look to the chip on the rock.

Figure 109. Rock stuck by heavy equipment.

Investigative Techniques – Friction

Look for evidence of equipment use in or near the ignition area. Use a magnet to search for the remains of metal particles within the specific origin area. Fires caused by sparks and hot metal fragments may smolder for minutes or hours and only transition to open flame and steady state flaming front after equipment operators have left the area. Signs of over-aggressive operation of the equipment may be present and should be looked for such as lawn mowers being used to clear dry vegetation in rocky soils or heavy equipment being used in rocky terrain during periods of high fire danger. When examining rotary blade equipment examine the cutting teeth or blade for damage. Collect the blade or teeth as evidence. Friction charring on stumps or trees from operation of equipment such as feller bunchers, cable logging yarders, etc. should be documented and collected as evidence when possible. Submit metal particles or control samples for forensic evaluation.

Figure 110. Friction particles found by using a magnet.

3. Fuel/Lubricant/Fluids: Ignition Factors

Combustible liquids used for the operation of equipment in the wildland 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, as a result of fuel line leaks or hydraulic line leaks.

In addition to fluids igniting by hot surfaces, combustible debris accumulations, such as leaves, dry grass, and pine needles may come into contact with heated surfaces within the engine compartment or the exhaust system.

Conditions: 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 at the origin, witness statements indicating a failure in the area of a fuel or hydraulic line, engine compartment fire or near exhaust system with remains of burned vegetation accumulations.

Figure 111. Examples of fuel, lubricant or fluid ignition factors.

4. Mechanical Breakdown: Ignition Factors

Mechanical breakdowns include tire, wheel, or bearing failures; brake failure, transmission failure, electrical system failure, dragging objects (friction), driveline failure, failed turbocharger, seized bearings, misaligned axles, etc. Each failure has the potential of creating heat.

Figure 112. Log truck mechanical breakdown ignition factor.

Conditions: 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 (friction). Often the operator of the vehicle will state that 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. When trailers or trucks are involved, overloading of the vehicle may cause the failure. When tires fail, the condition of the tire is often poor prior to the failure unless a road hazard had been run over, in which case the operator of the vehicle may make statements to that effect, or the road hazard may be located nearby.

5. 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 come into contact with the dry vegetation. This can take place as a result of dry vegetation being caught up or deposited on the vehicle or equipment and coming into contact with such items as the exhaust surfaces or hot engine areas. It can also take place when a vehicle or equipment is parked over and in contact with dry vegetation.

Conditions: Conditions include the burnt remains of dry vegetation accumulated on 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.

Figure 113. Conductive heat transfer ignition factor.

Investigation Techniques - Equipment General

- Make a thorough listing of all equipment that is believed to have been near the area of origin at or about the time that the ignition took place. Expand this time period for the duration it is believed a fire could have held over. When listing equipment, include make, model, serial number, age and general description. Isolate problem equipment.

- Identify who owns each piece of equipment and who was operating it at the time. Determine dates and times of operation and any change of operators. Sketch on a map the location and time of operation.
- In addition to listing the equipment, be sure to photograph each item near the origin area at the time of ignition, prior to being moved or inspected.
- Identify and document any tracks leading from the origin to the equipment.
- Interview each operator and each person that performed maintenance on the equipment. Obtain detailed witness statements from each subject.
- Inspect each piece of equipment with a qualified equipment mechanic if necessary. Examine the fuel system, electrical system, exhaust system and any friction contact surfaces and bearings. Photograph and fully describe any and all parts that appear to be deficient or show excessive wear or damage. Obtain written reports from assisting mechanics. Look for debris around the exhaust system or other hot engine surfaces.
- Follow up equipment inspections 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. Obtain witness statements from representatives that offer information on cause and effect.
- When evidence collection is not possible or practical, obtain photographs of the item and close-ups of the area of deficiencies or damage.
- 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 all deficiencies for fire protection requirements relating to use of such equipment, such as fire extinguishers, water source, and watchman service.
- Determine the terrain over which the equipment was used.

Railroad

Definition: Fires caused by any railroad operations, personnel, rolling stock and can include track and right-of-way maintenance. Historically, railroad fires were significant problems, but aggressive prevention has reduced present day occurrences in many areas.

Railroad structures such as trestles, bridges, and ties, are included in this category of fire cause.

Figure 114. Railroad trestle fire.

General Railroad Ignition Factors

Ignition factors include:

- Exhaust carbon.
- Brake shoe particles.
- Track maintenance.
- Right-of-way maintenance.
- Dynamic grid failure.
- Signal flares.
- Wheel slip.
- Wheel bearing failure (hotbox).
- Transients.

Railroad Exhaust Particles Ignition Factors

Exhaust particles from railroad equipment is a highly competent ignition source. Diesel carbon is bound together with polymeric lubricant resins and form particles with pumice-like, granular or flaky appearance which is often sooty or oily.

See Figure 115 for pumice-like appearance of railroad exhaust particle on the left, and sooty and oily looking railroad exhaust particle on the right.

Figure 115. Types of railroad exhaust factors.

Railroad exhaust particles range 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 particles emitted from a point in the exhaust stack may range from 900 to 1,200 °F. Under fanned conditions, which simulate an in-flight environment, exhaust particles have been observed as low as 690 °F. Depending upon their size, structure, and surrounding environment, they could be either cooled or have their temperature significantly raised from increased thermal activity. As the hot exhaust particle passes from an oxygen-depleted environment to the atmosphere, glowing or flaming combustion can occur. (DeBernardo, 1979)

Figure 116. Sizes of railroad exhaust particles.

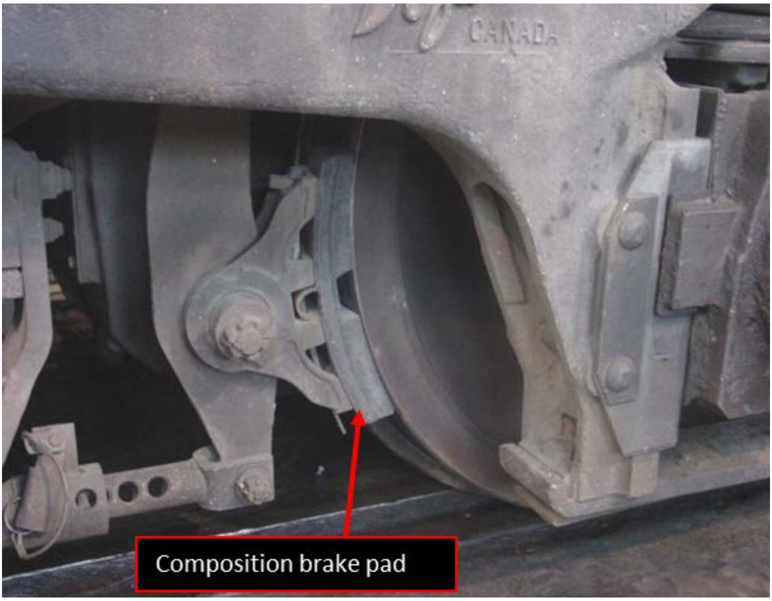
Auto-ignition of particles creates flaming projectiles that may remain thermally active for 30 seconds or longer. Swirling air from the passing train aids in the ignition of the vegetation. Research puts maximum in-flight distance at approximately 45 feet in still air with the average being 28 feet from the track centerline. (DeBernardo, 1979)

Exhaust particles from railroad equipment commonly will cause multiple ignition area s with origins generally within 45 feet of the downwind side of the tracks. Tunnel portals and cutbanks experience an increased incident of fire ignitions. 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 prior to pulling a grade. Deadhead locomotives and yard locomotives started up after a period without use or low power use have an increased potential for ejecting particles.

Brake Shoe Particles Ignition Factors

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.

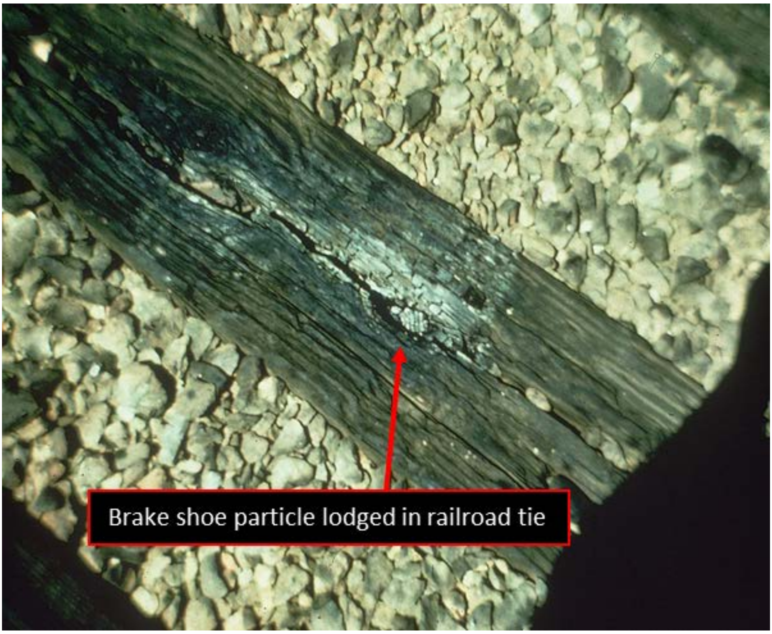
Figure 117. Railroad car brake pad.



Brake shoe particle ignition areas can be on the ties or close to the tracks in vegetation or other debris. A brake shoe particle will typically be found in the ignition area but may have rolled past or moved, particularly on steep slopes. The ignition area may be at a location associated with brake use and there may be multiple starts in a short distance.

Figure 118 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 118. Brake shoe particle in railroad tie.



The majority of trains are diesel-electric combination and may have air brakes with dynamic braking (electrical) or non-metallic composition brake show pads. Some trains now use disc brakes. Some older equipment may be equipped with metal shoes. Metal backing plate particles may shear off and land on ties or vegetation. The use of composition brake pads will lead to wear down. Brake shoes must be regularly maintained.

Track Maintenance Ignition Factors

Track wear requires regular maintenance and includes standard welding and cutting, thermal chemical catalyst welding, grinding, and rail stretching.

Catalyst welding exposes the fuels to an open flame and sparks. Hot ceramic molds may be carelessly discarded or buried in the fill.

Look for the remains of ceramic molds such as depicted in Figure 119. These can be near the rails, or may have been dropped or discarded a distance from the rail.

Figure 119. Ceramic molds along railroad track.

Track grinding can include manual grinding and machine grinding. 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 itself that moves as it grinds.

Track grinding slag which accumulates on the underside of the maintenance rolling stock can fall off and may look like Figure 120 below.

Figure 120. Track grinding slag.

Dynamic Brake Grid Failure Ignition Factors

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 is typically vented out the top of the locomotive car body. Excess heat created by this braking is vented through cooling fans which may result in overheating and failure with spectacular arcing and violent ejection of hot metal fragments. This failure is often accompanied by a loud noise that may be noticed by the train crew. The grid material may or may not be picked up by a magnet due to some of the non-ferrous material of the brake grid. Brake grids can produce 600 volts and extreme caution should be used around them.

Figure 121. Dynamic brake grid exhaust outlet.

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 had been going on or other train related hazards had been present.

Figure 122. Signal flare debris.

Right-of-way maintenance along railroads include burning, mowing, spraying, tree trimming, and brush removal. Activities can be crew based from vehicles and/or maintenance train based.

Figure 123. Right-of-way maintenance burning.

Wheel slip/slide Ignition Factors

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. While wheel slip or slide can cause hot metal particles to fall into the ties or vegetation, it is not a common ignition source.

Conditions: Wheel slip or slide may cause thin, heated, elongated metal shavings to fall into the ignition area fuel bed. They are most likely to be found where a train accelerates or decelerates. The track may have a *welded* appearance adjacent to the ignition area, which is often a tie, particularly if there is rot present on the tie.

Investigative Techniques: Recover metal fragments with a magnet or metal detector. Photograph the rail near the ignition area. Identify the train through dispatch records and interview the crew or engineer (or both).

Figure 124. Train wheel slip on train track.

Rail Car Axle Bearings Ignition Factors

Roller bearing within the hub and axle assembly can overheat and fail. The wheel roller bearings can be ejected out from the assembly and land either on the wooden ties or on vegetation while still hot enough to ignited the combustible materials upon which it lands.

Figure 125. Railroad wheel roller bearing hub assembly.

Figure 126. Roller bearing assembly which has been detected by a hotbox as being defective and tagged as *bad order*. Bad order is a railroad term for a defective item or items.

Figure 127. Roller bearing thrown from wheel assembly which was hot when it landed in the vegetation as exhibited by the burned area around it and under it.

