SOOT PARTICLES:

A Procedural Guide for Containing and Removing Wildfire-Caused Soot in Buildings

By Patrick J. Moffett, REA, CHMM

Notice:

This paper was first published in 1997 for the removal of "noticeable soot, embers and debris" in buildings and on contents caused by wildfires. In 2002, the paper added worker and occupant safety and health issues; and in 2008, the paper was rewritten to include wildfire smoke and soot characterization, convection, thermal dynamics, understanding PM_{10}.

This paper is intended to provide practical advice to restorers, adjusters and building owners who are faced with the cleanup of "extensive" wildfire caused soot particles settled in buildings and on contents in certain circumstances.

This paper is <u>not</u> intended to be a comprehensive guide for remediating all types and levels of smoke and soot contamination. Meaning, this paper provides general restorative guidelines for the removal of smoke odor and micro-fine soot and ash particles.

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COMMENTARY:

Before I offer guidance to restorers, adjusters and building owners on how to remove settled soot in buildings from wildfires, it is important to first discuss worker health and safety: I'm finding that across the public, from maid service to professional cleanup workers, individuals are not being appropriately protected from breathing in smoke and soot toxins. In other words, some people are not knowledgeable about the serious the health effects facing individuals who are required to cleanup wildfire smoke, soot and ash.

Case in Point: An employee in one of my classes a year ago said: "Since I'm required to use HEPA vacuums and negative air machines to cleanup and remove soot and fire damage debris in buildings; why am I not given a HEPA filtered mask that protects me?" At the time I felt I couldn't respond to the technician's question because I wasn't certain what his company's worker protection requirements were. A week later I reviewed various industry and government agency documents. I found employee respiratory protection for mitigating smoke and soot all over the board, from an N95, N-100, P100, to full-face mask with HEPA-organic vapor cartridges.

After researching the issue, I called the owner of the company and explained: "A dust mask is not enough based on EPA's recommendations in one document; – the P100 mask is lightweight and it is 99.97% efficient in protecting workers against both oil based and non-oil based particles down to 0.3 microns in size." "The N-95 mask isn't designed to provide workers with a higher degree of protection. The P100 mask is a better quality and fitting mask; it has increased respiratory protection features including an exhalation valve; and, where regulated levels of airborne particulates are present including asbestos, lead, and arsenic, the P100 provides a higher level of worker protection; the P100 media is able to capture sooty airborne oils that are common in soot contaminated and wildfire damaged buildings; and, the P100 meets NIOSH 42 CFR 84 P100 requirements." On completion of my explanation, the restorer agreed, "From this moment on, the absolute *'minimum level'* of respiratory protection for our workers will be the P100 mask."

Six months later I visited a jobsite the restorer was in the process of cleaning up. Employees were wearing their P100 masks. In speaking with the project supervisor he said: "Since we changed over to the P100 and became knowledgeable about its benefits, and became recertified in wearing it properly, we're finding the general quality of our work also went up." I asked, "Why do you think this is?" The supervisor replied, "We are taking more interest in protecting employees. Workers now have a sense of pride because we train them better and apparently, this is being passed on in the quality of their work."

In my lectures, we go over many of the same issues we always have: "worker protection, cleanup and remediation procedures." Restorers want to comply with OSHA safety and health requirements; yet, when it comes to actually providing appropriate respiratory protection on the job, appropriate respiratory protection is often left behind. In fact, to remove organic smoke toxins, workers are expected to wear carbon organic HEPA filtered cartridges on their masks. Meaning, an N95, N100 or even a P100 mask will not provide respiratory protection against airborne smoke toxins.

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PART I:

PARTICLES AND CHEMICALS IN SMOKE AND SOOT

State of California Fire Service

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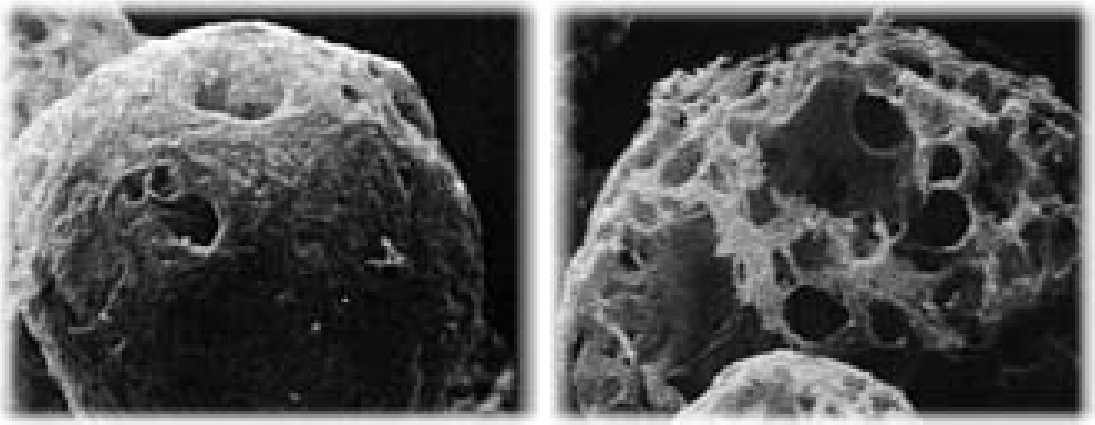
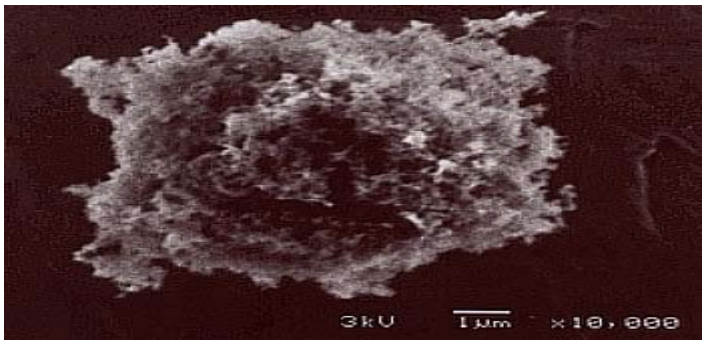
Example of carbon black and light ash soot



Electron microscopy of partially combusted particles



Electron microscopy of a black carbon soot particle

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PARTICLES AND CHEMICAL COMPOUNDS IN WILDFIRES

Wildfire Smoke Characterization

According to a 1994 scientific study prepared for the Fire and Aviation Management division of the U.S. Department of Agriculture Forest Service, contaminants of forest fire smoke can include carbon monoxide, hydrocarbons, benzo[*a*]pyrene, nitrogen oxides, volatile oxygenated organic compounds, acids, ketones, alcohols, and aldehydes, among other chemicals.

Wildfires depend on different types of wood and vegetation for their fuel. The fuel of wood and brush are composed of varying amounts of cellulose, lignin, tannins and other polyphenols, oils, fats, resins, waxes, and starches that produce different chemical compounds. Surprising to some people, even brush, trees and the burnt ground are capable of releasing toxic smoke in air.

