Council-certified
Fire and Smoke Damage
(CFSx)
Certification Program

Exam Study/Review Guide

Rev. 03-2024

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ACAC would like to thank the following industry peers who have volunteered their expertise to ensure that this document reflects the domains of knowledge relevant to fire and smoke damage consulting and addressed by the CFSx examination.

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A Note on Acronyms

ACAC's fire and smoke damage certification program encompasses three examinations:

Council-certified Fire and Smoke Damage Consultant (CFSC)
Council-certified Fire and Smoke Damage Technician (CFST)
Council-certified Fire and Smoke Damage Assistant Technician (CFSAT)

This guide describes the knowledge base for all three of these examinations; references to individual certifications will therefore appear as "CFSx," and should be understood to refer to all three designations.

Disclaimer

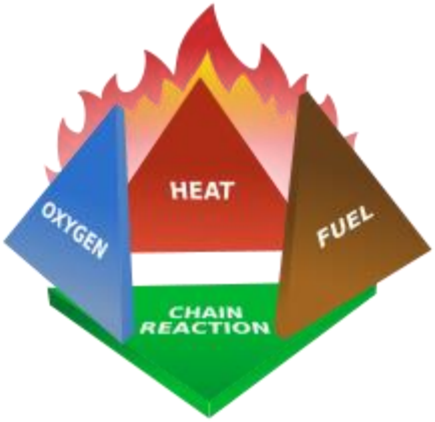
This document is designed to aid candidates in preparation for the Council-certified Fire and Smoke Damage (CFSx) certification examination. To this end, the document provides discussion of the domains of knowledge addressed by the exam and the exam topics identified by the CFSx certification board. These discussions are intended as guides to reading and study of the reference texts from which individual exam items are drawn.

This document is neither a standard of care nor a field manual for Fire and Smoke Damage Consultants. ACAC disclaims all responsibility for actions taken by individuals based on statements contained herein.

CFSx EXAMINATION TOPICS

GENERAL KNOWLEDGE

Fire is the rapid oxidation of a material in the exothermic chemical process of combustion, releasing heat, light and various reaction products. Fires start when a flammable or a combustible material, in combination with a sufficient quantity of an oxidizer such as oxygen gas or another oxygen-rich compound (though non-oxygen oxidizers exist), is exposed to a source of heat or ambient temperature above the flash point for the fuel/oxidizer mix. This process must be able to sustain a rate of rapid oxidation that produces a chain reaction.



This is commonly called the fire tetrahedron. Fire cannot exist without all of these elements in place, and in the right proportions. For example, a flammable liquid will start burning only if the fuel and oxygen are in the right proportions. Some fuel-oxygen mixes may require a catalyst: a substance that is not consumed, when added, in any chemical reaction during combustion, and enables the reactants to combust more readily.

Once ignited, a chain reaction must take place whereby fires can sustain their own heat by the further release of heat energy in the process. This combustion may propagate, provided there is a continuous supply of an oxidizer and fuel.

If the oxidizer is oxygen from surrounding air, the presence of a force of gravity, or some similar force caused by acceleration, is necessary to produce convection. Convection removes combustion products and brings a supply of oxygen to the fire. Without gravity, a fire rapidly surrounds itself with its own combustion products and non-oxidizing gases from the air, which exclude oxygen and extinguish the fire. Of course, this does not apply if oxygen is supplied to the fire by some process other than thermal convection.

Fire can be extinguished by removing any one of the elements of the fire tetrahedron. Consider a natural gas flame, such as from a stovetop burner. The fire can be extinguished by any of the following:

- turning off the gas supply, which removes the fuel source
- covering the flame completely, which smothers the flame as the combustion uses the available oxidizer (the oxygen in the air) and displaces it from the area around the flame with CO_2
- application of water, which removes heat from the fire faster than the fire can produce it (similarly, blowing hard on a flame will displace the heat of the currently burning gas from its fuel source, to the same end)
- application of a retardant chemical such as Halon to the flame, which retards the chemical reaction itself until the rate of combustion is too slow to maintain the chain reaction.

Fire is intensified by increasing the overall rate of combustion. Methods to do this include:

- balancing the input of fuel and oxidizer to stoichiometric proportions
- increasing fuel and oxidizer input in this balanced mix
- increasing the ambient temperature so the fire's own heat is better able to sustain combustion
- providing a catalyst or; a non-reactant medium in which the fuel and oxidizer can more readily react.

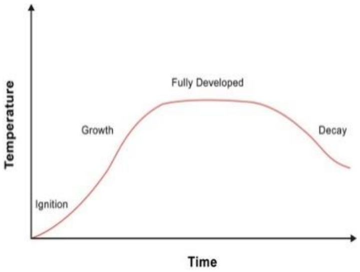
Characteristics and Behavior of Fires

There are many types of fires and multitudes of causative factors. However, the CFSx study guide and exam will focus on structure fires, protein fires and wildfires. ACAC encourages CFSx candidates to familiarize themselves with additional fire types, their distinctive characteristics and behavior, and the proper investigative and analytical methods used to determine their impact and exposure risks.

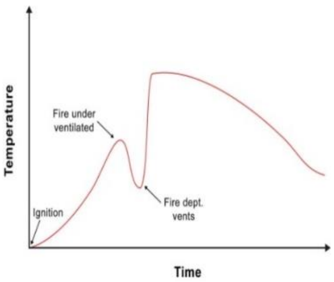
Structure Fires

Overall, structure fires continue to account for the vast majority of civilian casualties in fire related events. National Fire Protection Association (NFPA) estimates show that while residential structure fires account for only 25 percent of fires nationwide, they account for a disproportionate share of losses: 83 percent of fire deaths, 77 percent of fire injuries and 64 percent of direct dollar losses.

Structure fires can be caused by one or more complex chains of events, including intentional arson, children playing with heat sources, fireworks, explosives, chemicals, smoking, heating, cooking, appliances, electrical malfunction, spontaneous ignition or by the sun's own heat. Cooking-related events tend to be one of the leading causes of structure fires.



The Traditional Fire Development Curve shows the time history of a fuel-limited fire. In other words, the fire growth is not limited by a lack of oxygen. As more fuel becomes involved in the fire, the energy level continues to increase until all of the fuel available is burning (fully developed). Then as the fuel is burned away, the energy level begins to decay. The key is that oxygen is available to mix with the heated gases (fuel) to enable the completion of the fire tetrahedron and the generation of energy.



The Fire Behavior in a Structure Curve demonstrates the time history of a ventilation limited fire. In this case, the fire starts in a structure which has the doors and windows closed. Early in the fire growth stage there is adequate oxygen to mix with the heated gases, which results in flaming combustion. As the oxygen level within the structure is depleted, the fire decays, the heat release from the fire decreases and, as a result, the temperature decreases. When a vent is opened, such as when the fire department enters a door, oxygen is introduced. The oxygen mixes with the heated gases in the structure and the energy level begins to increase. This change in ventilation can result in a rapid increase in fire growth potentially leading to a flashover (fully developed compartment fire) condition.

Wildfires

In contrast to a typical structure fire, which usually originates within the structure and is often limited to a single building, a wildfire frequently takes on the form of a large and uncontrolled burn of natural vegetation. A wildfire can destroy or damage hundreds of homes in its path and continue to burn for weeks or even months. Burn patterns can be very unpredictable, and changes in direction and intensity can occur frequently and unexpectedly.

Wildfires may create their own weather patterns. The fire's intense heat generates updrafts that drive combustion particles thousands of feet into the air, where prevailing winds can carry them great distances. At the same time, air rushing in to feed the updrafts picks up other debris, such as sand and granular particles, that also becomes part of the air stream.

The extreme heat generated by the combustion process reduces vegetation to ash, which is ultra-light and easily transported in the environment. Other fuels, such as vehicles, buildings and building contents may burn and contribute to the mix of chemicals and particles that are found in wildfire smoke, soot and ash. Winds generated by larger weather patterns may transport smoke great distances. Many factors can influence fire behavior and the impact of the smoke plumes, including weather conditions, phase of the fire and topography. Weather systems can strongly influence where and how smoke will affect an area. For an example, high winds may increase fire spread, but they may lower smoke concentration as smoke mixes into a larger volume of air. Early in a fire, when the heat is intense, smoke will remain high in the air until it cools and begins to descend to the ground. Smoke becomes more widespread as it moves downwind eventually reaching ground level where the majority of fine particles can permeate structures. Particles of charred debris often continue to deposit long after the fire is extinguished. The largest particles in smoke generally settle close to the source within hours, while the smaller particles can be dispersed further away before settling. When a wildfire is in the smoldering phase, higher particle emissions may result due to incomplete combustion.

Understanding wildfire smoke can be useful when explaining some of the effects, but more precise knowledge may be needed when evaluating a wildfire's impact on a community or a specific site. Satellite images of the smoke plume, official weather alerts, fire department reports and local news sources can provide support for eyewitness accounts of the smoke's location, intensity and/or duration.

General evidence of a smoke-laden environment does not automatically mean that damage has occurred. This is best demonstrated by direct inspection of the property.

Protein Fires (Cooking Activity)

Protein fires involve the slow carbonization of fowl, fish or meat when cooked, reducing the food to carbonized material. Often the event is limited to the consumed protein material. Occasionally, the cooking vessel is also destroyed. Whether or not a fire actually occurred may be a matter of conjecture. Obviously, no one observes the event. The cause is usually human error. Prior to leaving the house, someone neglected to turn off the control or mistakenly turned the dial in the wrong direction. A stove malfunction could have a similar result.

Protein fires have two important aspects: 1) the odor is persistent and extremely noxious and 2) the usual black fire residues are not present. The absence of black carbon particles may prompt an observer to treat a protein fire purely as an airborne odor problem rather than the distribution of a nearly invisible, rancid film. The peculiar nature of protein residues may require a trial-and-error approach to locating and treating them.

Protein odors remain one of the more troublesome residues to handle; but with diligence and the proper restoration techniques, they are restorable. Fire residues are corrosive because they contain chlorides, sulfides and other acid precursors. A principal source of smoke acids are burned plastics, particularly PVC piping. However, protein fire residues do not contain those components and do not induce corrosion to a significant degree. The toxicity of substances is not proportional to the pungency of their odors.