Investigative Techniques Railroad – General

- Examine track and ties for indications of ignition source.
- Document condition of the rails, track, vegetative clearance, and other railroad structures.
- Sweep ignition area with magnet.
- 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 suspected deficiencies.
- Interview the train crew and maintenance crew.
- 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 close proximity, so ensure the examination includes a search for more than one ignition area.
- Search the nearby area on both sides of the track for ignition mechanisms that may not have started a fire. This includes carbon exhaust particles (Figure 100), brake shoe particles, grinder residue, burn piles, track heating, flares, metal fragments, dynamic grid fragments, track damage, etc.
- At the origin, search for, document and collect the actual remains of any of these ignition sources. These are usually recoverable.
- Check records for earlier fires along the track at different locations. These may be in another agency's jurisdiction.
- Obtain train maintenance records as necessary.
- 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.

Safety

Safety practices around railroad equipment and operations are a critical element of the investigation of a railroad caused fire. Always wear a hardhat, use eye and hearing protection, approved footwear such as a heavy boot and gloves, along with a high visibility reflective vest.

Blue flags/signal protection are applied and removed by railroad personnel and signifies that workmen are on, under, or between rolling equipment that is being repaired, serviced or inspected. An approved blue light must accompany a blue flag at night.

Never step on or stand inside the rails.

Switches are used to change the path of travel of railroad equipment from one track to another. On the main line, switches are used to put a train into a siding so another train can pass. If the incident involves a siding area, be careful when working around the switch areas, the switches move quickly and silently so it is easy to catch a foot. The person moving the switch may be hundreds of miles away, possibly in another state.

The area within one arm's length of the track is considered to be the *Red Zone* due to the hazards associated with work within that area.

Summary

The National Wildfire Coordinating Group (NWCG) course *Investigating Railroad Caused Wildfires* is available on CD or online at the NWCG Training Development Program site at http://training.nwcg.gov/courses/IRCW/index.htm.

Figure 128. Railroad Fire Investigation Training Material.

Children

Definition: Wildfires started by persons 12 years of age or younger. The child may be motivated by normal curiosity and use fire in experimental or play fashion. Matches or lighters are the most frequent ignition source. It often involves multiple children.

Ignition Factors: Children frequently use easily accessible ignition devices including both paper and wood matches, and lighters. Children may combine the ignition device with other fuels brought to the scene such as paper and cardboard. In other cases, the fuel bed may be prepared in a make believe fire pit or in a pile. Ignition devices may also be used to play with other ignition devices such as fireworks.

Circumstances: Children caused fires may have the appearance of fire play, including numerous matches or matchbooks, burned toys, cigarettes, paper, and boxes. The origins are usually away from adult supervision in hidden or *secret* areas such as forts and locations frequented by children such as fields. These may be accessed by dirt roads and dirt paths or worn paths through dead vegetation such as dry grass.

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 towards the fire scene.

Fires associated with children may have a corresponding pattern of fires involving structures, schools, or playgrounds. Children or neighbors and parents may attempt to suppress the fire in the early stages or by other civilians. Burned clothes or shoes on children in the area may be the result of attempted suppression actions.

Wildland fires which are associated to 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 footprints 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.

Children acting out due to family turmoil such as divorce, remarriage, lack of a two-parent environment, etc. may set fires in the wildland and structures; including closets, bedrooms, crawl spaces under the home, and the garage of their homes.

Figure 129. Match evidence.

Investigative Techniques

- Look for an origin away from adult supervision, but likely close to home, school, campgrounds, footpaths or playgrounds. Check for hidden *secret* areas or play forts and in locations normally frequented by children.
- Look for signs of fire play such as numerous matches, burned toys, stuffed animals, etc.
- Look for signs of any attempt to suppress the fire, these will typically be unsophisticated.
- Do a neighborhood canvas for witnesses.
- Determine if there have been other similar fires nearby.
- Contacts and interviews of children must be conducted in accordance with appropriate legal process.
- Interview children separately from their playmates.
- Look for and identify children watching the fire.
- Interview children in the area; even if not suspects: they may have information about other children.
- Determine if the actions are due to normal curiosity or a pathological behavior.
- Consider referral to juvenile authorities and/or an intervention program.

Miscellaneous

Definition: Wildfires that cannot by properly classified under other standard causes. Some of these are listed below but can include other ignition sources that are not listed.

- Powerlines.
- Fireworks.
- Cutting, welding, and grinding.
- Firearms use.
- Blasting.
- Structures.
- Glass refraction/magnification.
- Spontaneous combustion.
- Flare stack/pit fires.

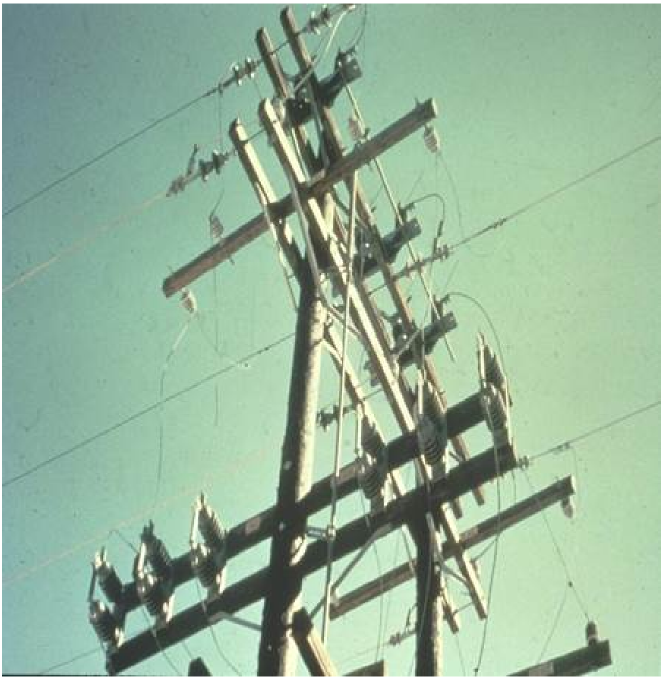
Definition - Powerlines. The category of powerlines includes all electrical equipment associated with the production, transmission, and use of electricity. The electrical grid or system for the transmission, distribution, and service of customers forms a complex web and is governed by regulations. The transmission of electricity has long been recognized as having an inherent danger above and beyond typical hazards. Early electrical distribution systems caused numerous fires, better engineering and prevention efforts have reduced the number. Powerlines are an ignition source that can lead to major fires, as many of the conditions that contribute to system faults and failures coincide with extreme fire behavior.

Powerline Ignition Factors: The ignition of a powerline fire often occurs due to high winds, contact with vegetation, equipment failure, or human or animal contact. Sometimes several of these factors may work to cause a fire, such as wind blowing vegetation into contact with the electrical equipment. Fires from powerlines can start as a result of conductor contact with standing vegetation due to inadequate clearances or with wildland fuels on the ground when electrical equipment, such as a conductor, falls to the ground and comes into contact with dry fuels. Sparks or molten metal from conductors or transformers can fall to the ground and ignite fires. These fires may occur in remote areas where fire suppression access is limited.

Most wildland fire investigators will be dealing with transmission, distribution, or service lines. **Transmission lines** are those towers or poles, conductors and equipment, which move electricity from the generation facility to a sub-station. These are generally of higher voltage relying on larger towers and generally transmit between 138kv – 765kv, but may also be as low as 69kv. **Distribution lines** carry power from sub-stations to the 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 five to ten times more line.

Distribution pole structure and equipment is closer to vegetation than transmission lines increasing the chance of fire by distribution lines.

Figure 130. Transmission line.



A **service line** transmits the electrical power from the transformer to the weather head at the customer. 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 protects it from arcing with other objects.

Powerline fires normally result from conductor failure or faulting, insulator failure, hardware failure, birds, small animals, and mylar balloons. Other factors such as poor cleaning and maintenance of the equipment can contribute to equipment failure.

Figure 131 is an example of a mylar balloon shorting out high voltage transmission lines, which resulted in a wildland fire. The metallic balloon crosses two conductors.

Figure 131. Mylar balloon stuck on transmission lines.

Various hardware is used including switches, fuses, connectors, splices, insulators and reclosers. A general familiarity with this hardware is important for wildland fire investigators. For more information, refer to *Powerline Fire Prevention Field Guide* on the California Wildland Fire Coordinating Group site at http://www.preventwildfireca.org/Field-Guides/.

Arc tracking on the insulator below is due to voltage tracking across a damaged insulator.

Figure 132. Arcing on a damaged insulator.

Conductor failure or faulting results when the conductor breaks, falls to the ground, arcs, and starts a fire. In some cases, a splice or connector may fail causing the line to fall. Faulting occurs when a line contacts or comes close to an adjacent phase or vegetation and faults or arcs. Line sag, high winds, and birds may also cause conductor failure or faulting. In some cases, the initial fault may not start a fire but one may ignite when an automatic or manual reclosing of the circuit takes place and the line is energized once again.

Line sag typically takes place when the conductor is subjected to increased load or solar heating, causing the line to *sag* lower towards the vegetation than normal. Lines experiencing sag may return to their normal position prior to the arrival of the wildland fire investigator. Regulations exist which require utilities to take into account during the construction of powerlines the potential of line sag during a certain range of temperatures. Line sag contact or proximity arc to adjacent vegetation includes arcing of 1 inch per 10kv.

Conductor failure or faulting is usually obvious and often includes charred vegetation, line down or intact, 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. Trees contacted in their crowns may exhibit damage similar to a lightning strike and/or scorching or charring of the crown and fire scorching nearer the ground with green foliage and an unburned tree bole in between these two areas of separate heat damage.

Figure 133. Arrow pointing to a limb damaged by contact with an electrical conductor with fire effects similar to lightning.

Figure 134. Staining and sooting on a wire conductor.

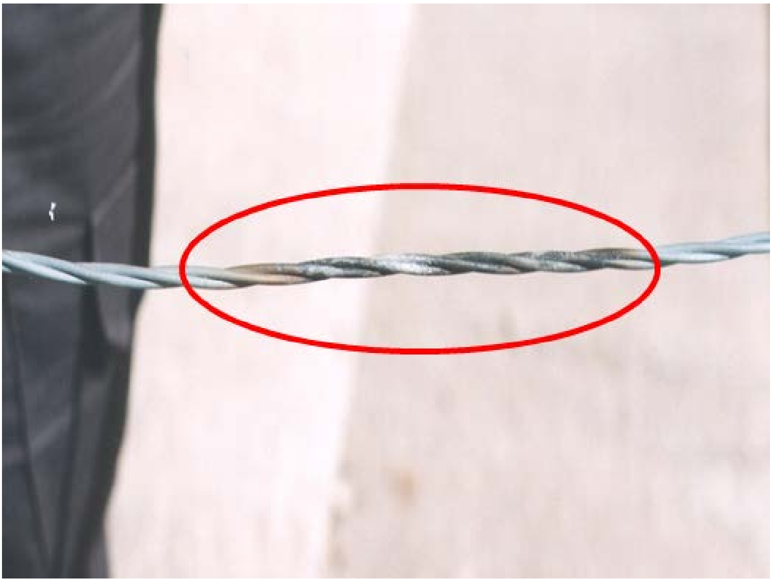


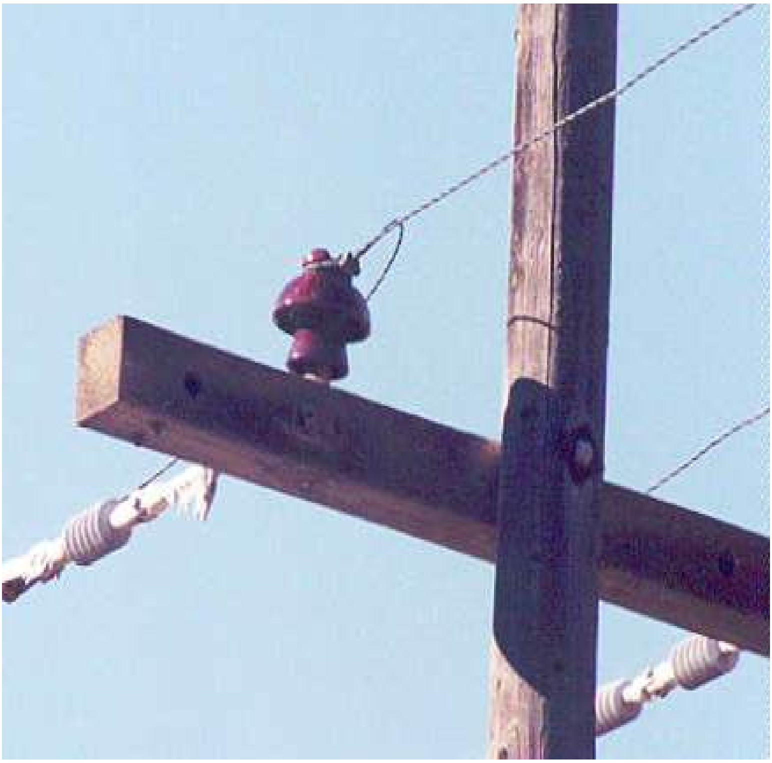
Figure 135. Blowhole near tree from electrical grounding.