A hotter wildfire will convert more fuel into elemental carbon, which forms into tiny particles that absorb light and appear in the sky as black smoke. A cooler wildfire combustion—or one that doesn't work as efficiently—yields less-pure forms of carbonized particles. Cooler combustion conditions tend to reflect light easier, thus, making the smoke to look white.

A wildfire can produce multiple colors of smoke: First, the shock of hot, flaming combustion of dry underbrush, dead foliage and leaves on trees and bushes tend to burn fast; they release large minute particles of black soot into the atmosphere. Burning heavier branches produce larger black particles. Second, the blaze also produces smoldering combustion, (think of the glowing logs at the bottom of a campfire—these embers are not burning quite as hot). Wood forests and wood framed buildings that are not completely combusted (consumed) tend to leave black char wood behind. As the wildfire continues to burn large trees a more complete combustion produces lighter color smoke as ash.

The basic byproducts of a fire are carbon dioxide and water. You can't see carbon dioxide, but water vapor in air might make smoke appear lighter in color. The steam produced by wildfire wood can turn into a white pyrocumulous cloud that mixes with black smoke and makes the plume look gray. A number of other factors, including weather, the growth stage of the wildfire, and terrain can influence wildfire behavior.

The intense heat, especially early in a fire, lofts smoke particles high in air, where smoke and soot byproducts remain until they cool and begin to fall towards the ground. Initial fire plumes tend to be wildfire wind-driven events, which can facilitate prediction of the smoke impact area. As smoke moves downwind, it becomes more dilute and widespread, where it eventually reaches ground level and settles on cooler surfaces. The amount and type of fuel and its moisture content affects smoke production, as does the stage of fire suppression. The smoldering phase of a fire can sometimes result in very high particle emissions (embers) in air due to incomplete combustion.

SOOT CHARACTERIZATION

Trees, Plants and Brush:

When burnt completely, vegetative soot is usually a color of ashen gray rather than of carbon black particles. For example, seeing vegetation soot as compared to a building's soot is different both in size, texture and color. Meaning, in most wildfires wood and brush is the only product the fire consumed; while in a building's fire, both wood-base products and synthetic products and contents leave higher amounts of black soot particles behind.

Oil-base Combustion:

A burning oil reservoir (e.g., an asphalt street, old oil well, storage area or building with oil drums, or a building's roof made from tar-base products), tend to burn very black because most of the fuel is being converted into elemental carbon. There's also very little moisture in oil, tar and plastic to make smoke look lighter in color. Other petroleum-based products that produce carbon black soot include hundreds of contents we see around us every day that are synthetic polymer plastic products, such as TVs, binders, printers, carpet, nylon draperies, vinyl windows, and lawn furniture. In addition, resin and synthetic glued products such as glue-lam beams, Pergo flooring, plywood, OSB, and MDF also create black soot when they burn.

Indoor Soot Deposits:

Soot created by burning candles are 0.06 to 0.1 micrometer (mm) in diameter. Soot created by wildfires can be 0.06 to 30.0mm and larger including embers that can be larger than an inch or two. Soot particles that are less than 1mm can penetrate almost all residential air conditioning filters and can severely reduce an electronic air cleaner's ability to remove minute soot particles from air. Both air filters and air cleaners should be cleaned or replaced several times during the next couple of weeks after a fire.

We hear on the news, "…when air quality from a wildfire is bad, turn on the air condition system to recirculate and trap airborne contaminants." The problem is – small soot particles less than 1mm, and firestorm vapors and gases are not removed by the building's ventilation system. Larger soot particles and embers do impact air conditioning coils and filters. On clean filters just recently installed before the firestorm, soot appears to be ashen gray or black, and they may have an oily-like feel to them.

In non-fire damaged buildings that have reservoirs of soot deposits, soot is attracted to cooler surfaces due to thermophoresis, a process in which particles migrate under the influence of forces created by temperature and moisture. The conductive force that attracts soot to some surfaces rather than others may be electrostatic. The dry air and static charge developed by wind conditions contribute to soiling of interior ceilings and wall surfaces more so than on exterior walls. Electrically charged materials include plastics products such as vertical blinds, TVs and computers. Non-electrically charged materials can also collect soot deposits because they are cooler or have higher moisture content than the heated air.

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CONVECTION

Combined with heat, low humidity and air pressure this dynamic creates a convection heat wave effect. This effect expands as the surrounding cooler air is warmed, resulting in an updraft shock wave (chimney or stack effect) to cause the building to burn or explode. As heat increases the ignition of dry materials occurs. The heat in the interior firestorm pyrolizes everything within its path, even though the fuel produced to feed the fire exceeds the oxygen available.

Surrounding a building is strong outward wind pressures that push against the structure. Surface thermal temperatures increase as surface moisture decreases. Ignition then comes from embers, flames or spontaneous combustion. Wildfire and new fuel fan the flame that consumes new oxygen supplies. As hot gases rise and heat increases, they add to the stack affect that sucks more air into the wildfire. A wildfire-firestorm spreads as much by thermal radiation (convection and radiant heat currents) as by flame contact.

The convection column is thermally produced as an ascending column of gases, smoke, and debris. As the fire combustion process increases, so do the rates of heat energy output and the magnitude of smoke.

The height a fire convection column that rises in air is dependent on:

1. The degree of instability of the air.
2. The heat energy output of the fire.
3. The speed of firestorm developing winds.

IT IS GOOD FOR WILDFIRES TO BALANCE THE ECOSYSTEM AS LONG AS THEY DO NOT DAMAGE PERSONAL PROPERTY

As explained by Professor Ray Arrowsmith of Arizona State University (ASU), a firestorm is photosynthesis in reverse.

- Photosynthesis:
  $6\ CO_2 + 6\ H_2O + \rightarrow$ heat from Sun $\rightarrow C_6H_{12}O_6 + 6\ O_2$
- Fire:
  $C_6H_{12}O_6 + 6\ O_2 \rightarrow 6\ CO_2 + 6\ H_2O$ + released heat

However, after a wildfire, photosynthesis $6\ CO_2 + 6\ H_2O + \rightarrow [sunlight] \rightarrow C_6H_{12}O_6 + 6\ O_2$ **is one of nature's most fundamental cleanup and deodorization processes on earth.** Photosynthesis is the beginning of the food chain and energy cycling in ecosystems on earth. When plant materials burn biologically, as food inside a living organism, we call this process respiration. When plant material burns as a physical process, it is called combustion. Photosynthesis, respiration, and combustion are major parts of the carbon cycle.

Understanding photosynthesis helps us understand the energy released in wildfires and the relationships between vegetation, fire and smoke. When wildfires burn a forest or California's chaparral, we call this nature's way of healing herself because plants that resprout after fires often have higher rates of photosynthesis than before a fire (Hastings, et al); yet, when wildfires burn a building, we call it a disaster.