Protein residues are distributed by the same mechanisms that drive visible smoke. However, because combustion is slow, the airborne residues have more time to infiltrate cavities around kitchen cabinets and nearby closets. As with other fire residues, only exposed surfaces receive significant fallout. When items are stacked, only the top item or exposed edges offer a landing space for airborne residues, which tend to fall vertically. Forced air systems may also be vulnerable under some circumstances.

Animal tissues, the primary fuel in cooking fires, are composed of three major components, proteins, lipids and water. Albumin is one of the longest known and probably the most studied of all proteins. Albumin is the most soluble protein in the body of all vertebrates and is the most prominent protein in plasma. Tryptophan is a routine constituent of most protein-based foods or dietary proteins. It is particularly plentiful in a number of common foods including meat, fish and poultry. After a protein fire, off-odor production of volatile protein compounds of the irradiated meat are produced including albumin and tryptophan which can be detected by collecting a sample of the residue. Investigators should consult the laboratory of their choice for guidance on sample collection and analysis.

Composition of Smoke

Smoke is a collection of airborne solid and liquid particulates and gases which emitted when a material undergoes combustion or pyrolysis.

The composition of smoke depends on the nature of the burning fuel and the conditions of combustion. Fires with high availability of oxygen burn at higher temperatures and produce smaller amounts of smoke. The particles are mostly composed of char with variable amounts of ash and soot or, with large temperature differences, condensed aerosol of water.

The visible particulate matter in such smokes is most commonly composed of carbon (soot) if hydrocarbon fuel is involved. Other particulates may be composed of drops of condensed tar or solid particles of ash. Soot is a major component in car exhaust, furnace puff back, burning candles and electrical fires. Wood used in construction and plant/tree material in wildfire events very rarely yield soot as a major component. Char and ash are the main components in most wildfires. The presence of metals in the fuel yields particles of metal oxides. Particles of inorganic salts may also be formed, e.g. ammonium sulfate, ammonium nitrate or sodium chloride. Inorganic salts present on the surface of the soot particles may make them hydrophilic.

Wildfires primarily burn wood and vegetation producing abundant amounts of smoke consisting of a complex combination of particulate matter, gaseous compounds and water vapor. Due to chemicals coating soil particles (waxes, resins, etc.), soils may become hydrophobic and are at greater risk to water erosion during moisture events. The composition of smoke is predicated on many influences, including temperature of the fire, fuel type and moisture content. Other influences are weather related including wind conditions. Wildfire smoke may contain numerous chemicals and other substances from incinerated structures, vehicles and industrial or manufacturing facilities. Additionally, combustion particles may undergo chemical change in the atmosphere.

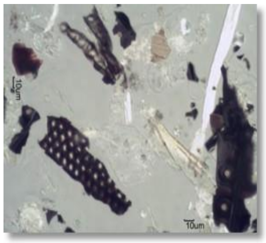
Although there may be commonalities, the broad range of potential wildfire products may require that their impact be studied on a case-by-case basis. Some research studies have attempted to generalize impacts from disparate wildfires, resulting in conclusions that may not withstand scrutiny. This suggests a need for caution in wildfire analysis.

Particles

Dust particles are always present in air. Airborne particles comprise an array of substances generated by materials and activities within the building as well as from exterior sources. The agglomeration of airborne particles into larger particles comprises the general category called dust. Typical components of interior dust are granular particles, fiberglass fragments, textile fibers, hair, gypsum particles, epithelial (skin) tissue, plant spores and insect fragments. Combustion particles also appear in domestic dust. Normally, the individual components of dust are not separately visible, but an overwhelming presence of a single material such as sawdust or drywall debris may be visibly dominant after remodeling or refinishing. Absent such concentrations, the normal coloration of dust is grey. As dust accumulates it obscures underlying surfaces and, with sufficient time, forms an opaque grey coating.

Char, Ash and Soot

Smoke is the visible airborne product of combustion and consists of particles, liquids, aerosols and gases, some of which condense as solids. As noted previously, combustion particles are a typical component of dust, generated by cooking, heating, smoking, fireplaces and external sources. Uncontrolled fires often generate concentrations of smoke particles sufficient to affect the appearance and utility of building surfaces and contents. Heavy smoke deposition is evident as a dark coating, often accompanied by a characteristic pungent odor. Depending on the fuel and fire temperature, combustion residues may be corrosive or exhibit other unwelcome chemical effects.



Settled combustion particles are called char particles and range in size from 1µ (.001 mm) to >500µ (.5 mm). The quantity, character and size of char particles vary with the fuel, duration of the pyrolysis process and temperature of combustion.[1] Char,

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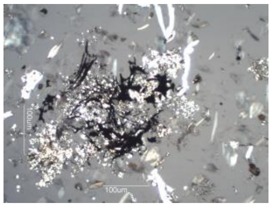
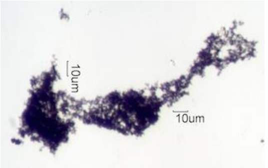
[1] Martin L. King and Brad Kovar, *Distribution of Combustion Particles in Buildings, Journal of Cleaning, Restoration and Inspection* (IICRC), December 2014, p. 11

as defined by ASTM, is a particulate larger than 1µm made by incomplete combustion which may not de-agglomerate or disperse by ordinary techniques, may contain material which is not black, and may contain some of the original material's cell structure, minerals, ash, cinders and so forth.[2] Leaf, bark or wood cell structure or features characteristic of a specified plant type are often present. In most cases they are sufficient to identify the type of wood or plant char and can be correlated with the fuel of fire in question.



In wildfire damaged or soot contaminated buildings, vegetative ash is the light grey/white powder remaining after vegetation is burned. In contrast, under optical microscopy, ash is not opaque, rather it is light colored with double refraction due to the presence of calcite; but many other minerals can be present as carbonates, hydroxides, and oxides. The original plant structure is often still present although faint and wispy. Most EDX spectra of ash show Ca, Mg, K, Na, Si in variable ratios depending on the precursor.



Soot, a term commonly used to describe all combustion emissions, actually describes a combustion by-product consisting of impure carbon particles resulting from the incomplete combustion of the gas-phase combustion process. ASTM describes soot as a submicron black powder generally produced as an unwanted by-product of combustion or pyrolysis. It consists of various quantities of carbonaceous and inorganic solids in conjunction with adsorbed and occluded organic tars and resins. Morphology of soot particles are similar to carbon black, fine micron/submicron-sized aciniform structures. The EDS spectrum of soot shows strong carbon concentrations with few or no trace elements present.

The heat of combustion produces ionized particles which, like dust, readily link together in chains and webs. For the same reason, settled combustion particles tend to bond preferentially with plastics, synthetic fibers and polymer-based coatings.

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[2] ASTM D6602-13

Chemicals, Gases and Vapors

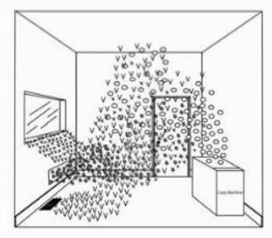
High temperature fires lead to production of nitrogen oxides. Sulfur content yields sulfur dioxide, or in the case of incomplete combustion, hydrogen sulfide. Carbon and hydrogen are almost completely oxidized to carbon dioxide and water. Fires burning with lack of oxygen produce a significantly wider palette of compounds, many of them toxic. Partial oxidation of carbon produces carbon monoxide; nitrogen-containing materials can yield hydrogen cyanide, ammonia and nitrogen oxides. Chlorofluorocarbons (Freon) involved in elevated temperature can produce phosgene gases.

Hydrogen gas can be produced instead of water. Content of halogens such as chlorine (e.g. in polyvinyl chloride or brominated flame retardants) may lead to production of other compounds (e.g., hydrogen chloride, phosgene, dioxin, and chloromethane, bromomethane and other halocarbons). Hydrogen fluoride can be formed from fluorocarbons, whether fluoropolymers subjected to fire or halocarbon fire suppression agents. Phosphorus and antimony oxides and their reaction products can be formed from some fire retardant additives, increasing smoke toxicity and corrosiveness. Pyrolysis of polychlorinated biphenyls (PCB) (e.g. from burning older transformer oil and, to lower degree, of other chlorine-containing materials) can produce 2,3,7,8-tetrachlorodibenzodioxin, a potent carcinogen, and other polychlorinated dibenzodioxins. Pyrolysis of fluoropolymers (e.g., Teflon) in presence of oxygen yields carbonyl fluoride (which hydrolyzes readily to HF and CO_2). Other compounds may be formed as well, for example, carbon tetrafluoride, hexafluoropropylene and highly toxic perfluoroisobutene (PFIB).

Pyrolysis of burning material, especially incomplete combustion or smoldering without adequate oxygen supply, results in production of large amounts of hydrocarbons, both aliphatic (methane, ethane, ethylene, acetylene) and aromatic terpenes, such as benzene and its derivatives, polycyclic aromatic hydrocarbons like benzo[a]pyrene studied as a carcinogen or retene. Heterocyclic compounds may be also present. Heavier hydrocarbons may condense as tar; smoke with significant tar content is yellow to brown.

Presence of sulfur can lead to formation of compounds like hydrogen sulfide, carbonyl sulfide, sulfur dioxide, carbon disulfide and thiols. Thiols tend to be adsorbed on surfaces and produce a lingering odor even long after the fire. Partial oxidation of the released hydrocarbons yields a wide palette of other compounds: aldehydes (e.g. formaldehyde, acrolein, and furfural), ketones, alcohols (often aromatic, e.g. phenol, guaiacol, syringol, catechol, and cresols) and carboxylic acids (formic acid, acetic acid, etc.).

Distribution and Deposition of Particles



Particles and their relative interaction with surfaces are dynamic in an occupied environment. Several forces and principles govern particle movement, suspension and resuspension. Dust particles travel on normal convection currents and tend to deposit wherever an airstream meets obstructions, is deflected or slowed. An example is the downward flow of air adjacent to a cold exterior wall or window. As the cooled falling air is deflected at floor level, some of the entrained particles settle out. The accumulation may become visible, since convection currents of this type tend to continue as long as the temperature differential exists. Gaps in the building envelope are often highlighted by an accumulation of dust particles filtered from air leaking through and around insulation. These dust filtration marks may be mistaken for smoke stains, especially when discovered after a fire event.

Dust particles exhibit polarity, i.e., the presence of discrete opposing electrical charges. Since opposite charges attract, dust particles tend to link together in chains, particularly where air is still. Often mistaken for spider webs, dust webs and strands may reach a foot or more in length. Polarity also explains the attraction of ionized dust to television and computer screens, whose polarity is inherent in their function.