Figure 136. Electrical resistance scar on tree trunk.

Circumstances: Powerline discharges to the ground may leave fulgurites. The shape and size of fulgurites created by powerlines may not be the same as those created by lightning. They will typically be solid and on or very near the surface of the soil and may include glass bubble looking formations on the surface.

A **failure of an insulator** may lead to a fire ignition. There are a variety of insulators but all of them are designed for the purpose of keeping the conductor from making grounding contact. A failure of an insulator can result in arcing to the pole or other hardware. Fire is often on the cross-arm or pole in addition to dropping to the ground in the form of burning wood.

Figure 137. 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 drop conductor.
- Tie down wire comes loose.
- Insulator comes off mounting peg.

In some States, certain equipment is required to have vegetative clearance due to their propensity for starting fires when they fail. These items may be referred to as non-exempt, meaning that they are not exempt from the law which requires the clearance. These items may include, fuses, disconnects, lightning arresters, clamps, and connectors. The wildland fire investigator should be aware that these types of equipment have a higher propensity for starting fires when they fail.

Figure 138. Fuse in open position.

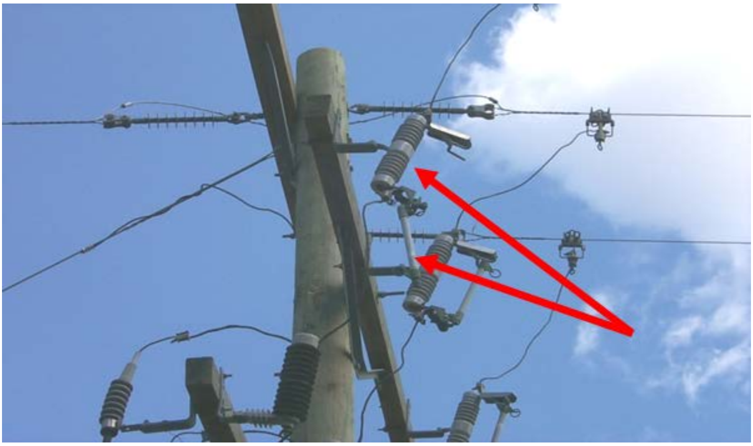


Figure 139. Solid blade disconnect.

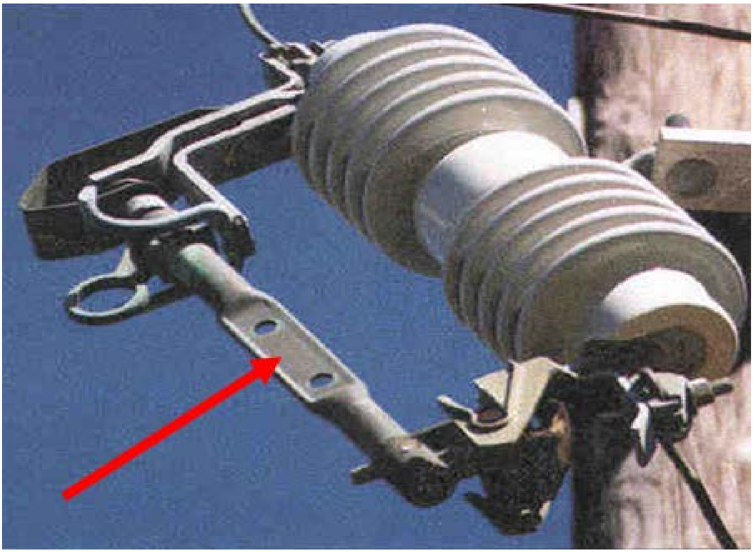


Figure 140. Inline disconnect.

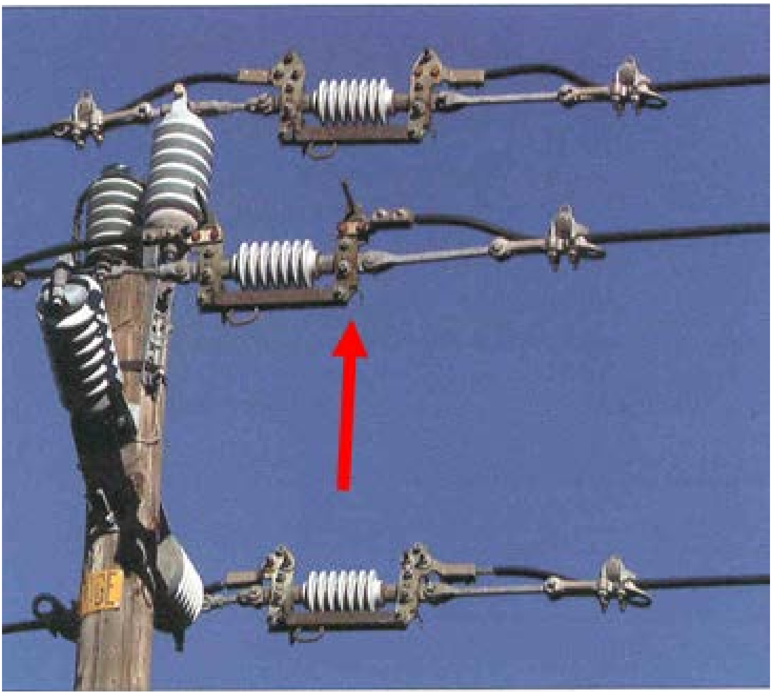


Figure 141. Lightning arresters.

Connectors and clamps connect conductors and jumpers. The potential for an arc increases when they are loose. They include hot tap clamps, split bolt connectors, LM connectors, and Fargo connectors.

Figure 142. Evidence of arcing.

Figure 143. Hot tap clamps.

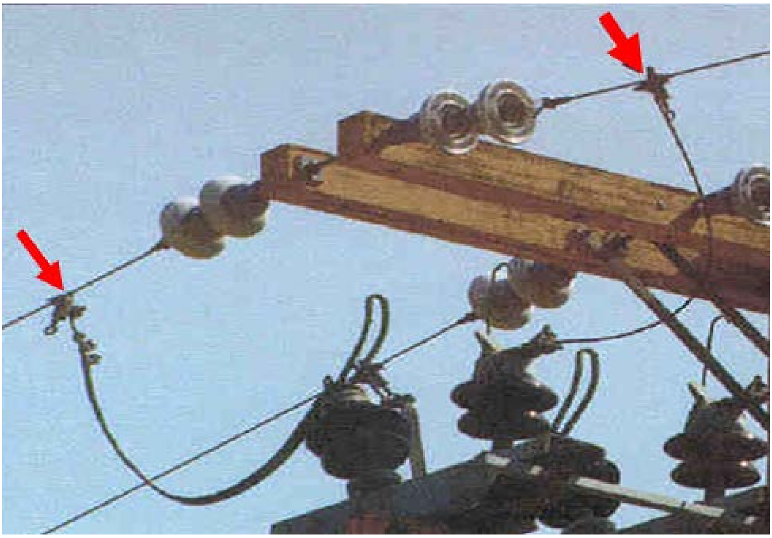


Figure 144. Hot tap clamps.

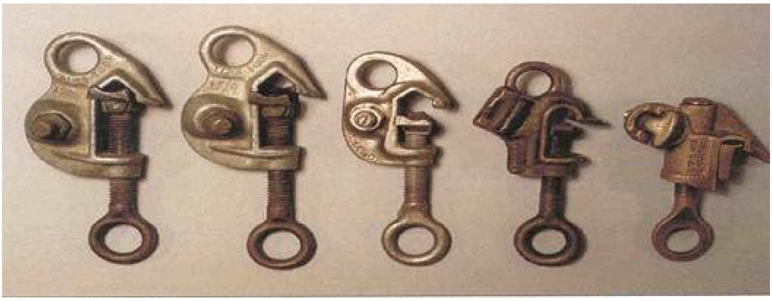


Figure 145. Split bolt connectors.

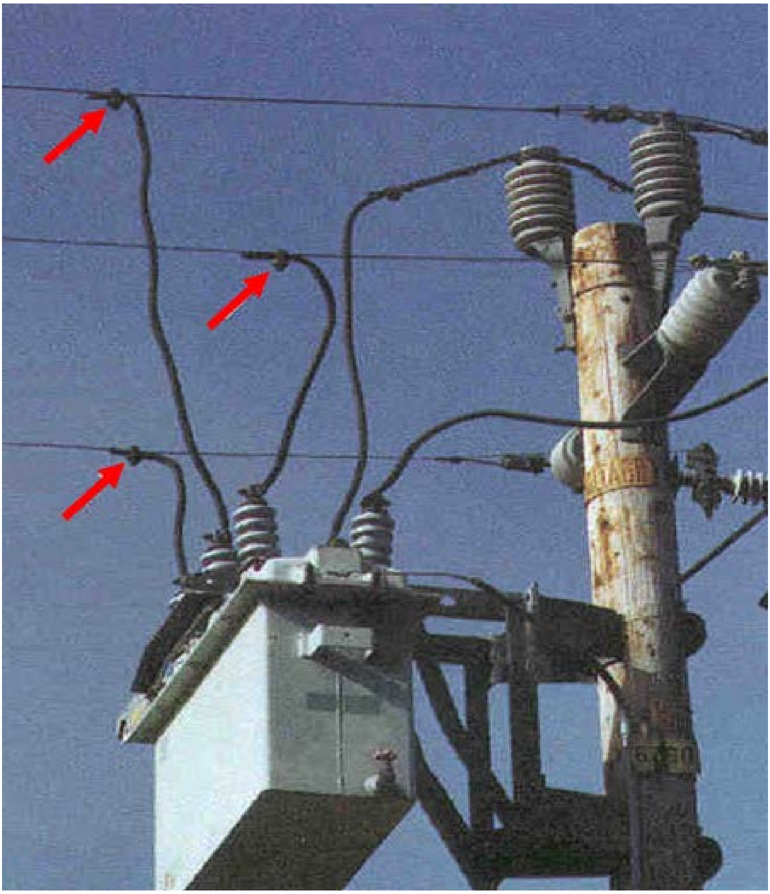


Figure 146. Split bolt connectors.

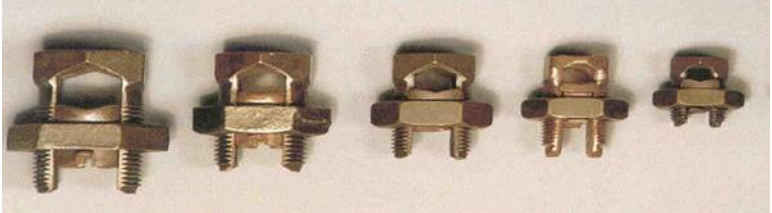
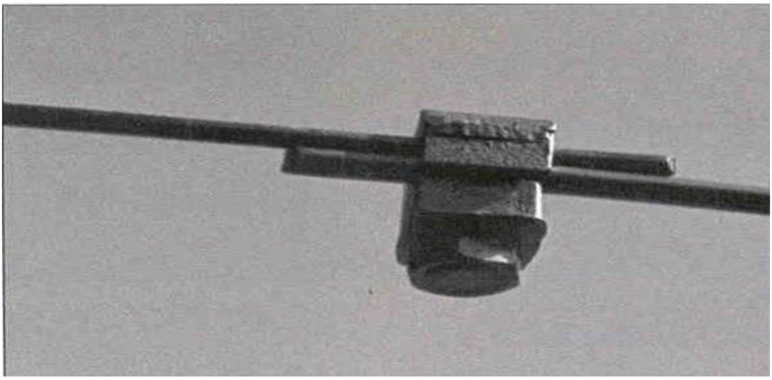


Figure 147. LM connector.

Figure 148. LM connector.

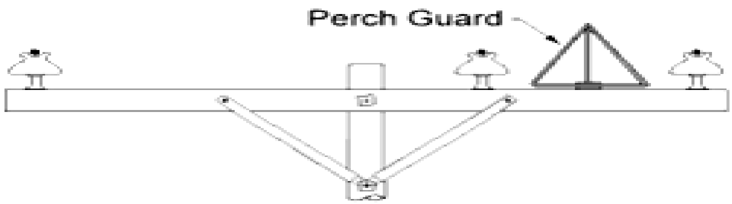


Birds and small mammals may come into contact with electrical equipment and contact two phases or transformer and jumper wires.

This can cause an arc and the bird or mammal often will catch on fire. While many wildland fire investigators may write this off to an act of nature, some consideration should be given to if the utility company had advanced warning concerning a bird or mammal problem. This may present in the form of perch guards or evidence of nesting material and the absence of perch guards.

Note that the perch guard in Figure 149 below is positioned between the two insulators or conductors which 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 149. Drawing of a perch guard between insulators.



In Figure 150, below, the conductors on the crossarms where the nest is located have been removed in an effort to reduce the arc hazard. New crossarms were added further down the pole. The utility company is aware of this situation and may have some responsibility to check it periodically to make sure that nest debris does not build up and reach the conductors below.