THERMAL DYNAMICS AND AIR PRESSURIZATION

Fires always produce an updraft. In large wildfires, the question becomes how the updraft interacts with the local weather. When local winds are stronger than the updraft, and the fire is (massive, uncontrolled and uncontained) you have a "conflagration." When the fire creates its own winds, you have a "firestorm." Firestorms generate their own weather and pressure systems. They even can create dust devils made with flaming gases that ignite everything it comes in contact with; and, they can create small tornadoes.

Thermal energy pressure and "firestorm effect" of a wildfire heat wave, affects buildings in different ways. Outside air pressure and the physical makeup of buildings (including flat and pitched roofs, gables, dormers and eaves, decks and patios) will cause the firestorm to engulf each structure in a unique manner. The eddy effect created around a building is not completely understood. If it was, we would build our buildings using better fire codes. To help demonstrate eddy effects, the "Large Eddy Simulation" (LES) technique was developed at the National Institute of Standards and Technology (NIST) over a nearly two decade period in their attempt to create a conceptual fire-eddy program.

In my conceptual example below I'm making decisions about what occurred based on eddies that may have affected two residential structures in different ways: Two homes of similar construction were built with the same exterior materials and the firestorm reached the backyard of both houses.

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You decide which house was not consumed by fire and why:

One house has Floorplan A; and the other has Floorplan B. Both houses were built at the same time 10 years ago and both have original ceramic tile fire resistant roofing materials.

- Plan A house has a pool between it and the hillside; while Plan B house has a 10 x 20 foot open framed patio and a yard with perimeter foliage.
- Plan A's foundation is at a 45^{o} angle to the hillside; and Plan B's foundation faces directly toward the hillside.
- Plan A is a single story structure; and Plan B is a two story structure.
- Plan A, the one story home, doesn't have decking; while Plan B has a roof covered deck off the master bedroom to view the hillside.
- Plan A has a concrete slab between the house and the pool; while Plan B has a nice planter with shrubs and flowers next to the house including hanging plants on the second floor master bedroom deck.
- Neither Plan A nor Plan B's occupants were home. Plan A's owners closed all the windows before they left; while Plan B's owners left the second story windows slightly open.

What do you think occurred and why? What could the homeowners have done to better protect their property?

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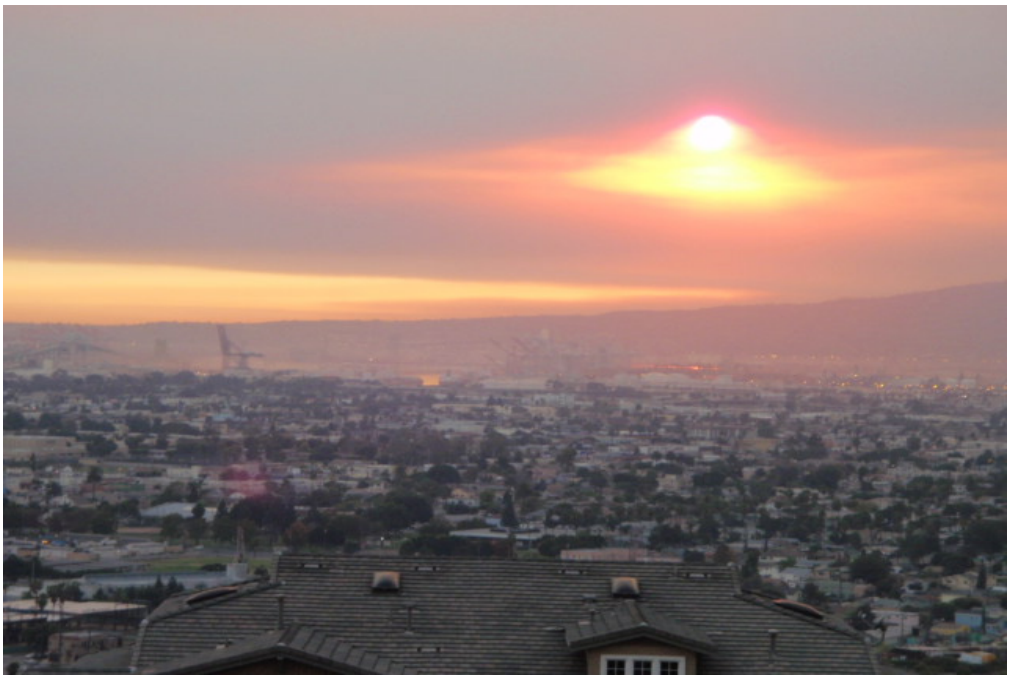
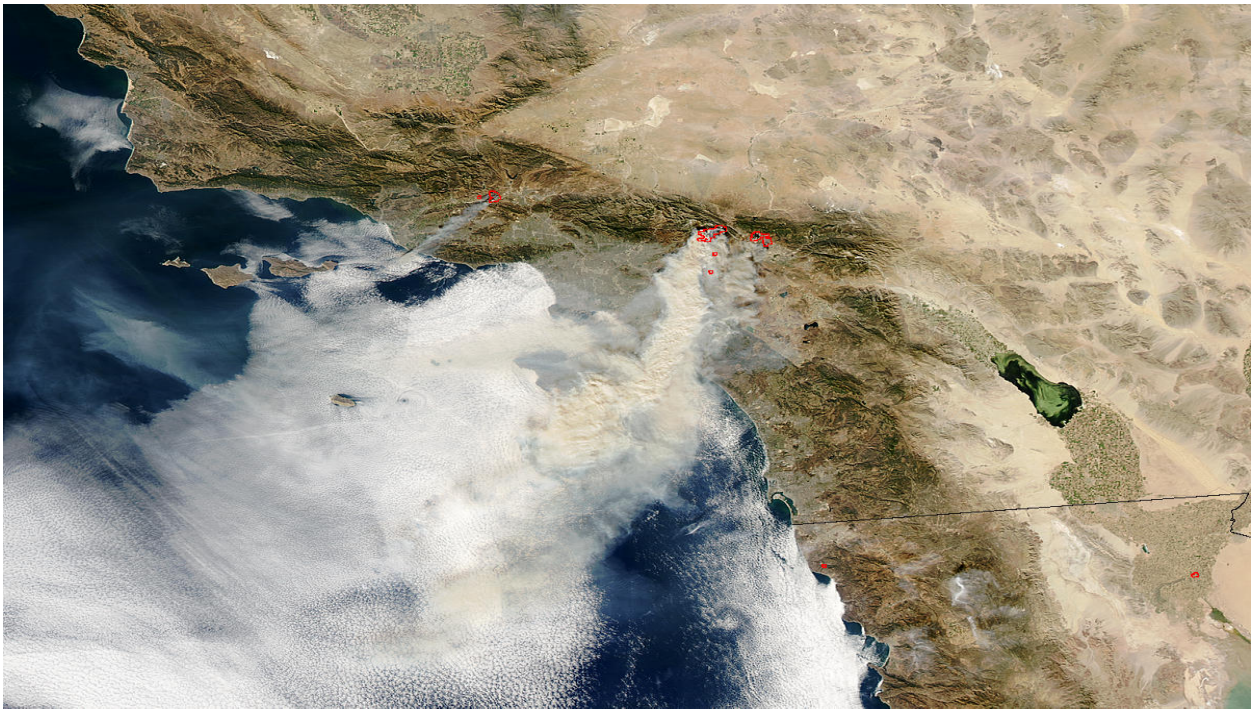
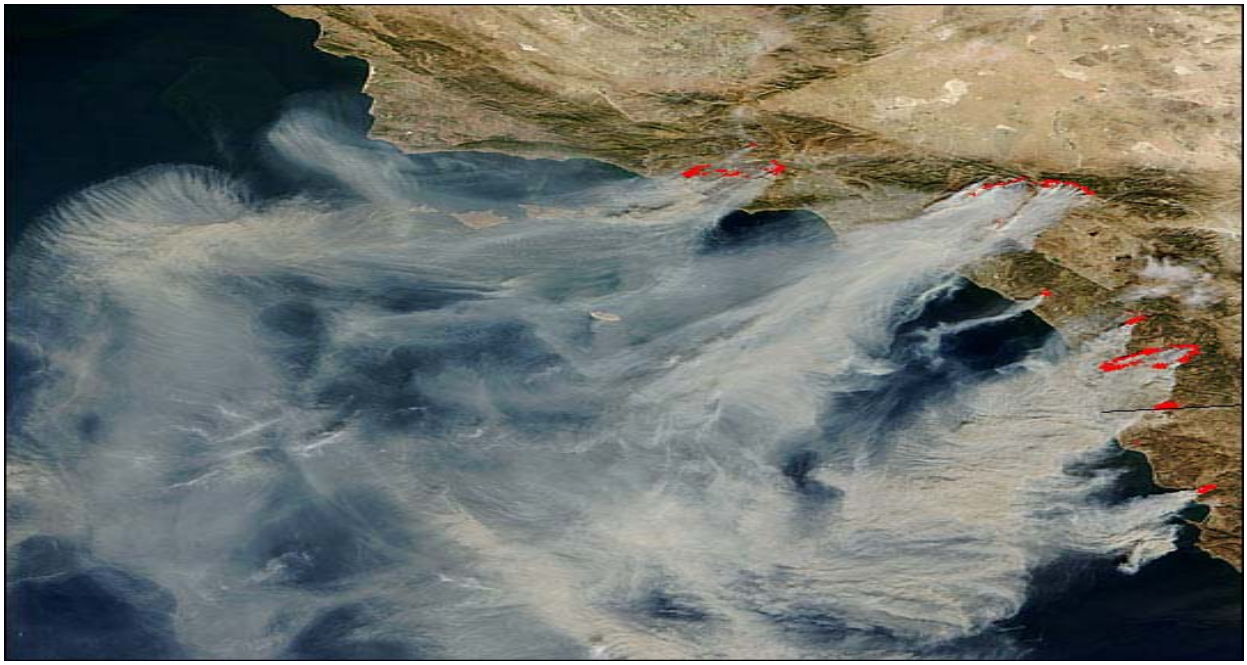
PART II:

ENVIRONMENTAL AND HUMAN HEALTH CONCERNS



Wildfire Sunset at Long Beach California © 2008 by Patrick Moffett





South Coast Air Quality Management District's southern California wildfire picture from space.

(Earlier photo followed by a later photo.)

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CHEMICAL BYPRODUCTS AND CHEMICAL SIGNATURES THAT AFFECT WORKERS COMPLETING SOOT CLEANUP

From the burning of organic materials, including smoke and soot, is a complex mixture of carbon dioxide and water, aerosols and vapors that compose a conglomeration of particles that are carbon and organic compounds.

Wildfires depend on different types of wood and vegetation for their fuel. The fuel of wood and brush are composed of varying amounts of cellulose, lignin, tannins and other polyphenols, oils, fats, resins, waxes, and starches that produce different chemical compounds. When burned completely, vegetative soot is in the form of an ash rather than black particles. For example, seeing vegetation burnt as compared to a building structure being burnt is different where vegetative smoke and soot is usually ashen grey while the building material's smoke and soot is closer to carbon black.

Often but not always, black particles are formed from combusted coal, wood, fuel oil, waste oil, paper, plastics, and other organic materials and refuse that are consumed by the wildfire. Black particles cannot tell you if the combusted materials are from burning chemicals or hazardous waste. Soot residue and vapor characteristics and their chemical signature must be analyzed by GC/MS. Soot contains about 60% or greater carbon content, plus inorganic and soluble organic fractions (National Institute of Environmental Health); yet, the individual compounds present in smoke numbers in the thousands (California Air Resources Board).

Soot Cleanup Workers versus Chimney Sweeps and Carcinogen Exposure

Workers who cleanup wildfire smoke and soot in buildings, attics, ventilation systems and contents are not *chimney sweeps*. However, workers who cleanup wildfire smoke and soot are believed to have the same or possibly higher level of respiratory exposure as chimney sweeps. Hundreds of chemical carcinogens, including mercury, found in wildfire soot are not typically present in wood-burning fireplace chimneys (National Science Foundation/National Center for Atmospheric Research).

Skin (scrotal) cancer was first linked to soot exposure of Chimney sweeps in 1775. The soluble organic fraction of soot consists of polycyclic aromatic hydrocarbons (PAHs) and their derivatives. Inorganic chemicals present in soot include a number of carcinogens: arsenic, cadmium, chromium, and nickel. Soot is an occupational carcinogen with strong associations for skin and lung cancer and a suggestive association for esophageal cancer (Siemiatycki, p. 327). Chimney sweeps had increased risk of skin and lung cancer (IARC).

Bottom line: Soot (Soots) is known as a human carcinogen based on evidence of carcinogenicity (listed in the First Annual Report on Carcinogens, 1980 report to Congress; Report on Carcinogens, 2005. USDHHS, Eleventh Edition).

Human Health Concerns Associated with the Burning of Organic Materials:

Human exposure to combustion of vegetative materials and building materials and contents, "…are known to release gases that can harm the health of some persons. Recent studies in pulmonary medicine suggests there is a correlation of combusted building materials and airway problems in children and adults" (D. Serebrisky, MD: *Inhalation Injury*; July, 24, 2006 E-Medicine). Seltzer, J. et al: *Environmental Hazards for Children in the Aftermath of Wildfires*. UCI School of Medicine, 2007, reported similar findings.)