Air ducts are conveyers of particles as well for particle settlement. Ventilation systems create their own distribution patterns of heated or cooled air. Even when a system is dormant, ducts may transport air by convection. The temperature difference between ducts and ambient air may cause particles to accumulate on both the interior and exterior of ductwork. After a fire, settled combustion particles may become re-entrained by air movement and continue to distribute via the ventilation system. Repolarized particles can be deposited around air diffusers and refrigerator tops and coils. Particulates collected by filters and blowers can provide a snapshot of particle identity and concentration.

Particle deposition in building interiors is moderated by differing characteristics of open and enclosed spaces. Open spaces consist of rooms and areas accessible, visible and directly served by the building's ventilation system. Enclosed spaces are the cavities within partitions, walls, ceilings, chases and soffits. These voids are sometimes referred to as interstitial spaces.

Not subject to temperature variations and air currents that characterize habitable areas, air within enclosed spaces is relatively still, and its ability to retain particles is substantially diminished. Air that is able to infiltrate loses entrained particles, resulting in long-term dust accumulations commonly found in enclosed spaces. Combustion products sometimes find avenues into enclosed spaces and may generate lingering smoke odors.

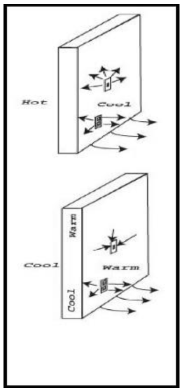
Building architects sometimes design intermediate spaces between floors to house HVAC units, communications equipment, electric cables and other utilities designed to serve a specific floor. Called interstitial spaces, these cavities commonly have concrete floors with lowered ceilings and may extend over a full floor or a portion of it. Large buildings may have alternating interstitial floors, designed to free the functional space from penetrations and chases that might inhibit modification or redesign.

An interstitial area acts as an enclosed space. Even though floor and ceiling penetrations are intended to be sealed, dust and combustion particles find their way in. During a fire, smoke particles may deposit on the tangle of electronic cables and hardware, raising problems of corrosion and odor.

The character of wildfire particles also influences their distribution. Their polarity attracts combustion particles to TV and computer screens as well as to each other, where they form long strands called smoke webs. Electrostatic bonding causes fine particles to adhere to walls and ceilings.

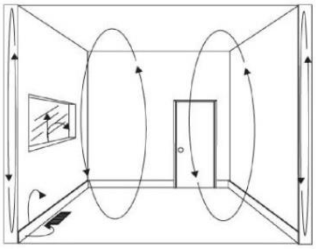
The distribution of wildfire particles within buildings differs from interior fires, where heat drives combustion particles upwards and the smoke path can be visually traced back to the source. Wildfire particles infiltrate buildings through visible apertures such as windows, doors and air vents, as well as through unperceived gaps in the building envelope. No longer propelled by heat, wildfire particles are transported by air currents and settle or fall when the air velocity is no longer sufficient to transport the particles. Forest fire particles tend to settle evenly on interior surfaces. Irregular concentrations, for example in a kitchen or vented attic, may point to other sources.

Temperature and Pressure



Building surfaces are heated and cooled by a variety of external and internal sources, some continuing, others fluctuating or seasonal. In general, building design seeks to minimize external influences in order to maintain a uniform and comfortable interior environment. However, temperature variation between surfaces is unavoidable. External temperatures may pressurize or depressurize attics and exterior walls. Fenestration and insulation add local temperature variations. Ventilation systems impose their own pathways.

Air molecules are energized by heat, which increases their kinetic pressure; and with fewer molecules occupying a given volume of air, warmer air rises and moves toward areas of lower energy. Greater energy also increases the ability of warmer air to carry particles. In this context, cool and warm are relative terms independent of specific temperatures.



Particle settling and accumulation involves general principles of air movement. For the purposes of this analysis, particles are defined as solid materials of a mass capable of being conveyed by air moving at relatively low velocity. The distance that airborne particles travel is inverse to their mass and proportional to their velocity. Mass in this case relates roughly to size, with the result that larger/heaver particles tend to settle out of an airstream earlier than smaller/lighter particles. As warmer air becomes diluted with cooler air, it becomes less able to carry particles, which progressively deposit as air movement slows. Minute particles may stay airborne for extended periods of time, limited by air movement and the tendency to agglomerate. Differences in surface temperature may induce a selective accumulation of particles on cooler surfaces.[3]

Rapid vs. Slow Combustion (Phase of Fire)

Blazing fires produce particles distinctly different from those emitted by smoldering fires. Blazing fires are oxygen-rich and burn vigorously. Cellulosic fuels are more completely consumed (oxidized) and their particles tend to be small. Propelled by high heat, smoke rises swiftly and follows a visible path.

In contrast to rapid combustion, smoldering fires tend to be oxygen-deficient and burn at lower temperatures. As a result they consume fuel less completely, often smoldering for long periods before breaking out as full combustion. Particles from smoldering fires tend to be more ionized, viscous and malodorous than the products of blazing fires. Because they are not driven by high heat, particles from smoldering fires tend to travel on normal air currents. Moving slowly, they permeate a wider area and find their way into crevices and cavities bypassed by more turbulent smoke. It should be noted that blazing fires can pass through a smoldering phase, so the characteristic residues of both may be present. After active ignition ceases, air currents gradually return to their normal patterns, distributing entrained particles as they go.

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[3] Martin L. King and Brad Kovar, *Distribution of Combustion Particles in Buildings, Journal of Cleaning, Restoration and Inspection* (IICRC), December 2014, p.11

Exterior Particle Distribution Associated with Wildfire exposure

Exterior surfaces sustain the direct impact of wildfire smoke and heat, so exterior building components may provide essential information on damage or its absence. All things considered, external damage is usually greatest on surfaces facing the fire source.

Forest fires may be remote or proximate. Particles from remote fires tend to diffuse over a general area, such as a town or community, where many properties are affected in a similar way and to a similar degree. In contrast, wildfire that approaches a subject property becomes a point source, and damage tends to be oriented toward that source and is specific to the site in question. A greater variation of impact between different sides of a structure can be expected from point-source fires. The inspector must be conscious of this distinction because it may determine the thrust of the investigation, even if elements of both types are present. Factors to be considered include:

- Location of the fire relative to the subject site
- Proximity of the fire
- Wind direction during and after the fire
- Topography of the subject area relative to the fire source, presence of significant geographic elements such as valleys, peaks, bodies of water, prevailing winds, rainfall and built obstructions
- Past smoke exposures, other fire history
- Alternate particle sources, such as highways, industrial facilities, airports, business centers, schools or sports facilities
- Building orientation relative to the fire; slope or hillside construction, nearby trees and vegetation
- Structural details of the subject property, including orientation of windows, doors, attic vents, garage doors as well as exterior surface materials, trims, lighting and HVAC equipment
- Appurtenant structures such as retaining walls, swimming pools, hot tubs, barbecue grills, storage sheds, patios, decks and porches

- Building age, history, recent painting, repairs and condition prior to the fire; occupancy, whether condominium, rental or owner-occupied
- Remediation or other repairs performed since the wildfire event[4]

Deposit Patterns

The physics of combustion, air currents and particle transport often produce characteristic deposit patterns. While many patterns are shared by dust and combustion particles, after a fire or furnace malfunction the high contrast of combustion particles tends to attract immediate attention. Some typical patterns of particle settlement are listed below:

Smoke Webs and Smoke Chains

These are sometimes mistaken for existing cobwebs that have attracted smoke particles. Actually the strands consist entirely of linked combustion particles. A source of the confusion may be the tendency of both smoke webs and dust webs to form in areas of still air, such as wall/ceiling corners. Smoke webs do not require pre-existing dust webs for support.

Ghosting

This is a term applied to the shadowy outlining of electrical outlets and wall-hung graphics that often appears after fires. The air behind a wall-mounted artwork is still. As warmer smoke-laden air approaches the perimeter and slows, graduated shading reflects the release of particles. A similar mechanism may appear as vertical stripes on exterior walls when studs provide a thermal bridge between the exterior sheathing and interior drywall. Junction boxes displace insulation when installed within exterior walls, resulting in a colder surface around wall outlets and a typical deposit pattern of combustion particles.

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[4] Brad Kovar, Martin L. King, Dr. P. Chakravarty and Dr. Michael Larrañaga, *Suggested Guidelines for Wildfire Smoke Damage and Remediation, Journal of Cleaning, Restoration and Inspection* (IICRC), June 2015, p. 25-26

Nail Pop

This describes an optical illusion created by ionized particles attracted to metal nails hidden beneath the joint compound of drywall. The graduated particle accumulation suggests a protruding nail head, which may disappear with cleaning. Painted drywall ceilings are especially prone to this effect.

Filtration Marks

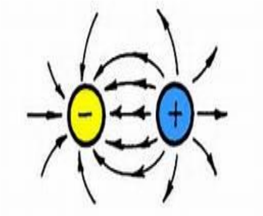
This describes dark streaks or splotches on the surface of insulation and dark lines on carpets. In both cases the discoloration consists of particles filtered from air in response to a pressure differential. The same mechanism may produce a dark horizontal shadow above a baseboard heater. These discolorations are not necessarily caused by a smoke incursion, since accumulated dust can develop considerable opacity.

Negative pressure at a lower floor sometimes creates streaks on carpeting that mirrors the outline of subfloor joints. These accumulations reflect ongoing air flow, but often leap into prominence after a fire or furnace puff-back.

Threshold Streaks

These are filtration marks that appear in carpeting at an entry door. A pressure imbalance sometimes arises when remote supply vents do not adequately feed a central air return, creating a zone of negative pressure. The constricted air passage permits carpeting to filter particles from the air stream, creating a visible streak. The same mechanism may lead to filtration lines in carpeting along baseboards.

Selective Deposition



This describes the variable attraction of dust and combustion particles to specific surfaces. The selectivity may be a response to transient differences in temperature (see Ghosting above) or inherent differences in polarity. The latter explains smoke particles adhering to vinyl and acrylic-based paint more readily than to oil-based paint. A chair upholstered in nylon will attract more particles than an identical chair covered in cotton fabric and will retain the particles more tenaciously. Dust exhibits the same response, as attested by its accumulation on computer monitors and TV screens.