Figure 150. Bird nest above wires.

In the case of a bird contacting the conductors, the contact may be short in nature and may or may not cause the line to open or an event to register.

Circumstances Continued

- 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 bird or mammal found near the ignition area.
- High winds or high temperatures (or both) prior to the fire.
- Recent power outages or brownouts.
- Pole damage or vehicle accident.

Investigative Techniques

- Before entering the area under or near the powerlines, first determine if it is safe to do so.
- Determine origin area.
- Determine height of tree (if caused by tree falling on line).
- 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 in and near the area of origin. Look for remains of failed equipment on ground.
- Determine distance of nearby limbs to conductors.
- Determine if legal clearances are present or not.
- Determine general age, size, and condition of vegetation that has fallen on the line. Measure debris on the ground.
- Determine height of powerline.
- Determine height of surrounding forest canopy.
- Determine distance between powerline and vegetation.
- Determine ownership of powerline.
- Determine location of the right-of-way boundary for the power line near the area or origin of fire. Record the distance from the ignition area to the edge of the right-of-way, indicating whether it is inside or outside. Get 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.
- Obtain witness statements from power company maintenance crew regarding what caused the power line failure or ignition from the failure.

- Determine if the utility company has removed any potential evidence and recover it if they have.
- Tree samples:
  - Take into possession the parts of the tree that shows 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.
- Video, photograph, and sketch all relevant areas.
- Note: The fire may not have started where the tree is on the line. For example, a fuse may have been activated or malfunctioned, causing a fire at a different location.
- Examine all poles, lines, fuses, transformers, insulators, splices, connectors, and grounding devices in the area of origin. Take photos and collect samples as needed. Request administrative warrant if needed.
- If a fuse or other mechanical malfunction, it may be necessary to obtain the services of an electrical engineer or powerline expert.
- Examine the scene with the powerline expert and take into possession all relevant evidence.
- If there is a direct short to the ground, examine the area for fulgurites.
- Obtain line data and maintenance records from the power company.
- Secure all relevant records from utility company.
- Consider sending preservation letter.
- Collect records concerning hazard reduction and past problems on the same circuit.

Powerline Safety: Use extreme caution when working around or under lines or near equipment. Always assume conductor is charged or may become charged until utility company provides assurances otherwise. Smoke and/or water spray can cause arcing which may reach to the ground. Never climb a pole. Wait for the arrival of utility crews to make the line safe. Look up, look out, and stay away. Wear proper protective equipment when working from bucket truck.

Fireworks

Definition: Fireworks may be classified in several different ways depending upon the jurisdiction. Most fireworks will fall into one of three categories, ground based and hand-held, aerial, or explosive.

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

Fireworks - Ground based and handheld: Emit flame and sparks which when set off adjacent to flammable vegetation can easily ignite a fire. Types include:

- Base fountains.
- Cone fountains.
- Sparklers.
- Roman candles.
- Wheels and spinners.
- Smokebombs.

Figure 151. Ground based fountains.

Fireworks – Aerial: 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 for an aerial firework which has not been launched properly. Exploded remains may start a fire some distance from launch site and downwind of the trajectory. Fireworks include bottle rockets, parachutes, wings and various sizes of mortars.

Figure 152. Aerial fireworks.

Fireworks – Explosives: Flash powder charge which is accompanied by a boom or bang. Can start fires but conditions may limit the probability. 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 to possess or use in certain states.

Figure 153. Explosive firework.

Circumstances: Fireworks use increases before and after holiday periods, leading to an increase of fireworks related fires. Evidence may include the remains of spent or malfunctioned devices, residue, packaging material, matches or discarded lighters, remains of punks, witness statements of seeing a flash, hearing a bang or seeing sparks and fire. Fragments of a device may be buried in soil and may be due to attempted suppression actions by the responsible party. Unsupervised juveniles may be present near the scene and should be questioned according to agency policy. Handheld fireworks which have been thrown into dry vegetation should be looked at as a possible act of arson.

Figure 154. Firecracker paper remains.

Investigative Techniques

- Search area for launch site and packaging materials.
- Canvass area for witnesses who may have seen or heard recent fireworks activity.
- Document distance from discharge of fireworks and fire origin along with clearances around discharge area.
- If found off roadway, document distance and describe fuel configuration to determine if fireworks item was thrown.
- Photograph and collect fireworks evidence in such a manner to avoid adding fingerprints or DNA.
- Identify type of fireworks used and note any identifying markings.
- Determine if firework was of a legal type in jurisdiction.
- Consider a motive of arson.

Firearms and Ammunition

Definition: Black powder discharge, tracer, incendiary, solid copper and copper jacketed and various types of ammunition are capable of causing wildfires through the discharge of hot materials or mechanical sparks caused when a bullet strikes a hard object and fragments, creating hot particles which land in the dry fuels.

Ignition Factors: U.S. Forest Service research and tests in January, 2013, were conducted using fourteen 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 1,400 ^{o}F. 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 ^{o}F, 7-10% relative humidity) and using highly receptive fuel bed (oven-dried peat moss with 3-5% 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 U.S. Forest Service National Technology & Development Program report *Ignition Potential of Rifle Bullets* at http://tmfire.us/Shooting_ignition_TechTips.pdf.

Figure 155. Rifle discharge at outdoor range.

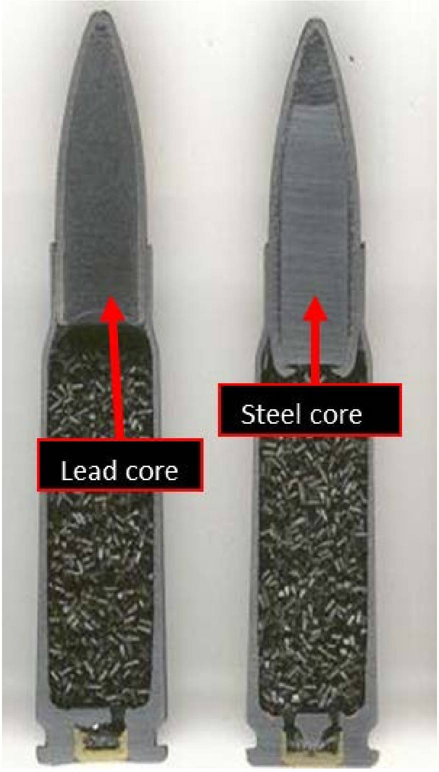
Black powder or flaming patch material directly discharged into flammable vegetation can cause fires. Projectiles such as steel core, steel jacket, steel component, copper, lead, lead core copper jacket, armor piercing (AP), incendiary, and tracer, are among those types of ammunition which can ignite wildland vegetation. Some manufacturers of shotgun shells have marketed shells which cause flame and sparks to be ejected from the barrel of the shotgun.

Any firearms projectile should be considered as a potential ignition source.

Steel core armor piercing (AP) rounds can be obtained from various sources including Chinese or Russian military surplus. The .223/5.54 and 7.62x39mm are the most common. These rounds have an interior steel shank which can start fires when it strikes hard objects such as steel and rocks. A true AP round will have a black or silver tip. Steel jacketed rounds can be recovered using a magnet and many outdoor shooting ranges that ban steel jacketed rounds use magnets to test the ammunition being brought onto the range. Copper plated steel jackets may not be detected by a magnet due to the copper plating.

An x-ray may need to be used to determine the internal components of a round.

Figure 156. Lead core and steel core rifle rounds.



Incendiary rounds may start fires upon impact. Phosphorous enclosed in the round auto-ignites upon exposure to oxygen. Incendiary rounds are considered to be competent ignition sources. Military incendiary rounds may have purple or blue tip. Incendiary rounds are available commercially in some states and various calibers.

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. Magnesium, strontium nitrate and oxidizer (calcium peroxide) traces may be found. Tracer rounds are available commercially in some states.

A military tracer round may have a red or orange tip. As with any of the markings on incendiary or tracer rounds, the paint can be sanded off or may not have been present if from foreign military surplus. Tracer rounds have a steel tip and hollow base and can be picked up by a magnet.

Figure 157. Tracer rifle round being fired at night.

Figure 158. Orange tip marking of tracer round.

Exploding Targets

Definition: Exploding targets detonate upon impact of the projectile, sending out hot particles. Exploding targets are typically a mixture of more than one compound which is generally not considered an explosive until combined. Exploding targets come commercially manufactured in either low or high velocity types. Homemade versions are also being used with similar effects.

Once mixed, the compounds form an explosive device. Wildland fire investigators working a scene which may include an exploding target should use caution when handling, collecting, packaging and storing residue or devices.

An example of a low velocity exploding target starting a fire can be viewed on YouTube at http://www.youtube.com/watch?v=HqxjgmYHQC0.

Figure 159. Exploding target at night.

Ignition Factors

Many of these products are binary explosives, meaning the individual components are not considered explosives until mixed. Once mixed, they are treated as explosives and cannot be transported. Exploding targets are not fireworks. The impact of a round to the container holding the mixed components detonates the mixture. Typical detonation includes a bright flash, sparks and flaming debris, a large volume of smoke which quickly rises and dissipates, and flying debris (shrapnel) which has in some incidents killed and wounded nearby spectators. Exploding targets are meant to be shot indicators but the use of exploding targets in many instances is done in an experimental environment in which the user simply wants to see how big an explosion they can get from using different amounts and types of components.

Circumstances

Examples of exploding target brand names that may be at the ignition area or in possession of shooters include Tannerite, Star Targets, Sure Shot, and Kick-Ass. For additional manufacturers, search the internet.

Fires caused from exploding targets can start far from the detonation site. There is documentation of persons putting together up to 250 pounds of explosives to detonate at one time, with material flying in excess of 100 feet. 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. 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:

- Tiny white pellets.
- Container fragments.
- Packaging material.
- Pieces of plastic.
- Blast damage.
- Shell casings.
- Duct tape.
- Plastic baggies.
- Soda bottles.

Figure 160. 0.5 lbs. of Tannerite detonated beneath the hood.

Other indicators at the scene of a firearms related fire may include:

- Metal appliances.
- Car bodies.
- Rocks near ignition area.
- Ammo boxes.
- Cartridge cases.
- Spent rounds.
- Bullet strikes.
- Targets.

Investigative Techniques

- Thoroughly search the origin area (impact site) and detonation point.
- Apply grid search technique when at range locations.
- Canvas area for witnesses.
- Collect evidence such as casings in such a manner to avoid adding fingerprints or DNA. Projectile may be buried in dirt or trees; use metal detector for recovery.
- Laboratory evaluation to attempt to match projectile and shell casing to firearm.

Cutting, Welding, and Grinding

Definition: These types of ignitions are normally caused by an industrial or agricultural operation, but may also result from an individual or residential activity.

Figure 161. Typical welding operation and cart construction used near residential and small business operations.

Ignition Factors

Fires result from cutting, welding, and grinding operations when hot metal fragments or sparks created by these activities land into a finely particulated fuel bed. Particles will often burrow and result in a smoldering fire prior to production of flaming combustion. The operator may be unaware of the smoldering fire. Welding particles generally land within 10 feet of the operation. Grinding particles are capable of starting fires at distances in excess of 40 feet. Larger particles form a more competent ignition source.

Circumstances

The physical evidence at or near the origin may include:

- Slag.
- Flux rods.
- Metal fragments.
- Discarded grinder discs.
- Welding cart wheel impressions.
- Fire extinguisher discharge residue or other evidence of attempted suppression.
- Location in relation to equipment or an equipment use area.

Figure 162. Slag located at the origin of a fire.

Fire extinguisher discharge residue or other evidence of attempted suppression relates to the Occupational Safety and Health Administration (OSHA) or other regulations that may apply to welding activities.

Figure 163. Welding by-products recovered from fire scene.

Investigative Techniques

- Document clearances, if any.
- Check permit compliance.
- Use magnet or metal detector.
- Exclude or analyze other reasonable potential causes.
- Evidence of welding.
- Interview witnesses, employees, operator.
- Document weather conditions.

Figure 164. Evidence of cutting operation.

Spontaneous Heating

Definition: 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 after periods of warm humid days in decomposing piles of organic material such as hay, grains, feeds, manure, sawdust, wood chip piles, and piled peat moss.

Ignition Factors. There are three categories of spontaneous heating.

1. Material with low ignition temperature that will ignite when exposed to air.
2. Material that undergoes rapid oxidation at normal temperatures and generates heat.
3. Organic materials that ignite as a result of biological and chemical reaction.

Ignition factors which are often present at the scene of a wildland fire caused by spontaneous heating include:

- Wood residue piled to 24 inches or greater.
- Moist/green material.
- Bacterial inoculation through soil mixing.
- Compacting.
- Bacteria processes raise core temperature to approximately 100 ^{o}F.

Different, dry materials may ignite at different depths.

Figure 165. Evidence of spontaneous heating.

Ignition factors also include:

- High air temperature.
- High relative humidity.
- Bacterial die-off raises core temperature to 160 ^{o}F.
- Chemical reaction.
- Thermal feedback causes pile collapse, oxygen intake.