The biggest health threat from smoke comes from breathing in fine particles (California EPA). Particulate matter is a generic term for particles suspended in air, typically as a mixture of both solid particles and liquid droplets. The characteristics, sources, and potential health effects of particulate matter depend on its source, the season, and atmospheric conditions. Additionally, the size of particles affects their potential to cause health effects.

Chronic exposure can lead to allergies, bronchitis, and emphysema, while acute exposure can cause impaired judgment, eye and respiratory irritation, and even death. In addition, some gases commonly released in burning, such as methane and ethylene have been shown to be carcinogenic in tests on laboratory animals.

In a news article in the Los Angeles Times, October 23, 2007, Michael Kleinman, professor of community and environmental medicine at the University of California, Irvine said: "The very small particles are the ones that can penetrate deeper in the lungs and have harsher health effects." "Particles, when deposited in the lungs, can cause tissue damage, inflammation and irritation. They can also penetrate and enter the bloodstream and change the way that blood coagulates, so people at highest risk of stroke have worse problems."

Hazardous Airborne Compounds

While we would like to believe wildfire soot is just a combination of trees and brush, there are other combustible materials outdoors and in homes, commercial buildings, warehouses and factories that produce different soot byproducts. In recent years wildfires consumed land that is part of the of the national registry for toxic substances (TOXMAP Regional Toxic Release Inventory (TRI) Summary, San Diego County, 2006). Nitrate, copper, ammonia, lead, styrene, xylene, and other compounds are present in the soil including petrochemicals (National Institute of Health, California Fires.) As restorers know, asbestos is a carcinogen that is found in buildings constructed before or around 1980 (California Air Quality Management District). Asbestos in fire cleanup jobs complicates the cleanup situation ("*Asbestos and Fire Cleanup – Precautions*." Santa Barbara County Air Pollution Control District).

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Understanding $PM_{2.5}$ and PM_{10}

Particle pollution (also called particulate matter or PM), is the term for a mixture of solid particles and liquid droplets suspended in air that change their size and chemical composition minute by minute, hour by hour and throughout the day.

Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye; while other particles are so small that they can only be detected using an electron microscope or particle counter. Particle pollution includes "*inhalable coarse particles*," with diameters larger than 2.5mm (micrometers) and smaller than 10mm; and "*fine particles,"* with diameters that are 2.5mm and smaller. $PM_{2.5}$ refers to the particle mass (total weight) of suspended particles <2.5 microns in diameter, for a cubic meter (1000 liters) of air where measurements are reported based on: (1) hourly particulate matter concentrations approaching 1,000 $\mu g/m^3$ particles of aerodynamic diameter up to 10 μm (PM_{10}); or (2) samples collected continuously over a 24 hour day sampling period. In wildfire smoke the concentrations of increased pollutants in air are found to be 10 to 20 times the typically observed ambient levels (American Thoracic Society).

Small smoke particles having a diameter less than or equal to 10mm are also known as particle pollution or PM_{10}. Smoke particles less than PM_{10} can be inhaled deep into the lungs; exposure to the smallest particles can affect the lungs and heart and possibly the bloodstream. Smoke particles tend to be very small, with a size range near the wavelength of visible light (0.4 – 0.7 micrometers) and are nearly completely within the fine particle ($PM_{2.5}$) range. Most regulatory agencies agree upon the 10 micrometer size as the cut off between respirable and non-respirable particles when monitoring airborne particulate matter, but 10 micrometers does not represent a strict boundary.

The major known carcinogenic components of smoke and incomplete combustion of wood products that produce toxic air are polycyclic aromatic hydrocarbons (PAHs) (AQMD Fact Sheet April 2008). Although other known chemicals including acrolein and carcinogens, such as carcinogens benzene and formaldehyde, can also be present in fire smoke (California Air Resources Board). Another pollutant of concern during wildfire events is carbon monoxide, which is a colorless, odorless gas produced by incomplete combustion of wood or other organic materials. Carbon monoxide levels are highest during the smoldering stages of a fire, especially in very close proximity to the fire.

In normal conditions, oxygen makes up about 21% of our air. High levels of PM_{10} means more polluted oxygen is passing through our lungs into our blood and to muscles which, in turn, affects our health and how we work to cleanup and remove soot throughout the day.

How small is 2.5 micrometers? Think about a single hair from your head. The average round part of a human hair is about 70 micrometers in diameter – making it 30 times larger than the largest fine particle (EPA).

PM_{10} Health Effects

Every day, primary particles are emitted directly into the atmosphere, such as diesel soot, whereas secondary particles are created through physicochemical transformation of gases, such as nitrate and sulfate formation from gaseous nitric acid and sulfur dioxide (SO_2), respectively. The numerous natural and anthropogenic sources of PM include motor vehicle emissions, tire fragmentation and resuspension of road dust, power generation and other industrial combustion, smelting and other metal processing, agriculture, construction and demolition activities, residential wood burning, windblown soil, pollens and molds, forest fires and combustion of agricultural debris, volcanic emissions, and sea spray.

Although there are thousands of chemicals that have been detected in PM in different locations, some of the more commonly found airborne constituents include nitrates, sulfates, elemental and organic carbon, organic compounds (e. g., polycyclic aromatic hydrocarbons), biological compounds (e. g., endotoxin, cell fragments), and a variety of metals (e. g., iron, copper, nickel, zinc, and vanadium) (American Heart Association). Like ambient urban air pollution, wildfire smoke contains numerous primary and secondary pollutants, including particles, polycyclic aromatic hydrocarbons, carbon monoxide, aldehydes, organic acids, organic compounds, gases, free radicals, and inorganic materials with diverse toxicologic properties, may explain the wide range of acute symptoms (Künzli, N. et al.).

Environmental Testing

In 1988, the U.S. Forest Service became a primary participant in the national visibility-monitoring program titled Interagency Monitoring of Protected Visual Environments (IMPROVE). IMPROVE monitoring indicates the public is increasingly concerned about air quality when PM_{10} concentrations are greater than 30 micrograms per cubic meter of air per 24-hours. Above 30 micrograms air quality levels affect visibility and human health standards.

Wildfires are natural events that are not subject to National Ambient Air Quality Standards (NAAQS), which for PM_{10} (24 hour average) is 150 micrograms per cubic meter. Note: PM_{10} concentrations in the air from the wildfires in Los Angeles August, 2000, Los Angeles September 2003, San Diego to Santa Barbara October 2007, Sierra Madre April 2008 and Santa Barbara to Chino 2008 were more than the accepted NAAQS for several days.