SITE CHARACTERIZATION

An accurate assessment of smoke impact requires sufficient knowledge of construction to anticipate the effect of airborne combustion particles on building components. This is especially important when combustion particles are corrosive or emit strong odors. For example, a failure to recognize the potential of a suspended ceiling to hide corrosive particles may have a substantial impact on vulnerable metals. Weeks of shutdown have been spent searching for the source of a strong smoke odor whose location was fairly predictable, based on the physics of building layout and air movement.

Information Gathering/Occupant Interviews

The collection of relevant data, including the statements of building occupants and other observers, is a basic requirement of smoke damage investigations. Building occupants can provide information that will supplement the sample evidence and investigator's observations. Occupant accounts of airborne particles and smoke odors within the interior and exterior of the property should be recorded, along with information of post-fire cleaning procedures and repairs. Occupants’ living habits, such as smoking, fireplace or candle use, should be included in the investigator's report.

Interior and Exterior Surfaces

Ceilings may form a continuous unbroken surface or employ modular elements such as acoustic panels and supporting tracks. In residences and many commercial buildings, the ceiling is directly affixed to solid joists or rafters, creating discrete channels blocked at the ends. Horizontal chases and lighting fixtures may interrupt the exposed ceiling as well as the enclosed air space.

Commercial construction often employs webbed joists over suspended ceilings to form an open cavity that houses air ducts, light fixtures, wiring and other utilities. The ceiling cavity itself may serve as a return air plenum. Thus, ceiling cavities may be open, filled or partially filled with insulation and utilities. Some ceilings permit air movement while others retard it.

The presence of ceilings as barriers to rising air currents renders them vulnerable to incursions of smoke as well as dust. The still air over a suspended ceiling often attracts heat-driven smoke particles and is often a primary focus of post-fire inspections. When a ceiling is breached by fire, the tracking of smoke and settled particles becomes more pressing because of potential corrosion and remote odor sites.

In traditional frame construction, exterior walls consist of uniformly spaced studs separated by fire stops and horizontal framing. Studs may be solid wood or pre-shaped metal. The latter will be affixed to metal channels. Metal studs allow air movement by virtue of precut openings for wiring. The exterior wall surface is usually enclosed by some form of sheathing. The vertical pockets between studs are filled with insulation. The assembly is covered with an interior finish, usually drywall, paneling, or in older homes, plaster. The sole and top plates have penetrations for wiring and plumbing lines that may form channels for airflow. Solid masonry or concrete walls often employ metal studs or horizontal furring for drywall. Both provide air space between the masonry and the interior finish if not filled with insulation.

Masonry veneer construction introduces an inaccessible drainage plane (air space) between the sheathing and masonry. Sheathing for masonry veneer walls is usually attached to traditional stud framing. If fire breaches the sheathing, the combustion particles between the masonry and sheathing cannot be accessed directly. Insulation above and below windows (and often other areas) is sometimes casually installed and subject to air seepage and resultant filtration stains. These dust accumulations are sometimes interpreted as evidence of infiltrated smoke.

Partitions are essentially closed boxes. Occasional penetrations may be cut for electrical outlets or switches and in top or bottom plates for wiring. Studs may be drilled to permit a horizontal run of electric cable. Metal studs have spaced perforations that permit airflow between stud pockets. However, the absence of connections to other assemblies tends to restrict air circulation within partitions.

Chases are finished enclosures designed to house plumbing, electrical or other utilities. Horizontal chases often enclose air ducts. Vertical chases most often enclose plumbing and electrical lines. Kitchens and bathrooms are often stacked vertically, connected by chases or wider chase walls. Ceiling penetrations may allow convection currents to carry particles to higher floors. The interior dynamics of a chase may depend on the system it houses. For example, the air surrounding HVAC ducts may be warmer or cooler than the ambient air. During a smoke incident, positive or negative pressure within a chase can determine if it attracts particle accumulation.

Soffits cover structural voids and irregularities for cosmetic reasons. Soffits over kitchen cabinets are a common example and may be open to wall and ceiling cavities, a factor in their ability to convey combustion particles.

Soffits covering the underside of stairs are both repositories and conveyers of smoke, often connecting the ceilings of adjacent levels. Stair soffits are vulnerable to heat-driven smoke particles and odor because of the stack effect and the fact that stair carriages may be inaccessible to treatment when adjacent to a wall. Tread mortises may be loosely-fitted, providing voids for particle deposit. For these reasons, stair assemblies tend to retain combustion particles and odors.

In residential construction, attics are usually vented at gable ends, eaves or both. The vents supply a continuing flow of exterior air which deposits an array of particles on exposed framing and insulation. Attic particles may contain combustion particles from chimney smoke and automotive exhausts, in addition to other external fire products. As a result, attics are not reliable indicators of interior combustion damage unless smoke odor is present or interior paths clearly exist. When attics are directly involved in a fire, the unfinished framing is able to absorb combustion products, amplified by the inaccessible corners and minimal headroom that usually exists at the eaves. Opening ceiling access from below is one way to reach these areas.

Cold ceramic tile and porcelain finishes make bathrooms conspicuous targets for combustion products. The condensation of combustion vapors may cause permanent stains. Chase walls for utilities may facilitate smoke distribution between floors. The space surrounding bathtubs is a frequent repository of particles and odor, with Jacuzzi equipment especially vulnerable. Use of hot showers or baths may activate smoke odors long after repairs have been completed.

Since fires often originate in stoves and ovens, the spaces behind and between cabinets become candidates for accumulating and transmitting combustion products. This normally unobstructed space may also serve as a route to a soffit or ceiling cavity. Access to this area via the soffit or ceiling may be less disruptive than cabinet removal. Treating smoke odors may be impeded by the absence of visible fire residues after so-called protein fires as discussed earlier.

While sharing the general characteristics of chases and soffits, fireplace surrounds and chimney chases may be independent sources of combustion particles and smoke odors. Clearance requirements create vertical cavities around chimneys that may permit downdrafts and carry odors into the living space. Faulty or aging flue sections often have cracks or voids that permit combustion products to escape and coat interior walls of the chase. Such on-going smoke odors may be mistakenly blamed on fire damage elsewhere in the building.

The scrutiny that follows a smoke incursion may reveal dust accumulations that are mistakenly perceived to be new. Despite evidence to the contrary, the error sometimes hardens into certainty. Areas susceptible to misinterpretation include:

- ***Recessed light fixtures.*** These are frequently surrounded by insulation which filters particles from the convection currents generated by the fixture’s heat. A dark ring on insulation surrounding the fixture is an ongoing condition unrelated to a single incursion of smoke.

- ***Hanging fixtures and chandeliers.*** The convection currents created by a fixture’s heat tend to deposit dust particles at any deflection or interruption to the vertical flow of air. Thus, the canopy, junction box and adjacent ceiling tend to accumulate visible dust. The plastic or cardboard “candles” that enclose the bulb sockets on chandeliers often display a noticeable buildup of dust particles. Electrostatic attraction may play a role in this accumulation. When located over a table where candles are burned, the prisms and arms of a chandelier may collect combustion particles as well as dust.

- ***Ceiling fans.*** The blades of circulating fans create a zone of negative pressure above the blades. As a result, the upper surfaces of revolving fan blades tend to accumulate dust and cannot serve as accurate indicators of combustion products. Insulation around ceiling exhaust fans often displays smoke like streaks from induced air currents.

- ***Electronics.*** Since opposing polarities attract, audio speakers, computer monitors, television screens and many other electronic devices tend to attract particles by virtue of their opposing static charges. In computers, the power supply tends to attract more particles than other components and may provide a quick estimate of particle concentration.

For insurance, the distinctions above may be critical: a “sudden and accidental” loss may be covered, while an ongoing accumulation of particles is not. Since dust and smoke particles respond to the same forces, the distinction between them is not always clear. Long-term dust accumulations may approach the opacity of combustion particles.

Tracking settled particles to a source is based on the principle that particle accumulation is greatest near the point of origin. A trail of progressive intensity (or its absence) may indicate a source. Examples of this are the typical deposit patterns of tobacco smoke and fireplace emissions. However, a layer of combustion particles will be significant no matter how dense the underlying dust may be, and the sudden appearance of a smoke odor tends to resolve identity questions. Microscopic analysis of lift samples may offer a swift and inexpensive way to distinguish settled combustion particles from normal dust components. Investigators should consult their chosen laboratory for guidance on sample collection and analysis.

Visual Inspections

Visual inspection of the subject property is the most important part of any investigation. It should have a clear and specific purpose. In the immediate aftermath of a fire event, resolving the source of dark-colored particles is not difficult. However, the processing of an insurance claim may require distinguishing dark-colored particles from other environmental or combustion sources. During the site inspection, the investigator(s) should document evidence of a fire event, such as heat and smoke damage, visible combustion particles and smoke odors. Key observations should be documented with photographs. The presence of any perceived smoke odors should also be acknowledged.

Since there are a host of forces and principles that govern particle movement and their relative interaction with surfaces, the investigation should include all interior and exterior spaces and surfaces where accumulations of combustion particles are likely.

The inspection should extend to furniture, flooring, baseboards, structural ledges, art works, window treatments, interior contents, knick-knacks, attic spaces, garages and detached structures.

Smoke Odor

Combustion usually produces smoke, an airborne mixture of solid particles, liquids, aerosols and gases, some of which solidify and deposit. Many of these combustion products emit volatile particles fine enough to trigger a human odor response. Variations in combustion temperature and fuel generate an array of substances with different scents and intensities. Even though there exists no single smoke odor, a general “burnt” component is often recognizable. Char and combustion particles may continue to emit odors long after they deposit.

- ***Subjectivity:*** Essentially, the experience of an odor is what a person makes of it. Odors are not inherently pleasing or obnoxious. No device can accurately predict what a person senses or how they will respond to an odor. Cumulative reports by test subjects may generate average response curves, but those arrays do not claim to mirror the response of a specific individual.

- ***Fatigue:*** Odor receptors are numbed by continued exposure to a scent. The term of exposure before olfactory fatigue sets in has been estimated to be about one minute. This may explain why a smoke odor sometimes seems to disappear or to arise when a person first enters a particular area.

- ***Conditioning:*** While human odor sensitivity appears to be inborn, the ability to identify and distinguish between scents can be learned. Perfumers and wine tasters demonstrate this acquired ability. Similarly, damage restorers can often distinguish residues of smoldering fires, wood fires or electrical fires by their characteristic odors. Individuals predisposed to finding smoke odors sometimes affix the smoke odor label to other odors that happen to be present.