Figure 166. Typical fire effects in sawdust or wood chips when spontaneous heating occurs.

Circumstances

Indicators may include a pile of green 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.

The presence of materials which may spontaneously combust, areas that exhibit outward burning from the interior of the pile (such as Figure 165), and vents (steam holes) present, are all clues of a possible spontaneous heating caused fire.

Spontaneous heating events may occur following a period of rain and or other water application to the fuel bed followed by a period of hot and dry weather.

Figure 167. Typical spontaneous heating fire effects in sawdust and wood chips.

Investigative Techniques

- Utilize photography and videotaping as much as possible when documenting suspect self-heating forest residue piles, including sawdust piles.
- Examine debris piles for species composition and particle size. Susceptible piles usually have a significant percentage of fines and the pile is compacted.
- 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: the greater the live foliage, the greater the likelihood of the pile self-heating.
- Determine the time period from pile creation to present time. Document the time lapse.
- Determine the extent that machinery was used in pushing up the piles and the degree of soil mixing involved in this process. Usually a soil inoculation is consistent with strong bacterial levels in the piles.

- Document any venting (steam holes) present and any associated pungent odor. Document creosote leakage, fungal activity and any strong odors associated with the exterior of the pile.
- 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).
- Record the weather leading up to pile ignition. Look for cool periods, followed by a significant change in weather that would suggest the pile experienced a strong exposure of exothermic heating. This element is thought to cause some form of thermal feedback that may quickly change pile conditions in favor of ignition.
- Make a determination if the piles were self-heating by examining unburned piles. If no unburned piles are available, make this determination by examining the residue of the burned piles and interviewing the operator and/or landowner.
- Document the operations that generated the residue piles and document other locations where suspect piles may exist. Inspect all associated piles and locations for evidence to support spontaneous combustion.
- Interview witnesses and workers, examine other unburned piles in area.
- Conduct a forensic evaluation.

Coal Seam Fires

Definition: Coal seams may be ignited by lightning, wildfires, or other ignition sources. Fires typically burn slowly along the seam and may resurface when seam nears the surface which cracks, and oxygen is introduced to the burning seam. These fires 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 168. Smoke discharging from coal seam fire.

Figure 169. Flaming combustion as cool seam fire surfaces and mixes with oxygen.

Electric Fences

Definition: Fires originating from electric fences used to contain domestic animals. 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 wildland fires. Underwriter Lab approved control heads are not as likely to start fires. Fires from this cause typically occur in the late-spring or early summer. Growing vegetation or vegetation which is just drying out may contact the fence wire and can be heated to its ignition temperature, causing a fire.

Figure 170. Grass residue is on the electric fence wire at 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.

Figure 171. Burn on small tree where electric wire was wrapped around it.

Fires can occur from both braided wire as well as solid wire.

Circumstances

Burned-off stubble, vegetation contact, vegetative transfer, intermittent char marks on the wire, are characteristics that should be noted. Conditions also include a fire origin along electric fence line, dry grass that has not been cut back from the fence, wires which are no longer mounted to insulators, and broken and failed insulators.

Investigative Techniques

- Determine if origin is near fence wire.
- Determine fence line condition and maintenance.
- Determine whether line was electrified.
- Observe and document power supply line from source to fence and document any contact with vegetation, lack of insulators, etc.

- Examine 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 line.
- Examine fence wire for discoloration or presence of charred vegetation.
- Forensic evaluation at scene by qualified electrical engineers before dismantling.
- Additional lab testing.

Figure 172. Forensic examination at scene before system is dismantled.

Refraction (Reflection)

Definition: The sun’s rays can be focused to a point of intense heat if concentrated by certain glass or shiny objects. This refraction or reflection process bends light rays, similar to that which occurs through a magnifying glass. The shiny, concave end of a metal-can may focus sunlight, but its short focal distance makes the potential as a possible cause highly unlikely. Fires started by these items are extremely 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.

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), unfrosted aerosol can bottoms, polished metal, and clear plastic bags filled with water or other clear liquid.

Fires started by glass refraction or reflection are very rare occurrences. This cause may have to be considered due to the presence of an object at the origin with the potential for starting a fire. Flat broken glass, lacking magnification or reflective properties, as well as colored glass will not start fires.

Investigative Techniques

- Document ignition area in relation to object's location and orientation to the sun at the time of day that the fire ignited.
- Document degree and periods of shading, this may require the wildland fire investigator to take into account the day of the year and the specific sun position on the day of ignition.
- Identify reflective items or concave glass in ignition area.
- Collect and test under similar conditions, any reflective objects suspected of causing a fire.
- Determine amount of sunlight at time of ignition.

Blasting

Definition: Fires started by flaming debris associated with blasting activities.

Ignition Factors: Fires from blasting operations will generally be near or in the blast perimeter. In some instances, materials may be propelled by the blast a distance away. Fire start may be delayed due to smoldering combustion.

Investigative Techniques

- Document blasting activities prior to the fire.
- Consider potential of additional explosions and explosive devices in the area and take appropriate safety measures. Consult with persons using blasting materials.
- Look for blasting/burned material remains at ignition area.
- Determine if permits were obtained and conditions followed.
- Permits/fire suppression requirements.
- Attempt to recover foreign debris/material at ignition area.

Flares

Definition: Fires resulting from commercial, industrial, or military flares. Compound is usually a mixture of sawdust, wax, sulphur, strontium nitrate, and potassium perchlorate. Flares burn at approximately 3600 ^{o}F.

Figure 173. Typical road flare with stand.

Ignition Factors: Mishandled or improperly placed flares are a highly competent ignition source. Flares are sometimes used as ignition sources by an arsonist. Hot cast-off material, chemical compound contained in cardboard tube, caps and strikers all are part of a flare caused fire ignition.

Figure 174. Typical deployment of roadside warning flares.

Aerial signal flares are sold as emergency signaling devices, some using standard caliber firearms, see example below.

Figure 175. Aerial signal flare device.

Flare guns, some sold as military surplus, flare guns used for boating, and those used for prescribed fire by some agencies can all send burning rounds into the wildland.

Figure 176. Flare gun and cartridge.

Circumstances

A scene with this potential cause may have multiple flares 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 accidental cause is present but may be some distance from roadway if arson is a cause. Slag will test positive for strontium nitrates. Flare caused fires may also occur along or near military grounds or air operations routes. Flare debris present in the form of caps, strikers, and slag. Cap and striker may have rolled or blown away from origin.

Figure 177. Flare slag at scene of fire.

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 launch site.

Oil and Gas Fires

Definition: Fires associated with the recovery and pumping of oil and gas products in the wildland. Flare pit and stack fires are among some types of oil and gas fires which may be encountered in the wildland environment. Flare pit and stack operations are designed to burn off excess or unwanted petroleum by-products. 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 oil well processing facilities. Flares fired to ignite gas during burn-off operations can start fires. Stack can *burp* and start fires. Flames and/or carbon particles ignite adjacent fuels.

Figure 178. Burning off gas by 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 179. 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 Flare Pit Fires

- Identify if an H_2S battery/well.
- Determine when flare was last lit and how (electric igniter or flare gun).
- Determine distance from battery.
- Commence preparation of sketch.
- Shoot a close-up photograph of stem of the pipe at the flare pit.
- Determine when the battery was last shut down for repairs.
- Examine the well site *Daily Recorder* to identify specific/significant changes in flow.
- Interview the operators to determine history of the battery site, for example, similar incidents.

- 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 Flare Stack Fires

- Identify if an H_2S battery or well.
- Determine when flare was last lit and how (electric igniter, flare gun, or other method).
- Was flare burning when first witness arrived?
- Is the flare monitored?
- Sketch site.
- Height of the stack.
- Base of stack to ground fuels (minimum 2½ times height of stack).
- Is there a *knockout drum* (a *sediment bowl* like tank to prevent condensate getting to the stack)?
- Close-up photograph of top of stack to identify carbon build-up.
- Examine the area for materials that may have *burped* from the flare stack or carbon dislodged from top of stack.
- Examine the well site *Daily Recorder* to identify specific/significant changes in flow.
- Interview operators to determine history of the battery site, for example, 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.

Figure 180. Flare stack malfunction leading to ground fire.

Flying Lanterns

Description. Flying lanterns are miniature hot air balloons made from paper or plastic, bamboo or lightweight wood, and wire with a solid fuel package. Homemade lanterns may use plastic garbage sacks. 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. Experimentation by young adults or teenagers is commonly associated to fires caused by flying lanterns, particularly if homemade. Manufacturers claim that the paper is treated with a fire retardant but many are not.

Flying lanterns can travel miles away from release site and are capable of reaching several thousand feet in altitude. Multiple lanterns may be released at a single time. Releases typically occur during nighttime hours for full visual effect, but can also be deployed during daytime activities.

Note: Oregon has classified flying lanterns as fireworks and banned them from use within the state.

Figure 181. Typical flying lantern in package.

Physical evidence at the scene may include remains of the wire or wood frame, pieces of bamboo or balsa wood, paper remains or ash, melted plastic bag, and the fuel package.

Figure 182. Remains of flying lantern after burning.

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. Determine the wind direction and strength prior to the fire.

Wind Turbines

Definition: Wind turbines use wind flow to generate electrical energy and are increasingly being placed into the wildland environment. Where more than one wind turbine is located in the same area, the term *wind farm* may be used.

Ignition Factors: equipment failures caused by the following:

- Lightning strikes.
- Gear box failures.
- Brake failure.
- Bearing failure.
- Blade failure.
- Generator failure.
- Construction and maintenance.
- Bird strikes.

There are constant activities that occur around a wind farm, so the wildland fire investigator should not assume that the fire ignited from a turbine. Activities such as maintenance, welding, cutting, grinding, and vehicles driving through dry grass are all associated fire causes.

Figure 183. Wind turbine fire.

Due to the technical aspect of wind turbine operations, wildland fire investigators are encouraged to seek the support of a subject matter expert.

Home Outdoor Wood Burning Furnaces

Definition: Referred to as *outdoor wood furnaces* or *outdoor wood boilers*, these devices can be modern manufactured models or homemade. They can be used to heat a structure by way of connecting to a central heating unit and/or are used to provide hot water. Either way, the furnace operates by burning firewood and may be burning wood even in the warmer parts of the year if it is being used to heat water also.

Ignition Factors: Home outdoor wood burning furnaces tend to have two major causes of fires: 1) discarded hot ash from cleaning the furnace out and; 2) lack of maintenance, including cleaning out the chimney. Furnaces tend to receive less maintenance than indoor wood heaters.

Circumstances: These units are typically located separately from the structure and are often enclosed in a portable or constructed shed for insulation. Most fires will originate in or close to this location.

Investigative Techniques

- Determine if wood furnace was in use at the time of the ignition.
- Determine when wood was last added.
- Determine the type of wood being used.
- Determine if the wood furnace firewood door was open or closed at the time of the fire.
- Determine if there is fire on the interior of the wood furnace box.
- Interview witnesses and owners.
- Determine maintenance.
- Determine location of ash disposal.
- Determine temperature of ash pile.

Structures

Definition: Fire spreading to the wildland due to failures or activities associated with a structure.

Structure fire investigation is a specialized 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 which show spread originated at or in structure.
- Smoke or flame coming from chimney.
- Power failure to structure or nearby area.
- Human activity in the area.

Investigative Techniques

- Identify need for specialized wildland fire investigator resource.
- Photograph burning structure early to document where and to what degree fire is burning in each portion of the structure.
- Conduct walk around of burning structure documenting degree of burn.
- Locate and document condition of gas service.
- Locate and document condition of electric service.
- Examine exterior for evidence of activity including containers or spill patterns which may indicate the use of an ignitable liquid accelerant.
- Interview occupant, reporting party, and other locals in the area to determined earliest sighting of fire, its location, and size.
- Examine doorway access for signs of forced entry.
- Examine windows for signs of forced entry and/or explosion indicators.
- Work from least burn to determine burn indicators and identify the room of origin.
- Examine room of origin for indicators of a specific area of origin.
- Examine specific area of origin for ignition sources.
- Identify ignition source and eliminate other ignition sources in room of origin and other rooms if need be.

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Chapter 7 - Arson Recognition

Definitions

Arson: The intentional and wrongful burning of someone else's property or one's own property (as to fraudulently collect insurance). (Garner, 2009)

Incendiary: Deliberately and unlawfully set fire to property. (Garner, 2009)

These terms are often used interchangeably, but it depends on the jurisdictional interpretation. Check with your prosecutor if you are not sure.

Arson is a felony, punishable by imprisonment of one year or more and/or a fine.

Figure 184. Arsonist escaping the scene.

Introduction

Arson may account for over 20% of all human-caused wildland fires, and up to 70%+ of fires in some jurisdictions. It is probable that many arson fires are going unrecognized. Fires classified as *Undetermined* should not be categorized as arson but may require repeated review to see if new evidence can assist in establishing a cause.