Appendix – Forest Fire Smoke Categories (PM-2.5 using TEOM PM-10)*

Categories	24hr (ug/m3)	8hr (ug/m3)	1hr (ug/m3)	Visibility (mile)
Good	0.0-15.4	0.0-22.0	0.0-40.0	>= 11.25
Moderate	15.5-40.4	22.1-57.7	40.1-80.0	5.62-11.24
Unhealthy to sensitive groups	40.5-65.4	57.8-93.4	80.1-175.0	2.57-5.61
Unhealthy	65.5-150.4	93.5-214.9	175.1-300.0	1.50-2.56
Very Unhealthy	150.5-250.4	215.0-357.7	300.1-500.0	0.9-1.49
Hazardous	>=250.5	>=357.8	>=500.1	<0.9

*(reference) http://www.deq.state.mt.us/FireUpdates/2001/Breakpoints.asp

PART III:

PROCEDURES FOR REMOVING WILDFIRE SOOT PARTICLES FROM CONTENTS

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COMMENTARY

Wildfire smoke and soot contamination buildings result in a condition where particles settle onto contents and fabrics and can absorb into porous surfaces. Depending on a number of factors including some of those listed below, much of the "dry soot" particles can be removed through HEPA vacuuming. While a vacuuming process sounds simple, the HEPA vacuuming requires training and experience to do it properly. Several typical experience and process management problems include:

- Homeowners and commercial building owners try their best to remove smoke and soot but can create a worse cleanup problem for themselves, their building and contents;
- Most janitors and maid service cleaning crews are poorly equipped and lack training to mitigate wildfire soot contamination situations;
- Most carpet cleaning contractors do not have the knowledge or industry certifications to complete a wildfire smoke and soot contaminated job properly;
- Restorers who are certified in fire restoration find that cleaning up wildfire smoke and soot is different than a building fire cleanup, and requires a separate set of skills;
- Some restorers only have their company owner certified in fire restoration. What this means, the actual service crews have limited knowledge and direction on how to cleanup wildfire soot properly.
- Some restorers are busy working on several wildfire jobs at the same time; they are often limited in the amount of equipment and the number of trained and certified crews that can respond;
- Environmental factors from outside the building continue to produce high particle counts resulting in a continued indoor air quality issue;
- Attempting to remove soot from damaged contents that remain in a soot contaminated building may limit the smoke and soot cleaning results;
- Removing soot from ceilings, walls and flooring while soot contaminated contents are in place may result in limited building cleaning and deodorization success;
- Trained and experienced restorers and technicians agree: HEPA vacuuming soot particles is the first step in the total cleaning process. Just because the building and its contents are HEPA vacuumed doesn't mean further cleaning, restoration and deodorization services are not required.

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The limitations for successfully removing "dry soot" deposits from building surfaces and contents depend on having the right soot, environment and surface conditions. Some of the these issues include:

- Some surfaces and materials can be damaged by settled smoke and soot particles.
- The fire department or wildfire management agency wet fogged, foamed or sprayed the building with water or a fire retardant such as phosgene, Phos-Chek and Fire-Trol; fire foams and fire-blocking gels such as Flame Seal, FireIce, AquaGel, Flame Guard Gel, and Thermo-Gel; wetting agents such as FireChem and KCR.
- The indoor relative humidity is above 30~40% since the time of the wildfire or at the time of soot cleanup and deodorization.
- Temperature and humidity changed shortly after the fire which allowed oily soot to bind (soot sorption) more easily with surfaces.
- Attempts were made by non-trained professionals to clean and deodorize interior surfaces of the building and contents before the restorer's involvement.
- There is a delay in time in removing loose settled soot before corrosion and pitting occurred.
- Porous building materials and contents absorbed smoke and soot into pores thus limiting the success of cleaning and deodorizing process.
- Ventilation systems were in use during and after the time of the wildfire.
- Attics and other non-occupied spaces having wildfire soot contamination can complicate the cleaning and deodorizing process of occupied spaces.
- Wind and outdoor conditions continue to affect the interior of a building.
- Air, surface and room partition barriers cannot be established that limit cross-contamination or re-entrainment of wildfire soot particles.
- Building occupants state they are experiencing adverse health effects.

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SMOKE AND SOOT PARTICLE AWARENESS

Soot becomes more difficult to remove over time. This is a fact that conservators working in museums discovered from one week to the next. Soot is often acidic, increasing the necessity to remove it quickly. Moreover, soot agglomerations are easily broken into minute particles of soot that pigment, and become physically trapped within even the smoothest of surfaces. To be most successful, salvage of soot-covered objects should attempt to minimize pressure, disruption, and dispersion of the soot layer, all of which will tend to drive the soot farther into the surface of the object (Royal Saskatchewan Museum).

Commercial Buildings and Sensitive Environments: "Notices that caution against touching sooty surfaces should be prepared as part of the disaster contingency preparations and be ready for posting following a fire, whether it is a full-scale museum fire or a localized fire. The "don't touch" signage can state that if a sooty object is touched, the pressure will disperse the soot and embed it into the surface, thus making the object uncleanable. Although such precautions may seem obvious, few people can resist running their fingers over a fresh layer of soot. The multitude of inspectors, officials, media, and managers who will tour the site within the first few days following a disaster are in special need of this reminder" (Spafford-Ricci and Graham, 2002).

Museums, Historical Buildings and Expensive Properties having Rare, Original Artwork and Valuable Contents: Following a fire, collections should be prioritized for salvage and conservation treatment according to the type of object and its relative sensitivity to soot damage. Objects with charred areas and structural damage are obviously the most unstable and should be given first priority. Collections can then be prioritized as follows: porous surfaces are more sensitive than nonporous surfaces, intricate surfaces are more sensitive than smooth surfaces, and organic materials are more sensitive than inorganic materials; objects can be further separated according to the degree of sootiness, with those that are less sooty often being at less risk. Objects or groups of objects thus prioritized can be recorded on a master table so that the salvage team can indicate the status of the salvage operations for each object group. This master table will aid in coordination of salvage operations, which are usually chaotic and involve a changing roster of persons working concurrently in different locations (JAIC, 39: 1, Article 2).

DOCUMENTATION

Buildings contaminated by wildfire smoke, soot and ash also have their contents contaminated. Depending on the use of the building, such as a home, health care, small business or manufacturing facility, smoke damage affecting the building will not greatly change; however, damage to contents and collectibles, outpatient surgical equipment, computers and manufacturing lathes can experience an increase of damage because of corrosion associated with fire retardants, acid in soot, humidity and a delay in caring for contents. In situations like these, building owners and tenants should rely on outside professionals. When fire insurance is available, most of the cleanup, deodorization, sanitizing and repair work should be covered under the policy.

It is highly recommended that the owner of the property and contents document the wildfire soot and ash condition that each structure experienced. In fact, Mercury, AAA, Allstate, Chubb, Safeco, AIG and Farmers Insurance Companies advertised on radio and TV: …the owner of the property should do whatever is necessary to document the fire damage, including taking reasonable steps to protect property from experiencing further damage.

Documentation Using Photos and Video:

One of the easiest forms of insurance, real estate and tax information documentation of damaged property is a collection of still pictures. Digital still pictures are preferred over disposable instamatic cameras because you are seldom limited by how many pictures you can take. What is even better than a bunch of still pictures is documentation by a video camera, that is, a movie of the damage.