- ***Emotion:*** Direct neural connections between odor receptors and the brain’s limbic system (described as the seat of emotional response) may explain the strong emotion that sometimes accompanies perception of an odor. It has also been found that an odor related to personal trauma may reawaken the earlier pain or anxiety. This may explain the strong aversion to smoke odor in some individuals who have experienced a disastrous fire.

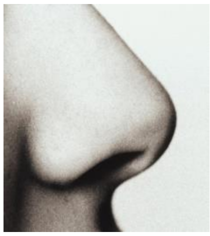
- ***Suggestion:*** Odor experiences are vulnerable to suggestion. Controlled experiments have demonstrated that odor responses can be induced where in fact no odor is present. Circumstances may produce an inherent bias. The importance of context is demonstrated when an individual who finds smoke odor repugnant is undisturbed or even attracted to the aroma of a fire-grilled steak.

- ***Toxicity:*** An aversion to smoke odor may arise from the notion that the odor itself is toxic. In reality, the mechanism of odor perception is independent of other physical effects. The toxicity of smoke has been exhaustively explored and does not correlate with odor. In fact, the most hazardous component of smoke, carbon monoxide (CO), is odorless. Conversely, as obnoxious as the odor of skunk is for many people, its physical effects are benign. In a fire the smell of smoke may be critically important in alerting residents to danger, but the toxicity of smoke does not reside in its odor.

- ***Environment:*** Environmental factors may amplify or diminish the intensity of odors, as warm, humid conditions tend to increase odor intensity and cold, dry air to reduce it. This may reflect the effect of moisture on neural receptors as well as the tendency of heat to energize volatile residues. Smoke odors may accumulate within an enclosed space, such as an attic, and escape with changes in temperature (pressure). Elevators may act as pumps and spread odors to other floors. Such intermittent incursions of odor may be difficult to trace.

- ***Allergic reactions:*** Allergic reactions occur when a person’s immune system reacts to normally harmless substances in the environment. Higher concentrations of an allergen usually induce more acute symptoms. Even though a particular type of smoke may have an easily identified odor, the odor itself is not an allergen. This is the same distinction noted with toxicity. While the distinction may seem academic, it has real consequences: individuals are not allergic to odors, but to substances that may accompany them. Perception of a smoke odor does not necessarily indicate the presence of an allergen.

Olfactory Perception



The sensation of odor is triggered by the impingement of airborne molecules on receptors in the nasal cavity, as processed in the mind of the receiver. The experience of odor (olfaction) is psychological, since interpretation of an odor involves memory and emotion. Response to an odor seems to occur at the moment it is detected. While abundant information is available on how humans process odors, no rationale has been able to predict an individual's sensitivity or response.
As a result, there exist no objective standards for evaluating an odor's effect. Further, there are a number of situations in which an environmental complaint may suggest a specific source. Even if the agent is a gas phase product, there are often particles associated with that source. These particles can aid in implicating that source by demonstrating an active path from the source to the receptor. Therefore, the reliance of olfactory perception alone, without the benefit of a sampling protocol, should be discouraged.

The experience of odor is inherently subjective. However, the subjective nature of smoke odors should not be a reason for abandoning rational analysis. Where the odor is clearly apparent, attention can be directed to finding and removing the source(s). Odors too faint for independent confirmation require a different approach. In both situations, familiarity with the mechanisms of odor perception can inform the response to smoke odor claims and may simplify their resolution.

Occupant Exposures

Along with heat, the burning of every combustible material or product produces smoke, gases and aerosols that, in sufficiently high concentration, present hazards to people in the vicinity. Products near those already burning may also contribute to the smoke as they decompose from exposure to the heat from the fire. Predominant among the hazards, which generally occur simultaneously, are the following:

- Sensory irritation of the upper and/or lower respiratory tract, which can affect speed of movement and the ability to negotiate escape and, at higher exposures, can lead to incapacitation or death
- Central nervous system depression resulting from inhalation of asphyxiant fire gases, which can, in ascending exposures, lead to impaired judgment, disorientation, loss of motor coordination, unconsciousness and, ultimately, death
- Thermal effects, including hyperthermia and thermal burns of the skin and respiratory tract

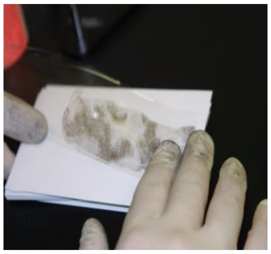
Exposure to these hazards is often prolonged by eye irritation and diminished visibility due to smoke obscuration, and it can affect the ability of occupants to see or negotiate escape routes efficiently. Survivors from a fire may also experience post-exposure complications that can lead to delayed health effects or even death. The nature and concentration of the generated smoke depends on a variety of factors. These include the quantity of the product that is burning, whether the product is flaming, smoldering or pyrolyzing, ventilation in the area, and distance from the fire. Thus, smoke toxicity is not a singular property of a product.

The threat to people from the heat and smoke depends on additional factors, including the entire ensemble of burning products, the location of people relative to the fire, the locations of exits from the burning enclosure and the paths to those exits. Additional factors include the time (in the fire growth history) at which people are in the vicinity of the fire-generated atmosphere and individual susceptibility of each person to the components of the smoke. Thus, the hazard and risk to people from exposure to the fire effluent (heat and smoke) from a burning product is also not a singular property of the product.

Particles are allergens, irritants, toxins, or infectious agents, and they affect attitudes in the workplace. It has been generally observed that the incidence of asthma and allergies in children and adults has increased. This seems to be true. In any event the incidence of respiratory complaints from homes, schools and offices has significantly increased. Many of these complaints, including those from asthma, are due to membrane irritants in the environment rather than allergens, but allergens are still a major concern.

SAMPLE COLLECTION

(NOTE: Since different laboratories may recommend different procedures and equipment, investigators should consult their chosen laboratories for specific guidance on sample collection and analysis.)



Environmental sampling is an imperfect science at best. However, even with samplings limitations, it remains the single most critical part of assessing environmental quality, accessing potential smoke damage or identifying the cause of health complaints. If the samples don't include a representation of the exposure that caused the problem, then no amount of analysis will detect the cause of the complaint.

Based on the fire and site information, the investigator develops a working hypothesis for the degree of fire and smoke exposure and the likelihood of fire-related damage to the subject property. The hypothesis steers the inspection toward specific areas where properly performed sampling may confirm or discount combustion particle accumulation.

The complexities associated with smoke damage investigations and the plethora of laboratory methodologies necessitate that investigators and laboratory analysts have appropriate training and experience. The following guidelines will help ensure vital evidence is not lost or red flags overlooked when processing and analyzing a smoke damage claim.

Sampling Strategies

Any given location or surface is visited by volumes of air which can propel combustion particles. Confidence levels in the outcome of the investigation are linked to appropriate sampling strategies. The investigator may consider the size of the subject property, points of entry and layout of the structure when determining the locations and number of samples to collect.

A sampling plan may include areas where accumulation of dark particulates is visible (exterior openings, attics, interior and exterior surfaces) as appropriate. Instructions may accompany laboratory samples that describe the objective of the investigation and recommend a specific test or tests appropriate to that objective.

Sampling Methods and Media

A preliminary condition of the sampling method or methods selected is that they should be efficient at collecting particles in some representative fashion. They should collect all of the types of particles that may be expected from the source event. They should collect them in a fashion suitable to the requirements of the analysis planned. The sampling procedures should consider the point or points of exposure. Cleaning the environment prior to sampling may remove these agents; and if we sample prior to the next cyclic event, the responsible agent will not be present. Samples that represent exposure history are an important aspect of sampling representative agents.

The sampling method should have the widest possible efficiency for the great variety of particles common in the environment. Particles settled on surfaces are a critical part of the sampling plan. These settled particles may accumulate to high levels; and when they are disturbed, they can create a short term extreme exposure within the personal envelope of the individual involved.

Factors Affecting Design of the Sampling Plan:[5]

1) Collection Efficiency
2) Collection Efficacy
3) Medium Suitable for Analysis
4) Consider Point Sources
5) Representation of Exposure

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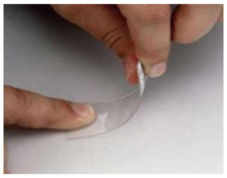
[5] E. Russ Crutcher, Ken Warner, and H. K. Crutcher, *Particles and Health: Environmental Forensic Analysis,* p. 66

Tape Lifts



Tape lift sampling can be used for collecting particles from surfaces with typical dust loading. Tape lift samples can be used for evaluating char, the primary indicator of wildfire smoke impact. Char generally consists of particles in the 1µ to 500µ range, making them readily visible with standard light microscopy. The tape lift technique preserves the relative positions of all the particles on the original surface, as well as the population per unit area.[6] [7]

Sample collection begins the same way for all of the adhesive tapes. The tape is pulled free from its storage position, placed on the surface to be sampled, then fixed to its transport carrier. If the tape is removed from its storage position too rapidly, it can build a static charge due to tribostatic differences between the adhesive and the surface from which it is being pulled. This static charge can collect particles from the air, hand, clothing or surface to be sampled, and it can draw particles from the edge of the roll of tape onto the main body of the adhesive. Investigators may clean the edges of the tape before beginning to collect samples by simply pulling off some of the tape and using it to clean the edges of the roll of tape or other carrier. To collect samples, pull the tape gently from its storage surface or roll to minimize the generation of static electricity and apply the tape to the surface to be sampled. Prepare the transport vessel, or carrier, to contain the tape lift and then remove the tape from the sampled surface and affix it to the carrier. A convenient carrier is a Ziploc or similar plastic bag. The inside of these bags tends to be very clean. The bag is typically inverted over one hand and the tape is taken from the sampled surface and stuck to the inside surface of the bag. Then the bag is drawn back into its normal position and sealed. The outside of the bag is then labeled with the sample position, time and the sampler's initials or name. Investigators should consult their chosen laboratories for guidance on the strengths and limitations of tape lift sampling, and whether it is recommended for a specific situation.