There is a mythology surrounding serial wildland fire-setting, much of which is based on anecdotal information not supported by research.

These myths have been institutionalized through *war stories* and training.

Serial Arson

Myths

- Numerous large fires that occur in rapid succession over short period.
- Elaborate and sophisticated devices.
- No physical evidence at the scene.
- Random and unpredictable incidents.
- Highly skilled and sophisticated offenders.

Reality

- Small fires that may escalate in both frequency and severity.
- No ignition source recovered or a single match.
- Physical evidence at the scene.
- Recognizable and predictable patterns.
- Unskilled and unsophisticated offenders.

The average serial arsonist is charged with 2.7 counts of arson and convicted on 2.5 counts and is suspected of setting an average of 35 fires before being apprehended. This high number of fires prior to apprehension can be related to poor origin and cause determinations, poor evidence collection, or *linkage blindness* (not recognizing the linking factors), and lack of sharing information between wildland fire investigators and affected jurisdictions.

The early identification of the arson series is critical because:

- Every fire set has the potential for tragic consequences.
- Fires may tend to escalate in frequency and/or severity.
- Fires increase resource drawdown.

Early detection may lead to additional charges which can increase sentences. Additional charges are more likely to result in plea bargains. Arson fires can tax the limited fire suppression resources and funding available, leaving less for other types of incidents.

Factors: Arson may be a challenging crime to solve and prosecute due to a number of factors.

Arsonists

- Work alone.
- Conceal their activities to avoid detection.
- Flee scene.
- Leave little obvious physical evidence.
- Rarely confide in others regarding their activities.
- Appear to function in a random and unpredictable manner.
- The commission of the crime is short in duration.
- Fire suppression activity may destroy or obscure evidence.
- Eyewitnesses to the crime are uncommon.
- Many prosecutors have little or no experience with wildland arson cases.
- Arson motives may appear to be unfathomable.

While these factors can make the apprehension of a serial arsonist difficult and time consuming, they can be caught in most instances.

As a Wildland Fire Investigator (INVF) certified by your agency, you will need to understand your role and authority when it comes to arson investigation. Check with your agency policy if you are not sure. Individuals certified by their agency as Wildland Fire Investigation Team Member (INTM) are typically trained in the investigation of wildland arson and involved in the development of an arson investigation case.

The role of the INVF is to link what may initially seem to be unconnected fires. This is done through physical evidence, pattern analysis, development of an investigation plan to identify the person responsible, forensic evidence, and behavioral evidence. These activities may lead to the observation of fire setting and subsequent arrest, charging, and bringing to trial the responsible party.

Figure 185. Arrest of arson suspect.

Role of the Wildland Fire Investigator

The role of the INVF is to examine and analyze the fires you respond to for an indication of arson; protect and secure the area of origin for further examination; provide timely notification to the appropriate level of wildland fire investigator according to agency policy or practice; maintain confidentiality of all aspects of the investigation and to assist as requested.

Do not assume or presume any law enforcement powers beyond those you are authorized to apply. Maintain strictest level of confidentiality.

Share information only with those who need to know. Do not release any information to the media without agency approval.

Many arson fires go unrecognized, often due to a lack of overt evidence or linkage blindness. The INVF is in the best position to detect an arson pattern in the early stages of development, often within two to three fires. It is important that the INVF have an awareness of arson indicators and be familiar with fire occurrence patterns.

Indications of an Arson Incident

Wildland arson fires are often set in multiples and may occur on the same day, during a single spree of arson setting, or over weeks or months and even years. Serial arson fires typically occur in close proximity to each other but can be a long distance apart. They can be set in the same or different agency jurisdictions. The pattern that is set up provides clues to the offender’s mode of operation.

The majority of wildland arson fire scenes are accessed by motor vehicle, including roads, ATV trails, power line right-of-way, etc. Roadside fire sets are the most common.

Figure 186. Roadside arson caused fire.

This is often due to the low risk of access and egress. The offender will more than likely look for easy quick access, with a low risk of being observed. There can be exceptions to this but; the reason isn’t always obvious. The level of risk that each offender is willing to take when setting fires may differ, but almost all arson offenders are looking for ways of managing their risks of apprehension.

Recent occurrence of undetermined cause fires in an area exceeding the normal fire history is one indicator that an arson series is taking place. Fires with no evidence of an ignition source is another. The discovery of delayed ignition devices at the fire scene is an important indicator of an arson series and method of operation. Many arson starts are *hot-set*, meaning the use of an open flame device which is often carried away from the fire scene with them. An increase in the history of night time fire occurrence may also be a clue that an arson series is taking place, darkness providing a reduced risk of discovery for the offender. The wildland fire investigator must address other potential reasonably possible causes that the data supports in the area of the origin.

Patterns and Linkage: Wildland fires may be connected by common patterns. Linking patterns may be chronological times-of-days and days-of-week of fire setting or geographical, as in the same area or road system. Target selection can sometimes help to link fires if analysis can show a common theme of target selection. Mode of Operation (MO), can link fires if the way each fire is fueled, ignited or managed is similar.

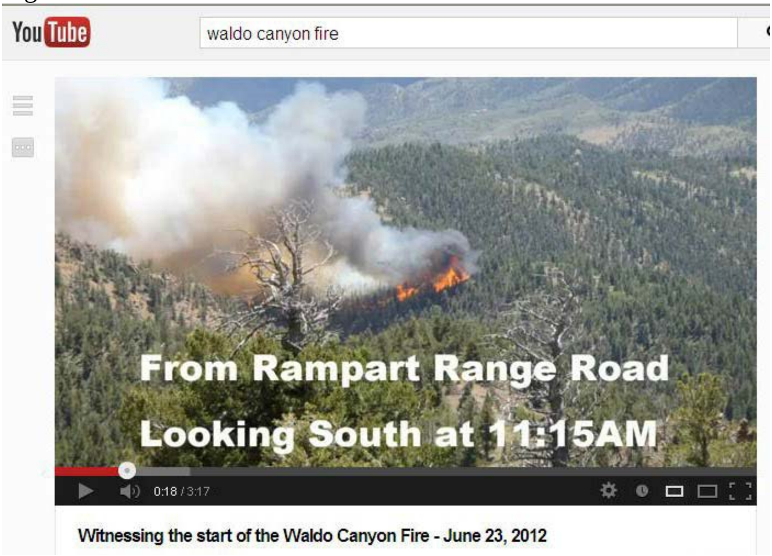
> **Example**: Five fires occurring on Tuesdays and Saturdays, between 1400 and 1600 hours, on the same road system, paper match recovered on two of them. In this example there is enough information to start to link the fires chronologically, geographically, and by mode of operation.

Arson Ignition Sources: Determination of the ignition source is an important aspect of the investigation. Wildland fire investigators should be aware of the various ignition sources that are commonly used.

Figure 187. Cigarette match device remains.

Sources of information on ignition devices include publications, the internet, and social media. Figure 188 is an example http://www.youtube.com/watch?v=hv9ZrJnHEF4.

Figure 188. Internet site for fire information.



Ignition sources may be characterized by how they are ignited:

- Electrical reaction.
- Chemical reaction.
- Mechanical reaction.

Electrical and chemical arson devices are relatively uncommon in wildland arson cases. Typically, electrical and chemical devices are used to ignite vehicles and structures which may spread to the wildland. The occasional use of chemicals to ignite a wildland fire may include the use of brake fluid and granular chlorine, a combination which provides a time delay which is somewhat unpredictable. Mechanical devices are much more common.

Ignition sources can be characterized by their ignition function including hot set and time delay or their delivery method, direct or remote.

A hot set is an open flame applied directly to available fuels. The device may be left at the scene or removed. Recent USFS research indicates that approximately 80 percent of offenders used a hot set device.

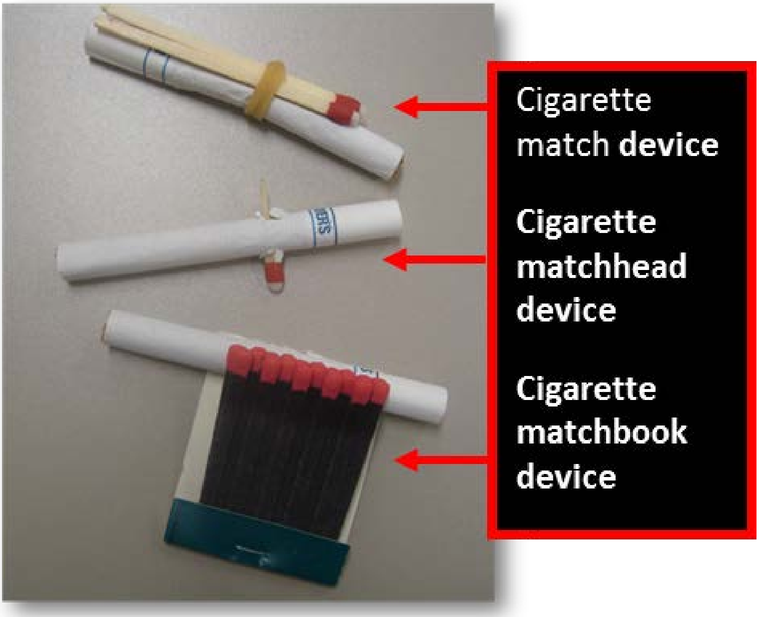
An offender may add to, rearrange or modify fuels to aid in ignition. They may also use available fuels in uncommon ways. This may become part of their mode of operation which helps to link fires to a single person or group of persons.

Draped moss can make an excellent host fuel for a hot set. A branch or moss can be lit well off the ground and still drop fire to the ground fuel.

Figure 189. Example of ignition of fuels off the ground.

Timed ignition sources incorporate a timer or delay mechanism which provides an opportunity for the offender to flee the scene and reduce the risk of being seen at the fire. Cigarette and match or matchbook (slow match) devices are two of the most common wildland time-delay devices used.

Figure 190. Examples of cigarette match device construction.



Each of these devices is based on the time delay achieved by the smoldering cigarette prior to it burning down to the matches themselves. Cigarette match devices can use either paper or wooden matches and may be attached using a unique or *signature* method which can help to link an offender. The cigarette match head device can also use either wooden or paper matches. In some cases the match head is cut completely off the match and is placed within the barrel of the cigarette so that it does not show up on the outside of the ash. Without close inspection, a wildland fire investigator can miss the match head within the ash and think that the fire was started by a discarded cigarette. The matchbook used to construct the cigarette matchbook device can yield valuable information on its cover and interior. This information should be documented. DNA can sometimes be recovered from the filters of cigarettes. Package the remains appropriately for sending to the lab if this is an option.

Timed ignition sources (devices) may be weighted to enhance the remote delivery with greater distance. The weight may be hidden under ash or lying nearby. Examine the ignition area carefully for objects which may have been used to weight the device. Objects used as weights can include: coins, rocks, nails, nuts, bolts, washers, or any other small, heavy object.

It takes a trained eye to find ignition devices in the ash and burnt debris. The remains may be on the surface or under the ash. A thorough and methodical scene inspection can increase the odds of locating these devices.

Remote delivery of a device includes launching it from a distance by hand or mechanical means. Hot set or timed ignition source can be included in this category. The method used to launch the device may help to link fires.

Direct delivery takes place when the device is hand-carried and placed in a specific location. Again, this can include both a hot set or timed ignition source.

Less Common Ignition Sources

Fireworks are used as ignition devices but it may be difficult to determine the intent of the offender. Hand delivered fireworks which are placed or thrown into dry vegetation should be looked at as a possible arson device. Fireworks which have been ignited on pavement or in a vegetation free area and move or jump about may prove harder to show motive. Pattern analysis and MO analysis will be crucial to determining arson when fireworks are being used.

Concave shaving mirrors may be placed to focus the sun's rays much the same way as using a magnifying glass. Multiple mirrors may be placed to set fires throughout the summer. Use of the mirrors will generally provide physical evidence at the ignition area and help to link similar fires.

Commercial slash burning or backfiring devices have limited availability. They may include a blasting cap and jellied gasoline. These devices leave physical evidence at the ignition area and may help to link fires.

A magnifying glass may be used to focus the sun's rays similar to a concave shaving mirror. Physical evidence will be present at the scene if it is used as a time delay device. Children may also be involved in using magnifying glasses to play with fire and they may leave the device behind.

A railroad or highway flare used as an arson device is often launched remotely from a moving vehicle. Telltale signs include white slag, the striker cap, and the remains of the flare itself. Similar flares may be found nearby or in a suspect's possession. Flares may be used as timed device by balancing it on a rock or setting one end in the soil.

Candles have been used as time delay devices. Regular candles or re-lighting trick birthday cake candles can be used. The candle can be enclosed in a flammable container to prevent extinguishment. Unburned container residue may be present at the ignition area. Candles may not melt entirely and a wax residue may be located below the ash or on the surface. The metal wick tab may become black in color but will often be present in the ash.