Unique to a video camera:

- The color picture quality is often outstanding even in low light.
- Focusing is usually automatic.
- You can easily describe in your own words the fire and soot that affected your building while zooming in on exterior and interior property damage.
- You can video contents in each room, their position and condition; and describe how they are fire damaged or soot contaminated.
- The video camera provides a more realistic 3-D view of damage and contamination that a 2-D still camera can't provide.
- Zooming in on each building material or content provides close-up details that most still cameras can't provide including filming: large to minute amounts of settled soot and ash; peeling and blistering; contrast shading differences including discoloration; corrosion and pitting.
- You can bring in one or more experts who will describe for the video camera the fire and smoke and what is required to mitigate soot contamination and repair fire damage.
- Unless you edit the video, you don't lose pictures like you can with prints.
- Making DVD copies of the video is instantaneous and inexpensive.
- The best of both worlds of documentation requires having a video of your home or business and its contents "before" the wildfire damage occurs and a video "after the fact."

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Professional Video Documentation:

Completing your own documentation of the fire damage and soot contamination is recommended. However, there are professionals qualified to document your loss. In many situations the cost of documenting the loss (as required by insurers) may be reimbursed under some fire insurance policies. Fire forensic video professionals are expected to be knowledgeable in construction and contents damage assessment. Meaning, they must know how buildings are built and how to look for defects caused by the fire, and how to assess and inspect most types of contents damage and contamination.

Video professionals will work with you to gain as much information about the extent of damage and contamination as necessary to meet your desired goals. Meaning, if all you require is a cursory overview video of the layout of the building and the fire damage that is in the garage, then the video specialist's job is limited. However, when you have extensive fire damage to the building and soot damage to valuable and irreplaceable antique contents and heirlooms, the video specialist's job just took on a life of its own. On completion, the professional's video it is expected to tell a story that documents pre-loss conditions (when possible) that explains the pre-fire loss quality and condition of the building, antique, artwork, mural, mosaic, library or collection, and their current state or condition.

A properly prepared video documentation of fire damage and soot contamination represents an invaluable description of building and contents that many parties rely on, including but not limited to: property loss adjusters, tax specialists, appraisal experts, cleaning and restoration professionals.

Other parties may have a future interest in the DVD and seeing the extent of property damage almost firsthand. A DVD showing how the restoration process was completed and rebuilt back to pre-loss condition, how charred wood and smoke and soot was abated, and the installation of new wood framing would be of interest to: renewal and new insurance underwriters; disclosure to a new buyer at the time of property sale; getting appraisal and mortgage companies to agree that there is not a diminution of value affecting the property; subrogation and settlement proceedings; and tax audits.

Unique to antique and historically significant contents is determining the extent of damage and contamination at the time of loss "as soon as possible," no matter if the damage is limited: to cracking and peeling of the veneer; pitting of the finish and the loss of the antique patina; the legs of the Queen Ann chair are sitting in water; the nickel plating on the 13 foot tall 18th Century gold leaf mirror appears to be damaged; soot is behind the glass of a signed Monet print; the heat of the fire caused moisture to evaporate out of the furniture causing the joints to crack; asbestos acoustic ceiling plaster appears to have fallen on the collection; leather bound books are stained; three pieces of a 12 piece ivory collection are damaged beyond repair; the floor safe full of family jewelry is filled with water; one of two 5 foot tall Ming jars from Emperor Jiajing (circa 1521) is tipped on its side and we don't know if it's cracked; the American Indian headdress from the Sioux tribe from 1884 has soot on it; Wild Bill Hickok's guns appear to be rusted; the collection of Lincoln signed documents are damaged; and so on.

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FOLLOWING A DECISION LOGIC APPROACH: HOW THE CLEANUP PROCESS BEGINS AND PROCEEDS

When Only a Small Amount of Nuisance Wildfire Soot and Ash is Indoors Affecting Contents:

- Once the fire is out change ventilation system filters as soon as possible. (For best results purchase filters having a MERV rating of 6 to 8.)
- Ensure ventilation filters fit properly and there are no air gaps around the filter. When air gaps are present, use ventilation system rated duct tape to seal or secure the filter in place.
- When an outdoor breeze is present, keep doors and windows closed and turn on ventilation systems.
- Cleanup the surrounding outdoor environment of excess soot and ash. It is amazing how much wildfire particulate matter becomes tracked back indoors. For the first couple of days after the wildfire, it may be necessary to rewash exterior surfaces.
- When entering residential structures, make it a habit to change outdoor shoes to indoor shoes and slippers. When entering commercial structures, ensure clean walk-off mats are present.
- Cleaning is generally limited to vacuuming. When possible use HEPA rated vacuums with soft bristle attachments and HEPA rated carpet vacuums.
- In cleaning building materials and contents most of the cleaning takes place on the top of floors and the surface of contents where settled soot and ash is present.
- Detergent washing is required when soot and ash is:
    - Ground down into a black residue such as on ceramic tile, wood and vinyl floors;
    - In contact with food preparation surfaces;
    - In contact with dishes, children's toys and certain types of clothing, upholstery and interior finishes;
    - In contact with materials and contents that can be damaged by soot and ash.

When a Strong Smoke Odor Exists Indoors and/or Surfaces are covered in Soot and Ash:

- Follow the guidelines outlined above.
- Hire a ventilation system contractor to assess and inspect the system(s) cleanliness and ventilation efficiency.
- Hire an IICRC or RIA certified fire damage restoration contractor to assess and inspect the building and its contents.
- Notify your insurance company about the smoke odor and soot contamination.
- Except for protecting property from further damage, do not touch soot contaminated surfaces.
- Video document the extent of damage and contamination.
- Unless you are skilled in the art of soot cleaning, detergent washing of fire-soot contaminated materials and deodorization, allow certified restoration professionals to complete the job.

PROFESIONAL SOOT DAMAGE CLEANUP CONSIDERATIONS

Commentary:

In all my years of cleaning up smoke and soot, ash and embers from structures and contents, to removing damaged building framing and char from salvageable building materials, I found that some professional restorers use the same worker crews to remove damaged building materials as they do to clean damaged contents. I attempt to discourage this practice in my restoration classes and lectures.

In speaking with restorers from Canada, Europe and the U.S., the general consensus is: (1) allow the guys do the grunt work; (2) allow the gals to do the fine contents cleanup work. While this sounds sexist and is, the idea behind it is sound. Pay attention to the strengths and abilities of your crews and develop teams who excel in painstaking, thorough cleanup and other teams who are best at tromping around, tearing out walls or moving big contents. It is the plain fact that there are both men and women you wouldn't trust in a China shop, as the saying goes.