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[6] ASTM D6602-13

[7] Brad Kovar, Martin L. King, Dr. P. Chakravarty and Dr. Michael Larrañaga, *Suggested Guidelines for Wildfire Smoke Damage and Remediation*, Journal of Cleaning, Restoration and Inspection (IICRC), June 2015, p. 28

Wipes

Dry wiping a surface may be an adequate sampling technique if the layer of particles is very thick. At that point spatial relationships are not usually important. For thin layers of particles, wiping may be biased by size, shape and other parameters in terms of the efficiency of collection. Wiping a cloth over a surface creates a static charge. Particles may be moved by wiping, but many of the smaller particles will not be collected because the electrostatic charge on the surface has greater attraction for the particles than the van der Waals force between the particle and the wiper. Once the particles have been moved, there is an issue of release from the wiper, another sampling problem unless the wiper is processed in total. For thinly loaded surfaces, dry wipes may be subject to a large variance in collection efficiency that may be as significant as the environmental variance being investigated.

Wet wiping a surface may be efficient in removing and collecting particles in thin particle films. That follows as a result of the removal of electro-static, van der Waals and capillary forces holding the particles on the surface and the addition of capillary and shear forces removing the particles. This method may introduce various biases, including one for the solubility of the particles in the solvent used to moisten the wiper. It does have the advantage of being able to sample a large area. When relatively large areas of a smooth, non-porous surface need to be sampled, this can be an effective approach.

When a moist wiper is used, it may leave traces of the liquid agent, with the particles it contains, behind. The addition of a moist wiper to a thick layer of particles may significantly increase the strength of the capillary forces between particles and to the surface if insufficient liquid is used. This may result in the formation of a thick mud layer that is not easily removed. Investigators should consult their chosen laboratories for guidance on the strengths and limitations of wet wipe sampling, and whether it is recommended for a specific situation.

Micro Vacuuming

All of the techniques for collecting particles from surfaces discussed so far collect particles through the direct application of force. Vacuuming, by contrast, uses an indirect force.. A vacuum creates a low pressure area and draws air into a particle trapping device. For airborne particles it is easier to model what is being collected, as we will see later; but for surface particles the relevant collection force is fluid shear at the surface, and the magnitude of the force is dependent on the drag force on the particle. The drag force is dependent on the shape of the particle, the boundary layer velocity profile and the slope of the pressure gradient created by the vacuum device at the location of the particle.

If the airflow caused by the vacuum is all that is used, then an efficiency of about 20% can be expected for 20 micrometer particles.[8] The efficiency can be increased by adding another force to loft the particles and then collect them as airborne particles. The beater bar on a home vacuum cleaner is an example. One precision piece of equipment designed for using vacuum to monitor surface particle concentrations uses a directed high velocity jet of air and a fixed geometry to direct particles into the vacuum orifice for collection. This system may be more efficient for spheres than for flat particles. When hand sampling carpet, the inlet apparatus is often used to disturb the surface and knock particles off of the fiber surface for collection.

Vacuuming is used frequently on carpet, cloth and porous surfaces or on those surfaces with very heavy deposits. This is sometimes the best sampling method available for those surfaces. At these times it is important to keep in mind the fit-for-purpose model. The sample method, vacuuming, may have a high variance. In some situations, there may be little justification for expending resources for a low variance, highly accurate analysis. One of the most common applications of vacuum sampling is in assessing exposure to allergens in carpeted facilities. Investigators should consult their chosen laboratories for guidance on the strengths

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[8] E. Russ Crutcher, Ken Warner, and H. K. Crutcher, *Particles and Health: Environmental Forensic Analysis*
p. 84

and limitations of vacuum sampling, and whether it is recommended for a specific situation.

Sampling Airborne Particles

It is a common assumption that an air sample is a better representation of exposure than a settled dust sample. However, investigators should compare correlations between settled particles and various types of sampling before deciding on a particular methodology. In particular, when considering the sampling time delay generally associated with the claim process, consideration must be taken that airborne chemicals and gases may have since dissipated and particles settled after the fire event.

Sample Efficiencies

Sampling surfaces presents, first, the problem of collection efficiency from the surface, and then, the problem of recovering the particles from the agent used to collect the particles (tape, wiper, filter or trap) for analysis. Some processes may be very effective at collecting particles, but they may present difficulties in recovering the particles for analysis. Other processes may not collect the particles very well, but the particles can be easily mounted for analysis. Ideally, we want a process that is both efficient in collection and easily processed for analysis. An additional desire is that the spatial relationships and associations between the particles be preserved.

The collection efficiency of a tape lift from a typical surface is around 95% for particles of all sizes, including the important size range below 20 micrometers. Wiping with a moist cloth is next at about 75%. A dry cloth drops to about 45% for particles under 20 micrometers. Vacuuming is about 20% efficient for particles of 20 micrometers in diameter and drops with a slope of 45% for smaller particles (e.g. efficiency at 5 micrometers is 5%).[9]

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[9] E. Russ Crutcher, Ken Warner, and H. K. Crutcher, *Particles and Health: Environmental Forensic Analysis*
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Background Sampling

EPA 838/08, Site Contamination – Determination of Background Concentration and *EPA 540/F-94/030 Establishing Background Levels* specifies that background sampling locations should be selected from areas on the site or in the vicinity of the site not known to be impacted by combustion particles from the (wildfire) event. Combustion particles from everyday activities such as wood-burning fireplaces, stoves, candles, cigarettes and vehicular source particles are part of the background.

The location and number of background samples depends on several factors, including the objectives of the investigation, the size of the site, the number and type of alternative combustion sources, as well as particle intensity and pathway considerations. If it is necessary to collect multiple background samples, it is recommended that background and test samples be collected concurrently, but remain clearly distinguished. Composite samples from multiple surfaces should not be collected for determining particle concentrations.

To permit comparison, background and investigation samples may be collected using the same methodology. Preferably, they may be handled by the same laboratory and analyst using identical procedures. Investigators should consult their chosen laboratories for guidance on the collection and handling of samples.

Once background samples have been collected and analyzed, the information may be interpreted to establish background concentration(s) for the subject site. This background data can then be compared with actual site data in order to determine if investigative sample concentrations equal or exceed background levels. Average background concentrations may be applied if sufficient background samples have been collected from a relatively homogeneous environment and if alternative sources of combustion particles are insignificant or absent. This method of comparative analysis may be useful in determining the scope of restoration if that is warranted.

Other challenges include the absence of publications on acceptable concentrations for settled combustion particles, scant agreement among hygienists on a concentration level that would constitute "damage" and levels that would necessitate remedial action. In a post-remediation scenario, there are no published concentration levels that would constitute a clean environment. It should be understood that damage has no objective criteria.

STANDARDS AND GUIDELINES

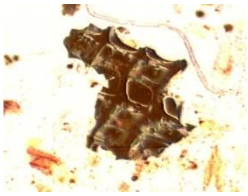
No standards, regulations or exposure limits currently exist for settled combustion particles (char or ash) in indoor environments. Further, with the exception of *ASTM D6602-13 Standard Practice for Sampling and Testing of Possible Carbon Black Fugitive Emissions or Other Environmental Particulate, or Both*, which does not specifically address fire-related particles, there are no standards for laboratory analysis. Qualified laboratories may use different methodologies to arrive at their findings for a particular sample. Investigators should consult their chosen laboratories for guidance on methods of analysis.

IESO/RIA 6001 Standard for the Evaluation of Heating, Ventilation and Air Conditioning (HVAC) Interior Surfaces to Determine the Presence of Fire-Related Particulate as a Result of a Fire in a Structure is specific to HVAC systems and structural fires, but the collection and laboratory methods described may apply to some aspects of settled wildfire particles.

SAMPLE ANALYSIS (Characterizing Combustion Sources)

Investigators should exercise prudence when selecting an analytical laboratory. Qualified laboratories may offer an array of techniques that include polarized light microscopy (PLM), transmission electron microscopy (TEM), scanning electron microscope (SEM) and electron dispersive X-ray analysis (EDX). Further options may include Fourier transform infrared spectrometry (FTIR), gas chromatography/mass spectrometry (GC/ MS) and high performance liquid chromatography (HPLC). Most of these analytical methods are used for determining the intensity and composition of submicron soot particles and are useful in distinguishing alternative sources of combustion particles and accelerants.

Polarized Light Microscopy (PLM) and Epi-Reflected Light Microscopy (RLM)



Carbonized material (char and ash) may be analyzed using optical microscopy (epi-reflected and polarized light microcopy). Initial examination by low power reflected light microscopy is first performed to help define and report the macroscopic texture and color of the dust sample and determine the absence or presence of large fire residue particles in the sample (char or suspect ash). The samples are analyzed for traits such as color, size, morphology and evidence of cellular morphology. PLM analysis can be used to characterize settled particles. Under PLM scrutiny, some char particles may appear the same as other opaque particles and may lead to false negatives or positives.

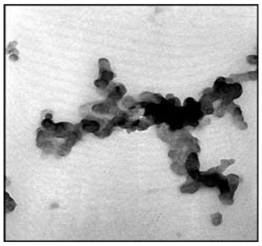
Polarizing microscopy can be used with reflected and transmitted light. Reflected light (RLM) can be used to study opaque materials such as mineral oxides and sulfides, metals and silicon wafers and requires stress-free objectives that have not been corrected for viewing through a coverslip. The reflected light microscope uses an system of mirrors, prisms and semi-mirrored glasses which let the light pass in one direction and reflect it in the other.

Because the electrons of the conductive layer of metals interact strongly with photons, which make the sample not transparent enough to be observed with a transmitted light microscope, the reflected light microscope was created.

Reflected light microscopy is often referred as incident light, dpi-illumination or metallurgical microscopy, and can be used for fluorescence and for imaging specimens that remain opaque even when ground to a thickness of 30 micrometers. Much like the fluorescence microscope, in reflected bright field microscopy the sample is illuminated from above through the objective.

A very important technique in reflected light microscopy is the existence of a dark field, which creates a bright contrast in regions which have a small inclination to the surface by an oblique illumination, which is obtained by placing an obstacle in the center of the light beam. If significant interferences and “look-alike” particles are present (a common occurrence), dark field reflected light microscopy may be indicated. Investigators should consult their chosen laboratories for guidance on the selection of analytical methodologies.

Electron Microscopy (TEM or SEM) and Energy-Dispersive X-Ray Spectrometry (EDX)



Larger aciniform clusters of soot can be detected using Optical Microscopy at magnifications of approximately 600x. Identification for soot using Optical Microscopy may be presumptive.