Tracer or Incendiary bullets are available through military or commercial civilian sources. Some states have regulations banning the use or possession and transport of tracer and incendiary bullets. These rounds may be used at both developed and undeveloped ranges. Remote origins within sight of a road or trail should be looked at for this type of cause.

Accelerants may not necessarily be in liquid form. Crumpled up paper, staged fuel modifications such as concentrating pine needles near the origin, or any other items capable of accelerating the fire’s spread, which were not naturally or ordinarily there prior to someone placing them or rearranging them there, can constitute an effort to accelerate a wildland fire.

While the use of ignitable liquids to accelerate the fire’s spread and intensity is not common in the wildland, accelerants should be routinely looked for. In one limited study of U. S. Forest Service cases, 23% of convicted arsonists admitted to using accelerants at least once. Dark sooting, smell, and burn patterns consistent with an ignitable liquid can be a clue to its use. Consider taking soil samples or using an accelerant detection K-9, or both.

Other incendiary devices may include:

- Charcoal briquettes.
- Cotton rope.
- Incense sticks.
- Firework punks.
- Mosquito coils.
- Paper wrapped around a rock.
- Punky logs or stumps.
- Exploding targets.
- Ping pong ball/gunpowder.

Arson Motives

Motive is the reason why someone commits a crime. Motive is an emotional, psychological or material need that impels and is satisfied by a specific behavior, for example, setting fires. It does not need to be proven to convict the offender. Motive is often relevant to the investigation and prosecution and may provide direction for focusing the investigation once arson has been established. Most wildland fire setting is motivated by an emotional or psychological need.

Wildland fire investigators should be cautioned not to use motive to support a hypothesis of arson. Motive should be considered after arson has been established as a cause and used to identify suspect(s) and potentially link fires.

The Federal Bureau of Investigation (FBI) classifies arson into six categories:

- 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.

Excitement motive relates to fires set to satisfy an emotional need to create excitement. Subsets include 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 or it may include insurance fraud. Fireline arson as a motive relates to firefighters making additional money by seeing that fire escapes the boundaries of control and extend the need for the firefighting effort. Fire-setting firefighter or contractor motive, *the blacker the forest, the greener the wallet* may be the direct result of a firefighter or of someone who does either support work or contracting during fire suppression activities.

Vandalism motivated fires are generally nuisance type fires, lit simply for destructive purposes. The offenders are usually young and male. The offender may have an accompanying pattern of nuisance or school related fires in a nearby town. Equipment in the woods may be targeted. Fires are less likely to be set directly to the natural resources themselves.

Figure 191. Arson to equipment.

Crime concealment motivated offenders set fires to destroy the evidence of a primary crime other than arson, such as homicide and vehicle theft. Scene security and evidence protection is particularly vital as well as cooperation with law enforcement.

Extremism or terrorism includes fires motivated by political or social agendas. In the U.S., radical environmentalists have been associated with this activity. The potential for non-domestic terrorism exists but is rare. Fires are typically targeted against logging equipment and related facilities along with other human improvements which exist in the natural resource environment.

Mixed motives: Serial arsonists may have a mixture of motives. Power maintenance and anger may be underlying motivations for many arsonists. Wildland fire investigators should consider both primary and secondary motives.

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 the excitement, recognition and/or profit.

- Juvenile fire-setters may act out of curiosity, *cry for help*, or delinquent fire-setting in older youths considered to-fall under the vandalism, excitement or attention motive categories.
- Mentally disturbed fire-setters may set fires as a symptom of a mental disorder.
- Female fire-setters have increased in the last few years with motives of retaliation, excitement or attention, often associated with relationships that have gone bad.
- Cultural firesetters may set fire based on historical land management practices. Do not assume that the fire is culturally based just because of past cultural practices. Most current cultural fires have roots in other motives such as vandalism, excitement, revenge, and intimidation.

Psychology of Arson

Many mental health experts disagree on the mental state of arsonists. *Pyromania* as a stand-alone mental disorder is essentially considered by many experts to be a myth. It is no longer in the DSM5 (American Psychiatric Association, 2013). These persons are more likely to be motivated by criminal intent or the fire setting is a manifestation of another underlying mental disorder. The wildland fire investigator should focus on identifiable criminal motives and should not attempt to diagnose the mental state of the offender.

Many offenders state they would have continued lighting fires even if they had known they were going to be apprehended. Fire setting may restore a feeling of power and control to an offender who has little of either in his or her life.

Excerpts from psychiatric evaluations or even statements from the offender may include:

- He is a loner who has maintained few friends and has never married.
- He describes himself as a wuss, stupid and feeling bad.
- He says, “I need some help. I have held so much inside for so long.”

Themes that consistently appear in psychological research and evaluations include:

- Poor social adjustment skills.
- Anger expressed as retaliation.
- Feeling of helplessness or lack of power (or both).
- Low self-esteem in general.
- Victimized by society.

- The fire-setting behavior is a response learned at an early age that provides emotional relief.
- Compulsive behavior.

Classification of Arsonists

Arson is divided into three classifications, single, spree, and serial.

- Single arsonist - an offender who sets a single fire then ceases.
- Spree arsonist - an offender who sets fires at three or more separate locations with no emotional cooling-off period in between the fires.
- Serial arsonist - a person who sets three or more fires, at the same or different locations, with an emotional cooling-off period between the incidents. The cooling-off period is the result of temporary psychological relief that results from the act of setting the fires.

Behavioral Characteristics

A wildland serial arsonist will normally set fires primarily to vegetation, but may set fire to vehicles and structures. 90%+ operate within their comfort zone, an area they are familiar with and feel that the risk of detection is acceptable. Serial wildland arson will often occur after a precipitating stressor prior to fires. Approximately 40% of serial wildland arsonist set fires exclusively in daylight. Most drive to the scene and may remain on scene to watch the fire or participate in fire suppression. Some serial wildland arsonists may remain nearby and watch from a vantage point or later return to the crime scene. (Steensland, 2004) (Sapp, et al., 1996) (Sapp, et al., 1994).

Role of the Wildland Fire Investigator

As a Wildland Fire Investigator (INVF), follow agency policy when determining your role on a suspected arson fire scene. Take scene security and protection measures. Request additional investigative resources as necessary. Conduct an origin investigation. Collect evidence in accordance with agency policy and determine the cause and the ignition sequence. Wait for the arrival of a more qualified wildland fire investigator while performing all of the normal activities associated with the location and protection of evidence, scene security and potential witness identification.

The following Figures show various ignition devices as they were discovered at a wildland arson scene, followed by photos of the pre-fire ignition device.

Figures 192 to 194 show the remains of a fusee device. Figure 195 shows the pre-fire fusee. Figure 196 shows burnt hole in pants from fuse.

Figure 192. Remains of a fusee ignition device.

Figure 193. Slag from fusee on rock.

Figure 194. Remains of cardboard base from fusee.

Figure 195. Pre-fire road flare/fusee.

Figure 196. Burn holes on pant legs of suspect from fusee slag.

Figure 197 shows the remains of a rope and match device, Figure 198 shows the pre-fire device.

Figure 197. Burnt remains of cotton rope with matches tied to it.

Figure 198. Cotton rope with matches tied to it prior to burning.

Figure 199 show remains of an incense stick and match device, Figure 200 shows the pre-fire device.

Figure 199. Burnt remains of incense stick with paper matches attached.

Figure 200. Incense stick with paper matches before being burned.

Figures 201 and 202 show the remains of a rock wrapped in paper device, Figure 203 shows the pre-fire device.

Figure 201. Rock at ignition area.

Figure 202. Paper remains protected under ignition device/rock.

Figure 203. Rock wrapped in paper prior to burning.

Determination of Arson

After a determination of arson is made, proceed within the limitations of your role and authorities. Make the necessary referrals according to your agency policy. Remember to maintain strictest confidentiality, *Need to know*. Do not release any information to the public, media, or non-assisting agency.

Chapter 8 - Court Preparation and Testimony

The Civil Process

Filing of the case: The civil legal process prior to trial typically begins with the filing of a complaint. In the complaint, the plaintiff presents their theory of the case and the hoped for remedy.

An answer is filed by the defendants as their response and outlining their affirmative defenses.

Discovery stage

During the discovery stage, both sides exchange all non-privileged relevant evidence. Over 90% of contested cases do not get past the discovery stage. A number of discovery processes will take place during this stage.

Interrogatories: lists of written questions served by each side on the other in an effort to get answers to key questions pertaining to the case.

Request for Production: a process in which one side or the other formally requests that all documentary and physical evidence be produced for examination.

Request for Admissions: a process in which each side will attempt to narrow the contested issues in a case by getting admissions from the other side so that they do not need to be contested.

In each of these stages, the wildland fire investigator may be asked to provide certain documents or answer questions about the case. It is important to emphasize that these discovery instruments have enforceable deadlines, with sanctions (possibly monetary) for failing to meet the deadlines.

Depositions (Examinations) Stage

Depositions are a form of the discovery process and include the examination of persons who have knowledge about the case. The questioning in a deposition is similar to that during trial. The person to be deposed will be given a notice by the side desiring to take their testimony. This notice may be served directly to the person or may be served to the legal representative of the person. During the deposition, direct questions will be asked by the noticing attorney(s) and cross examination may also take place. In some cases, where there are multiple defendants, multiple attorneys for the defendants will take turns asking the questions they each have.

A deposition is taken under oath and before a Court Reporter but there is no judge or jury (finder of fact) present. The counsel's objections are for the record only, requiring an answer to the question unless it is privileged and/or you are advised not to answer it by your legal representative. As it sometimes takes a moment for an attorney to voice an objection, it is recommended that after each question is asked, the person being deposed should pause a second or two before answering, allowing the objection to be lodged first, if there is one.

Remember, a Court Reporter will be taking your testimony down in a written transcript. In addition, a videographer may be present who is videotaping the testimony of the person being deposed. For these reasons, speak so that the Court Reporter can hear you, and not too fast. Most reporters will advise you if they are having a problem getting all of your testimony.

After the deposition a copy of the transcript will be provided for review. Corrections and answers can be modified during review of the transcript but subject to further questioning during the trial phase.

For this reason, always try to give a complete answer to specific questions during your deposition. If there are questions during the process, ask for clarification or to restate the questions.. If legal advice is needed, request a moment with the legal representative.

Subpoenas

A subpoena is a command by the court to present yourself for formal questioning at a deposition or for trial. A subpoena *duces tecum* (production of evidence) is a command by the court to bring all requested documentation for use at the hearing or trial. Know the agency's policy on responding to subpoenas.

Motions and Pre-Testimony Trial Processes

Pre-trial motions may include the following:

Summary Judgment: One or both sides will ask the judge to rule on the case prior to trial based on information presented to the judge by each party.

Motion to Dismiss: a motion by the defendants requesting that the case be dismissed due to some alleged failure to meet the burden of proof.

Motion to Suppress Evidence: a process used to exclude certain evidence from being admitted into court.

Daubert Hearing: an assessment by a trial court judge on the admissibility of *expert* testimony, scientific or technical. It is conducted out of the jury's presence and is usually based on a motion *in limine*, which occurs before the trial even begins and determines which evidence or testimony will be presented to the jury. It typically occurs after the discovery phase so the hearing is completed before the trial starts. *Daubert* applies to all federal courts and to courts in approximately half of the states.

Voir dire: a form of examination used to determine the qualifications of an expert witness and can be used to exclude the witness and/or limit their testimony. *Voir dire* is also used during the selection of a jury in the case of a jury trial to determine the qualifications of each juror. This may result in a juror being dismissed from serving.

Prior to any testimony during a trial, opening arguments will be presented by each side to the trier of fact.

Testimony at trial: begins with direct questioning of the witnesses for the plaintiff(s) first, as the burden of proof is on the plaintiff(s). The defendant’s attorneys will have the opportunity to cross-examine each witness which may be followed by further questions by the plaintiff’s attorneys called re-direct. Once the plaintiffs have put forward all of their witnesses and rested their case, the defendants will then present their defense witnesses and evidence. The plaintiffs will have the opportunity to cross examine each defense witness. Typically, these defense witnesses will be put forth to rebut the testimony of witnesses for the plaintiffs or to bring into question aspects of the plaintiffs case. Once the defendants have rested their case, the plaintiffs may call rebuttal witnesses to address issues brought up by the testimony of the defendant’s witnesses. This could include the wildland fire investigator.

A civil trial will end with final motions and closing arguments by each side. After deliberation, the finder of fact (judge or jury) issue a verdict, also called a judgment.

Appeals may be filed after the trial which is generally limited to issues of law, not findings of fact.

The Criminal Process

In a criminal proceeding, an indictment is issued as a formal written accusation of a crime, made by a grand jury. An information is a formal criminal charge made by a prosecutor without a grand-jury indictment. An information is most often for misdemeanor charges but about half of the states allow it to be used for felony charges.