The use of Scanning Electron Microscopy (SEM) and Transmission Electron Microscopy (TEM) have been used in some applications for the confirmatory analysis of ash, char, and soot. SEM analysis of tape lift, bulk, and micro-vac samples can identify wildfire ash constituents (oxides of Magnesium, Silicon, Potassium, and Calcium), and plant phytoliths. SEM and TEM can also be used for the confirmatory analysis of soot clusters and individual soot particles in some cases. Semi-volatile soot particles, especially in the case of indoor fires, can disappear when placed under the vacuum of an Electron Microscope. As a result, false negatives for soot are possible when using SEM or TEM. Investigators should consult their chosen laboratories for guidance on the selection of an analytical methodology.

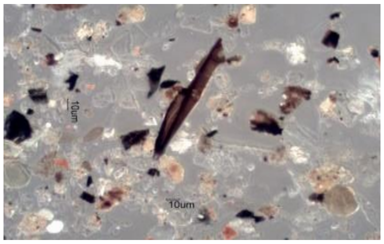
Other Laboratory Analytical Methods

Identifying the origin of combustion product formation can help to eliminate potential sources. The identification of the source of black carbon may be performed using transmission electron microscopy (TEM) in conjunction with attenuated total reflection - Fourier transform infrared spectroscopy (ATR-FTIR) and gas chromatography/mass spectrometry (GC/MS). The analysis is based upon the different particle sizes and the presence of selected functional groups in the samples that distinguish sources such as paraffin residue from candles or fuel oil from oil heaters. Investigators should consult their chosen laboratories for guidance on the selection of an analytical methodology.

pH Analysis

pH analysis on bulk dust samples may help determine the potential presence or absence of “corrosive ash” and can be performed by most laboratories.

Alternative Approaches to Char, Ash and Soot Analysis



Ideally, sample collection is performed soon after the suspected exposure to wildfire smoke. When this is impossible, contextual types of analysis such as particle assemblage may allow identification of fire-related particles at later times after the event.

Before a fire event, most properties will already have a background of settled combustion particles generated from numerous alternative sources. Considering elements of this background along with fire-related particles as part of a contextual “assemblage” may help investigators characterize the sources and results of a fire event. In the case of a wildfire, for example, such an assemblage may consist of charred wood from plants indigenous to the area where the fire took place, fire retardant, burnt clay from the soil, and pyrolized calcium oxalate phytoliths from the bark and leaves of the various plants and trees.

Particle assemblage analysis may allow investigators to identify a characteristic particle signature created by a specific fire event using particle types rather than percent coverage. This type of analysis may also allow fire-related particles to be analyzed independently of background particles.

It is important to recognize that some accepted techniques for particle analysis may involve metrics and standards that were not intended for evaluating combustion particles after a fire event. Investigators must exercise professional judgment, evaluate the analytical methods available and select a method that is appropriate to the situation and the purpose of the study.

CFSx candidates should familiarize themselves with each analytical method used by laboratories to characterize combustion particles. Different types of fires, oxygen availability and fuel consumed may produce unique emissions which may require specific analytical methods and sample media. Investigative goals may also play a role in analytical strategies.

Laboratory Terminology

None Detected (ND) denotes the absence of an analyte in the subsample analyzed. Trace levels of the analyte may be present in the sample below the limit of detection (LOD).

Limit of Detection (LOD): The minimum concentration that can be theoretically achieved for a given analytical procedure in the absence of matrix or sample processing effects. Particle analysis is limited to a single occurrence of an analyte particle in the sub-sample analyzed.

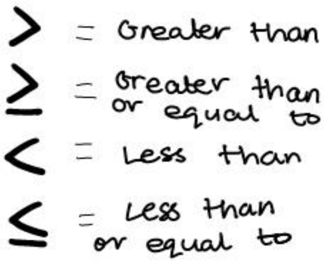
Limit of Quantitation (LOQ): The minimum concentration of an analyte that can be measured within specified limits of precision and accuracy during routine laboratory operating conditions

Visual Area Estimation (VAE): VAE technique estimates the relative projected area of a certain type of particulate from a mixture of particulate by comparison to data derived from analysis of calibration materials having similar texture and particulate content. Due to bi-dimensional nature of the measurements, in some cases the particle thickness could affect the results.

Concentrations for bulk samples are derived from VAE unless otherwise noted. Air sample concentrations are calculated to particles per unit volume.

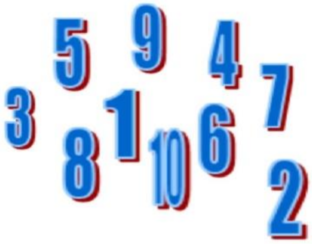
DATA INTERPRETATION

Data interpretation can be very challenging considering the lack of standards for settled combustion particles in indoor environments. Scant agreement among hygienists and their organizations on a concentration level that would constitute "damage" and remedial action may complicate the task.



Damage has been defined as "an alteration resulting in impairment or loss of function, appearance, utility or value." These elements of damage are subjective concepts which are usually negotiated between the interested parties. The investigator should not attempt to relate the presence of combustion particles to property damage or value. The objective of the investigation is to determine the presence or absence of combustion residues related to the claim and, if appropriate, to determine if the residues or settled particles exceed background levels.

Smoke from a fire event causes damage when combustion particles alter the appearance of building surfaces or personal property or when they constitute a nuisance by transferring dark residues to hands and clothing. Smoke particles may penetrate electronic devices or other equipment and interfere with their operation. Ash is a common form of wildfire residue. Ash crumbles easily into superfine particles that resemble normal household dust, but it has been found to contain toxic elements. Fine granular material may accompany and settle out with combustion particles.



As with any type of testing or sampling, investigators need benchmarks or thresholds to which they compare their results. There may be no published data against which field data may be compared. Comparison data may be based on in-house research or other published information. However, some published information may not account for regional variations, site-specific characteristics, variations in collection media or the presence of alternative combustion sources. Determining prior background levels by sampling uncleaned areas away from alternative combustion sources, points of entry and fire origin may help in attributing combustion particles to a fire event.

For comparative information, some hygiene firms use a threshold of 1% and greater (limit of optical detection) for combustion particles/soot as the trigger to initiate remedial action. Other firms may use a 5% to 10% concentration level of combustion particles/soot before recommending remedial action. In some cases, normal background levels may be as high as 3% to 5%. It is important to note, due to regular environmental dust accumulation, the concentrations of the combustion by-products present in a certain area will diminish with time, even if no remediation or cleaning is involved.

Until a standard is developed and damage/exposure limits are published, CFSx candidates should do internal research, conduct case studies and consult with their laboratory to gain confidence prior to establishing in-house thresholds.

ELEMENTS OF AN INVESTIGATOR'S REPORT

Smoke damage investigations should be well documented by a written report which includes the laboratory analysis, any analytical data collected from the field and a chain of custody. While most investigators' reports are uniquely formatted, written reports should contain specifics of the assignment, a well-defined purpose, background details, specific sampling methods used, laboratory procedures, visual observations and olfactory perceptions, summary of investigative and laboratory findings, conclusions and recommendations. Digital photographs of key observations should accompany the written report.

CFSx candidates who prepare and recommend remediation protocols in their investigative reports should familiarize themselves with the available fire and smoke damage remediation guidelines published by authoritative sources such as RIA, IICRC and FEMA. The source should be referenced in the investigative report.

REMEDIATION

The goal of restoration after a fire event is to return properties as closely as possible to their pre-damage state. To accomplish this, restoration specialists match their procedures to the type and intensity of damage. The character of the impacted surface usually determines which procedures can be safely employed. For example, pressure washing that is safe for plain brick may damage antique brick or an EIFS system. In the absence of heat damage, major consideration is given to whether a surface absorbs water (stucco, textiles, unfinished wood) or is impervious (glass, vinyl siding, painted wood).

As a general rule of thumb, different restoration methods and measures are used depending on the type of fire damage that occurred. Generally, high-oxygen, blazing fires will produce dry dusty soot on which dry sponges are effective in removing initial deposits followed with a detergent solution. Conversely, slow-burning, low-oxygen smoldering fires will result in greasy, wet deposits that will easily smear. The use of a dry sponge will create smears and cause soot to spread. Pre-moistened detergent wipes with frequent media changes should be considered in this type of fire.

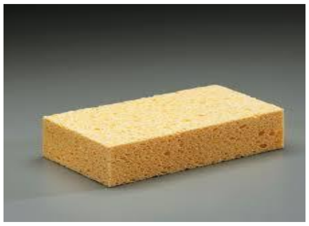
The remediation methods and guidelines which follow are not intended to be technically exhaustive. Investigators who design and recommend remediation protocols and/or confirm remediation success should familiarize themselves with published, authoritative remediation guidelines from respected sources and always include the referenced source in their remediation protocols.

Initial Steps

Removal of loose combustion particles is a universal first step. Freshly settled ash and char are lightly bonded and preexisting dust insulates the surface. Removal of particles at this stage simplifies later procedures and may prove sufficient in itself. The HEPA (High Efficiency Particulate Air) vacuum is an essential tool. HEPA filters capture 99.97% of fine particles down to 0.3µm that household vacuums exhaust back into the air. In order to remove combustion particles to the fullest degree possible, repeated slow HEPA vacuuming may be required. High-velocity blowers may supplant vacuuming on sensitive exterior surfaces. The importance of early and thorough removal of combustion particles cannot be overemphasized.[10]

Because settled combustion particles can redistribute, effective restoration may require professional assistance for particle removal from attics, duct chases, roof overhangs and other inaccessible areas.

Additional Procedures



HEPA vacuuming may be supplemented by other dry removal techniques such as soft brushing, wiping with cellular rubber sponges or applying adhesive rollers. This may include the use of air scrubbers to prevent redistribution of fine particles. If dry removal procedures do not adequately restore the original condition, application of a solvent may be required. If the introduction of moisture might alter or damage the surface, restoration should be suspended until additional approval is obtained.

Detergent-water solutions release particles that adhere electrostatically to smooth and textured surfaces. Dissolved particles should be removed rather than redistributed, which requires specific extraction techniques and frequent changes of collection media. Pre-moistened absorbent wipes may be effective for this process. Exterior surfaces may respond to washing/rinsing with a soft water spray, in contrast to pressure-washing, which may change surface appearance or inject water into the wall system.