In a criminal proceeding in federal court, a Grand jury issues an indictment while at the state level and a prosecutor issues an information charging the crimes and stating the theory of the case. An arraignment hearing will take place before a judge to formally charge the accused of the crimes and in some cases, the accused will enter a plea. In some cases, an extension for entering a plea may be granted by the court. The accused may plead guilty, not guilty, or *nolo contendere*. *Nolo contendere* means, “I will not contest it”, usually treated by a criminal court as a guilty plea. The difference is that in pleading *nolo contendere*, the plea cannot be used against the defendant in a subsequent civil proceeding.

If the accused pleads not guilty during the arraignment, some jurisdictions will proceed to a preliminary hearing in which the prosecutor will put on a condensed version of the case to show that there is enough evidence to support the charges and for a trial to take place. The right to a preliminary hearing can be waived by the defendant. The wildland fire investigator will likely be called to testify during the preliminary hearing, however, in some States a single sworn officer is allowed to testify to hearsay evidence only during this phase of the proceedings. This may negate the need for the wildland fire investigator to appear at the preliminary hearing. During the preliminary hearing, sworn testimony is taken which can be used during the trial itself.

Discovery will take place just as in a civil case but in the criminal case generally only the prosecutor has to share evidence and information.

Pre-trial motions to suppress evidence will be followed by the *Voir Dire* process of selecting a jury and/or qualifying expert witnesses. Just as in civil cases, in federal court and approximately half the state courts, the qualifying expert witnesses may take place prior to the trial in a *Daubert* hearing. In other state courts, the qualifying of expert witnesses is generally done during the opening of each expert’s testimony. Daubert hearings are less common in criminal cases, but are used extensively in civil cases.

During the *Daubert* hearing, the expert will be asked questions concerning their qualifications, opinions, and expertise. This is done under sworn testimony before a judge.

In some State courts the qualifying of experts is often done before the judge and jury as the expert witness is called to the stand. The defense may or may not challenge the expert witness or may ask only limited questions if the expert is clearly well qualified. This is often an effort by the defense to avoid bringing out the positive qualifications of the expert and building up their credibility in front of the jury or judge. The prosecutor can, and often will, question the expert witness about their qualifications in an effort to build credibility with the jury or judge. The judge will typically give the jury an instruction which advises them that it is up to the jury to determine how much weight each expert's testimony is given. This instruction is typically given prior to the testimony of the expert witness.

Opening arguments will take place just as in a civil case prior to any witness testimony. Testimony will follow the opening arguments with the prosecution presenting their case and witnesses first with cross-examination and re-direct questioning taking place. Once the prosecution rests its case, the defense will have the opportunity to present its case. This can be preceded by a motion to dismiss for lack of evidence by the defense after the closing of the prosecution's case. These motions are rarely approved and the defense will normally proceed with its case.

The wildland fire investigator can be called to the stand for the prosecution or the defense. The wildland fire investigator or other prosecution experts can be called following the defense case as a rebuttal to the testimony of defense witnesses and experts.

Closing arguments are given by the defense and the prosecutor, and the finder of fact (judge or jury) will deliberate and issue a verdict.

Following a verdict, appeals may be filed concerning the case. The prosecutor can appeal almost any issue of law (for example, Judge dismisses case without verdict, suppression of evidence), but cannot appeal a verdict of not guilty. The defense can appeal any issue of law.

Types of Evidence

Witness testimony is a type of evidence. A witness can provide what is called **direct evidence** in the form of statements like "I saw him do it". Direct evidence can include documents which establish a fact.

Circumstantial or indirect evidence: typically proof of a chain of circumstances pointing to the existence or non-existence of certain facts. *Footprints in the dirt near the origin area matched shoes worn by suspect* is an example of circumstantial evidence.

Judicial Notice: also known as judicial cognizance or judicial knowledge, is used to describe the court's acceptance without further proof of well-known and indisputable facts. Often these facts were the subject of previous rulings and acceptance.

Fact Witnesses: testimony based on factual observations that they made themselves. Hearsay information, opinions, and conclusions are generally not allowed from fact witnesses. Most cases require fact witnesses.

Expert Witnesses

Federal Rules of Evidence - RULE 702 (2013 revision)

Federal rule 702 provides guidance as to when expert witness testimony is allowed (2013). A witness who is qualified as an expert by knowledge, skill, experience, training, or education may testify in the form of an opinion or otherwise if:

- The expert's scientific, technical, or other specialized knowledge will help the trier of fact to understand the evidence or to determine a fact in issue;
- The testimony is based on sufficient facts or data;
- The testimony is the product of reliable principles and methods and;
- The expert has reliably applied the principles and methods to the facts of the case.

Many States have similar *Rules of Evidence*. The wildland fire investigator should be familiar with the relevant *Rules of Evidence* that your court may apply.

Daubert v. Merrell-Dow Pharmaceutical Company - US Supreme Court 1993

In the 1993 *Daubert v. Merrell-Dow Pharmaceutical Company* case, the U.S. Supreme Court ruled that expert testimony must be relevant; and reliable (1993 U.S.).

The Supreme Court ruled that the judge will serve as a gatekeeper and apply the following four part, non-exclusive, test to decide a proffered expert testimony's reliability.

- Can the theory or technique be tested;
- Has the theory or technique been subjected to peer review;
- Is there a known or potential rate of error associated with this theory or technique; and
- Does this theory or technique have a general acceptance in that particular discipline's community?

Michigan-Miller's Mutual v. Benfield - 11th circuit 1998

Michigan-Miller's Mutual v. Benfield involved a fire trespass case in Federal court (1998). During the appeal to the 11th circuit court in 1998, the court tendered the expert's testimony excluded because:

- Failure to meet FRE 702 (Daubert test) standard.
- Did not perform any tests or take any samples.
- No scientific basis for opinion.

Expert Witnesses are those who are qualified by education, knowledge, skill, or experience and are allowed to draw inferences, form conclusions, and testify as to their opinions. Most fire cases require expert testimony. The trial court judge determines expert witness qualifications, conclusions and methodology in a Federal court, during a hearing using FRE 702, often referred to as a *Daubert* hearing due to the name of the Supreme Court case which established the test to be applied to expert qualification and reliability.

Under *Daubert*, the Supreme Court has held that the trial court judge acts as the *gatekeeper* for the purpose of determining the admissibility of an expert's testimony. The Daubert process may or may not be followed by State, and/or crown courts. Where State courts do not apply the *Daubert* criteria they apply similar criteria and the judge or jury can be the gatekeeper.

***Voir Dire* - Qualifying Expert Witnesses:**

Voir dire is the first step in qualifying a proposed witness as an expert. It is similar to a trial within a trial. The prosecution/plaintiff and defense counsel have significant freedom to question the proposed expert's qualifications. The expert's qualifications must be established prior to giving expert testimony. A voir dire process is also used to select juries.

The prosecution, plaintiff and defense counsel establishes qualifications of their respective proposed expert witnesses.

Opposing counsel may cross examine the expert to reduce credibility of proposed expert witness. The expert's testimony is allowed by the judge if the minimum *Daubert* qualifications are met. Some state jurisdictions do not use *Daubert*. The trier of fact (judge or jury) decides weight and credibility given to each expert's testimony.

All proposed expert witnesses should possess an accurate and up to date curriculum vitae. The curriculum vitae should include relevant information to establish his or her expertise. It should include information in the following areas:

- Employment history.
- Training received (and passed).
- Training conducted.
- Professional affiliations.
- Papers or publications written.
- Professional resources used; and
- Additional qualifications.

It is important for wildland fire investigators who may be called to testify as an expert witness to communicate qualifications, training and experience. In a vitae (CV) or testimony, do not exaggerate qualifications. It is recommended that the wildland fire investigator keep a current CV.

During an investigation, use a systematic approach that meets the requirements for expert testimony. Document actions and findings in such a way that they can be clearly presented to the triers of fact. Ask, are the conclusions corroborated and supported scientifically? Have the other reasonable possible causes been addressed, if not why not?

Investigation Report and Effective Testimony

Prior to your testimony, review the case files, notes, documents, and evidence to refresh your memory. Obtain and review transcripts of your prior testimony to ensure consistency. While on the stand, use of the investigative report to refresh memory is allowed with permission from the judge. Be prepared!

For trials and depositions, come a little early in case there have been any legal or other developments. Wear proper attire. Check with your counsel concerning appropriate uniforms or dress clothes. Be physically and mentally prepared. While on the stand, sit comfortably, and erect without slouching.

Listen and respond carefully only to the question asked. Do not volunteer information. Avoid unintentional, non-verbal communications. Pause a second before answering to allow your counsel to object if necessary. Do not try to outsmart, or argue with, opposing counsel. Try to direct your responses to the attorneys, be sure to respond to the members of the jury, as they are ultimately the ones who will decide the case.

Provide responsive answers on direct examination (for example, answer the question asked). On cross examination, if the question cannot be answered with a yes or no, you may explain your answer. If the answer is incorrectly stated, correct it immediately or clarify it. Avoid police or fire jargon, acronyms, or legalese.

If you don't know the answer to a question, say, "I don't know". Do not exaggerate or make overly broad statements. Avoid absolutisms such as *never*, or *always*, etc. Be serious and avoid smiling or laughing. When an attorney objects to a question, allow time for the judge to rule. When questioned by opposing counsel do not look to your counsel for help.

Do not leave the stand until excused. Do not leave the courtroom or courthouse without consulting your attorney. Anything you look at while testifying can and will be examined by opposing counsel. Refer to reports rather than notes, if possible.

The most important principle is to always tell the TRUTH.

Opposing counsel may attempt to impeach you for seemingly conflicting deposition and trial testimony. Seemingly different answers can often be reconciled. Consider whether or not the questions were different or are the underlying facts different? Have you come upon new information which caused you to change or modify your testimony in some way? Clarify your answer without becoming defensive. If you cannot explain the difference simply state which response is correct.

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Appendix A: Investigation Checklist

<u>At the Time of Dispatch:</u>

- ☐ Date of dispatch call.
- ☐ Time of dispatch call.
- ☐ Caller.
- ☐ Call back #.
- ☐ Assignment.
- ☐ Order #.
- ☐ P Code/accounting code.
- ☐ Incident name.
- ☐ Incident #.
- ☐ Controlling agency.
- ☐ Agency unit.
- ☐ Incident size/acres.
- ☐ Fuels.
- ☐ On-scene contact.
- ☐ Contact radio frequency.
- ☐ Contact phone #.
- ☐ Incident location.
- ☐ Directions to the incident.
- ☐ Fire start date & time.
- ☐ Reporting party.
- ☐ Special equipment/personnel.

On-Scene

The following list is in the order that the tasks should be completed; however, circumstances at the scene may dictate a different order for some tasks such as photography, collection of evidence in danger of destruction, or taking statements from witnesses before they leave the area.

- ☐ Protect general origin.
- ☐ Take weather observations.
- ☐ Identify witnesses.
- ☐ Identify & protect evidence.
- ☐ Walk general origin perimeter (twice).
- ☐ Mark macro-scale indicators.
- ☐ Identify initial run.
- ☐ Walk initial run & 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 & source, if possible.
- ☐ Take photographs & complete photo log.
- ☐ Sketch & 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 & lab reports.
  - Suppression cost estimates.
  - Damage & loss estimates.
  - Fire behavior input and output documents.
- Prepare vicinity map.
- Prepare location map.
- Prepare scene diagram with measurement table.
- Prepare evidence/ property log and secure evidence.
- Conduct follow-up interviews & 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

Equipment
Items as outlined may be required for any wildland fire investigation. Additional items may be needed. A unique situation may require a phone call to Federal, State, or local crimes labs as to storage and transportation of the samples.

- Case or backpack.
- Compass.
- Clinometer.
- GPS.
- Digital camera, spare batteries and storage cards.
- Video camera, tapes and batteries (optional).
- Flagging.
- 100’ tape measure.
- Notebook/paper/clipboard.
- Forms.
- Pen(s), pencil(s), markers.
- Ruler.
- Latex and/or nitrile gloves.
- Plastic bags (clear).
- Paper bags (variety of sizes).
- Clean metal cans (quart & gallon).
- Pill tins/boxes.
- Cardboard boxes (variety of sizes).
- Evidence tape.
- Evidence tags.
- Tape recorder (optional).
- Grid lane pins & string.
- Flashlight.
- Paintbrush (fine).
- Probe.
- Magnet.

- Magnifying glass.
- Numbered evidence tents.
- Metal detector (optional).
- Binoculars.
- Tweezers.
- Scissors.
- Adhesive tape.
- Knife or multi-purpose tool.
- High temperature digital thermometer (optional).
- Traffic cones (optional).
- Clean trowel.
- Nails & washers for reference points.
- Knee pads.
- Coveralls.
- Hard hat and other personal protective equipment.
- Colored pin flags.
    - Red: advancing fire (head).
    - Yellow: lateral fire (flank).
    - Blue: backing fire (rear).
    - White: evidence.
    - Lime: areas/points of interest.