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[10] Brad Kovar, Martin L. King, Dr. P. Chakravarty and Dr. Michael Larrañaga, *Suggested Guidelines for Wildfire Smoke Damage and Remediation*, Journal of Cleaning, Restoration and Inspection (IICRC), June 2015, p. 30

Intensive Cleaning

Intensive or immersion cleaning of absorbent materials such as carpeting, upholstery or clothing may require professional equipment and training, but should be preceded by thorough HEPA vacuuming and evaluation. Trial cleanings in inconspicuous areas can establish effective procedures and avoid costly errors. Less aggressive procedures may be preferred over one-size-fits-all cleaning systems. Remediation should be performed by experienced fire damage restorers who are familiar with current technology and materials. It should be noted that extremely small opaque particles in textiles may be visible under high magnification but should not be presumed to originate in a specific fire event unless valid comparison samples are available.

Ventilation Systems

HVAC filters should be replaced or cleaned. Air return plenums, A/C coils and blowers should be wipe-tested and cleaned if necessary. Ventilation systems operating during a fire event may be impacted throughout, with deposits generally greater on the return side. Sampling of supply registers may establish or preclude more extensive duct cleaning. In evaluating air systems, it should be understood that its surfaces were not free of particles before the fire. Professional experience and the use of comparison samples may help in attempts to distinguish preexisting combustion particles from recent additions.

Exterior Structures

Swimming pools and hot tubs may be heavily impacted by fire particles. Restoration is usually performed by the parties who customarily service these facilities for the owner; however, siding, decks, driveways, concrete railings and cast decorations will benefit from timely air washing or spray rinsing, which may mitigate the need for more intensive work.

Smoke Odor Restoration

When smoke odor is pungent enough to be recognized by casual observation, the remedy is to find the source and remove it. This may be problematic after repairs have been completed. Unlike the search for moisture, devices for locating hidden odors do not exist. As a result, exposing odor sites may involve a disruptive trial-and-error process. Persistent smoke odor sites may display accumulations of absorbed or settled combustion residues. Knowledge of building design and smoke behavior can narrow the search, as will the review of repair specifications and post-damage photographs.

Various commercial products and devices are claimed to deodorize combustion residues with masking scents, odor "neutralizers," sealers or chemical agents such as ozone or hydroxyl ions. These procedures may be effective in some situations. However, their results may be temporary and they may contribute odors or other unwelcome lung irritants. Additionally, they may be ineffective in treating unexposed odor sites. Procedures which physically remove the odor sources can reliably eliminate smoke odors.

When a reported smoke odor is too faint to be independently verified, evidence based remedies are futile. Does the odor objectively exist? If a specific area or repeated appearance is cited, logical analysis may provide an explanation.

Whether search-and-removal or replacement is more feasible often hinges on larger issues of time and cost. In commercial situations, relocation to unaffected surroundings may be necessary to avoid disrupting business. Collateral issues such as seasonal pressures or revenue loss may determine the feasibility of various repair options.

Post-Remediation Verification

The purpose of a post-remediation verification after fire and smoke damage is to determine the efficacy of cleaning fire-related combustion particles and residues from structural elements, finishing materials and/or personal items/contents within the designated work area(s). The post-remediation verification provides a measure of assurance, within the limitations of sampling, visual observations/olfactory perception and analysis, that the structure and contents have been remediated to a pre-loss condition.

Criteria for clearance may include absence of visible or analytical evidence of fire-related combustion particles or residues on surfaces and the absence of smoke odors.

GLOSSARY OF FIRE AND SMOKE DAMAGE TERMS

Accelerant - Flammable fuel (often liquid) used by some arsonists to increase size or intensity of fire.

Acronyms:

COC – Chain of custody

DF – Dark field illumination

EDS – Energy dispersive spectroscopy used in conjunction with SEM and/or TEM for elemental identification

GC/MS – Gas chromatography with mass spectrometry detection

LM – Light microscope

PLM – Polarizing light microscopy

SEM – Scanning electron microscopy

TEM – Transmission electron microscopy

Adjuster –An insurance person who understands policy interpretations and coverage and serves as a coordinating link between the insured and insurance company, and often contractors involved in cleanup, deodorizing and restoration services. A person or organization licensed to evaluate the amount of damage to property and negotiate insurance losses.

Adjuster, public – A person licensed by the state who, for compensation, is contracted and then acts on behalf the insured, negotiating for or effecting the settlement of a claim involving loss or damage.

Adjuster, independent – A licensed individual who works on a contract basis and charges a fee to adjust the insurance company's claim.

Agglomerate (soot) - A group of individual, sub-micron-sized soot particles (which individually cannot be resolved using light microscopy techniques) that have clustered together to form a larger soot particle (subsequently greater than one micron in size and visible during an optical microscope examination).

Aerial fuels - All live and dead vegetation in the forest canopy or above surface fuels, including tree branches, twigs and cones, snags, moss and high brush.

Ash - The end product of incomplete combustion, which will be mostly mineral, but usually still contain an amount of combustible organic or other oxidizable residues.

Assessment - An inspection process where the building or area of damage and/or contamination is evaluated.

Backfire - A fire set along the inner edge of a fire line to consume the fuel in the path of a wildfire and/or change the direction of force of the fire's convection column.

Brush - A collective term that refers to stands of vegetation dominated by shrubby, woody plants or low growing trees, usually of a type undesirable for livestock or timber management.

Brush fire or wildfire - A fire burning in vegetation that is predominantly shrubs, brush and scrub growth.

Carbon black - A submicron black carbon powder commercially produced under controlled conditions by burning hydrocarbons in insufficient air; it is composed of colloidal carbon of well-defined acinoform morphology.

Char - A particulate larger than 1µm made by incomplete combustion which may not deagglomerate or disperse by ordinary techniques, may contain material which is not black, and may contain some of the original material’s cell structure, minerals, ash, cinders and so forth.

Combustion - The rapid process of oxidation that occurs when organic matter ignites and burns, producing light and heat. In fire damaged buildings and in wildfires, combustion is the incomplete burning of materials (byproduct residue).

Deodorization - The process of odor removal by removing physical materials containing odors or by adding chemicals.

EIFS – Exterior Insulation Finishing System

Electrical fire – A fire originating in an electrical device or wiring. An electrical fire may become noticeable by its distinct pungent odor.

Fast-flaming fires - Fast-flaming fires result from the ignition of flammable liquids, wood, paper or open flames that ignite other items. These fires produce large quantities of flames with smaller amounts of smoke and are the most common types of home fires. A smoldering fire can also become a flaming fire, as the fire moves through the home and ignites different materials.

FEMA Cleanup Guidelines, wildfire – The Federal Emergency Management Agency (FEMA) provides wildfire smoke remediation guidelines. The FEMA document outlines cleaning and remediation actions homeowners should undertake following a wildfire to reduce smoke and ash contamination of their properties. The course of actions specified by FEMA includes

- Pressure washing the exterior of the home, walks and automobiles
- Washing all interior walls and hard surfaces with mild soap or other appropriate cleaning solutions or products and rinse thoroughly; including inside cabinets, drawers and closets
- Launder or dry clean all clothing
- Cleaning all household items

- Cleaning all carpets, window coverings, upholstered furniture and mattresses with steam or other appropriate equipment to clean, disinfect and deodorize

A precaution not provided in the FEMA pamphlet is that cleaning actions should be performed in a way to minimize the re-entrainment of particles. Cleaning methods that should be avoided include vacuuming, dry dusting, sweeping and vigorous wiping that will aerosolize smoke particulates from surfaces.

Fuel - Combustible material including vegetation such as grass, leaves, ground litter, plants, shrubs and trees that feed a fire.

HEPA - A high efficiency particulate air (filter). A filter that is capable of removing 99.97% of particles at 0.3 microns.

Inspection - Documentation of visual condition of a surface.

Microscopist - An analyst trained and experienced in the use of one or more microscopes.

Morphology - The physical shape of a substance.

PAH - Polycyclic aromatic hydrocarbon. A group of over 100 different organic compounds composed of several benzene rings. Some PAHs are persistent and carcinogenic.

Partial loss - Circumstances in which the property was not completely destroyed.

Protein fire - The slow combustion or carbonization of animal fat (e.g., beef, poultry, fish) during a fire. Combustion decomposition produces a clear fine mist that is often invisible, but haves an obnoxious and persistent odor. Protein odor is capable of penetrating the smallest of pores and spaces. Protein fires can be an isolated fire such as an oven where a turkey is charred. In this instance there is no other visible damage besides a strong smell. Protein fires can produce a clear color residue having a baked-on finish. This strong finish requires a lot of scrubbing and degreasing to clean walls, cabinets and floors. Even when surfaces are at their cleanest, some odors will not have diminished because they penetrated cracks and pores of surrounding materials.

Pyrolysis - The chemical decomposition of a compound into one or more other substances by heat alone; pyrolysis often precedes combustion.

Retardant - A substance or chemical agent which reduced the flammability of combustibles.

Sample - A small fractional part of a material or a specified number of objects that is selected for testing, inspection, specific observations or particular characteristics.

Smoke - The visible airborne product of incomplete combustion, consisting of suspended particles, gases, or solid and liquid aerosols.

Smoke damage - Smoke damage is physical damage that is caused from the smoke created by a fire but not the fire itself. This is a type of damage that is typically insured under a homeowner’s insurance policy or other policy that covers damage from fire.

Smoldering fire - The slow, low-temperature, flameless form of combustion, sustained by the heat evolved when oxygen directly attacks the surface of a condensed-phase fuel.

Soot or black carbon - A submicron black powder generally produced as an unwanted by-product of combustion or pyrolysis. It consists of various quantities of carbonaceous and inorganic solids in conjunction with absorbed or occluded organic tars and resins.

Soot cluster - A group or agglomeration of individual soot particles.

Sticky tape or tape lift - a section of tape with a sticky, solvent-soluble adhesive used in the collection of particles from surfaces.

Structure fire - Fire originating in and burning any part or all of any building, shelter or other structure.

Total Loss - Any loss in which a property, after a fire event, that cannot be returned to its original value.

Wipe - A small piece of uncolored, non-fragranced cellulosic or synthetic material used to collect combustion particles from surfaces.

Further Reading and References

AIHA, *Technical Guide for Wildfire Impact Assessments for the OEHS Professional* (2018)

IICRC, S760 *Standard for Professional Wildfire Investigations and Restoration of Impacts to Structures, Systems, and Contents* (forthcoming)

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