REMOVAL OF WILDFIRE SOOT FROM CONTENTS AND COLLECTIBLES THROUGH HEPA VACUUMING

HEPA vacuuming is the first active step that must take place during salvage of soot contaminated items. The initial content damage assessment and inspection includes a surface soot removal process which involves HEPA vacuuming; and vacuuming certainly before contents are moved and sometimes packed and stored. One purpose of HEPA vacuuming is to stop further damage. Some valuables can be damaged by soot contamination (including corrosion). HEPA vacuums should be rated for asbestos level cleanup and come to the job as standup and backpack types (e.g., Nilfisk, Minuteman, Pullman-Holt, Euroclean). I say this because not all HEPA vacuums are the same quality. There is a reason why one HEPA vacuum will cost $99.00 and another one will cost $5,000.00. Consider staying with an industrial quality name brand.

Workers who participate in HEPA Vacuuming and Cleaning Processes must be:

- Educated on creating a safe cleaning area for themselves.
- Educated on how to process the soot contaminated building while avoiding cross contamination.
- Educated on how to safely touch and handle upholstered items, draperies, silks and other fabrics.
- Educated on how to safely and gently handle books, photos, manuscripts, prints and paintings.
- Working in teams of two persons that have equal skills and ability.
- Wearing clean cotton gloves "not Latex gloves" that can cause surfaces to smear.
- Wearing a minimal of a P100 disposable mask, eye protection, smock and other PPE.
- The first team to come in contact with upholstery, furniture, valuables, artwork and collectibles.

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- Using a HEPA vacuum with "like-new" brushes, crevice and mini-attachments.
  - Use a variety of vacuum attachments that lessens soot transfer.
  - Replace attachments often with clean attachments.

Procedural Process for HEPA Vacuuming Contents, Collectibles, Artwork and Historically Significant Items:

1) Why is a Procedural Process Necessary?

a. Antiques, historical collections, artwork and upholstered furniture can be damaged through improper handling. Educating workers on the proper handling and vacuuming of contents decreases damage, contamination and cost of restoration.

b. Soot can permanently damage items and decrease their value. Meaning, some items experience increasing damage and loss of value the longer soot and ash remains on them.

c. Removing soot before handling an item can identify underlying problems including cracks, deterioration, heat, moisture, pitting and structural damage.

d. The cleaning and restoration process is complicated from smearing and imbedding of particles including chemicals, oily and acid-base residues into finishes.

2) Ethics and My Responsibility to Properly Inform Parties:

a. This paper on soot removal involving HEPA vacuuming and the use of brushes on works of art, collectibles and historically significant items including buildings, does not and cannot assume all practitioners who read the paper have been trained properly to remove soot, ash and their chemical constituents. It is expected that all practitioners who remove soot particles from contents and furniture to works of art, collectibles and historically significant items are expertly trained and experienced before applying their trade.

   i. Workers exposed to smoke and soot may experience adverse health effects. Also, workers who disturb smoke and soot may release particles, chemicals and toxins in the air that may affect the health of other people.

   ii. Further advice about specific cleaning and deodorizing applications must come from an onsite certified fire/smoke remediation specialist, certified restorer (CR) or an art conservator.

3) Risk and Process Management:

a. As mentioned earlier in this paper, wildfire soot and ash carries with it properties and chemicals that are known to affect human health and also damage materials and contents. Soot and ash cleanup should only be completed by healthy persons. In some situations the cleanup and removal of soot deposits requires professional help. These professionals are known as fire damage restoration specialists who have training, certification and experience in the fire cleanup and deodorization/restoration industry. That said, even restoration specialists are limited by training and experience when it comes to handling and cleaning museum quality items and historically significant materials. In these instances, conservators must be consulted with and when necessary, they should take over the conservation of certain items.

b. Some wildfire affected homes and business may require just a spring cleaning after a "light dusting" of soot and ash. However, homes and businesses that are close to a wildfire can experience extensive soot particle and smoke odor diffusion throughout attics, ventilation systems and the interior spaces. Soot and ash "fallout" in these situations may require the interior and its contents to have multiple cleanings until the community experiences a lessening of particles in air currents.

c. The goal in cleaning a building and its contents requires removing as much of the light dusting or extensive soot fallout as soon as possible. This process increases indoor air quality and the building's hygiene; and it lessens damage that can affect contents and building material finishes.

4) Human Response to Wildfire Hazards:

a. It is not unusual to see people react differently when a wildfire descends on their community and home. Sometimes a person's reaction is to save their life by leaving; while others may attempt to stay and protect personal property. It is a sad day when people like actor Christopher Lloyd lost his home and possessions to the 2008 Montecito Wildfire; however, actors John Cleese, Oprah Winfrey and Rob Lowe were fortunate to have their homes saved. A couple of days later singer Stevie Wonder lost his home and all possessions in the Porter Ranch Wildfire. In the 2007 Malibu wildfires, a neighbor's home was saved because of the actions of Guns N' Roses singer Axl Rose.

b. Possessions are important to all of us. After a fire, some people come back to their homes and business to find the property and all their contents are okay. While we are grateful our possessions are saved this doesn't mean this is the end of the story. Owners enter their homes and find the property full of soot. At other properties the fire sprinkler flooded the interior including saturating contents.

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c. This paper only deals with controlling and removing soot contamination and not property that experienced direct fire and heat damage, water damage or contamination from a retardant spray.

5) Characteristics of Soot Deposits:

a. Soot represents the liquid and solid fragments of pyrolysis. It may be composed of hundreds of different compounds that will vary depending on the materials that are pyrolyzed in a fire. Regardless of the nature of these compounds, all soot is composed of an oily-tarry matrix combined with carbon and, as such, has predictable characteristics. Soot particles in smoke may be as small as 1μm in diameter and therefore are often not distinguishable under a compound microscope. The substance that is visible to the naked eye is a soot web formed when the oily materials surrounding the carbon black soot is attracted to one another and form agglomerations. During a fire, soot agglomerations are segregated in the air due to flotation effects, the larger agglomerations dropping out of the air closest to the fire and the finer agglomerations farther from the fire. Soot particles will penetrate the finest crevices of a surface and remain physically trapped, their attachment enhanced by electrostatic attraction. In solution, the carbon can reach an atomic scale of fineness that will then be redeposited in this size when a cleaning solvent evaporates. Soot will embed into porous and compromised surfaces such as those melted by the heat of a fire (Williams 1990).

6) As a General Procedure:

a. When HEPA vacuuming is required before moving items to a safe place, general vacuuming procedures consider prioritizing vacuuming of the most valuable items first such as artwork and antiques and removing them. (1) Prioritizing may begin at the point entry and continuing to the farthest room; or (2) just identifying items that require vacuuming priority over other items:

   i. Note: prioritizing contents HEPA vacuuming is different for HEPA vacuuming the building. The building's interior requires: (1) HEPA vacuuming the structure from the source of the fire and vacuuming outwards; or (2) vacuuming HEPA from the farthest soot affected room and working back to the least affected room.

      1. (This is consistent with Michigan's DOH, HEPA vacuuming requirements for lead dust exposures.)

      2. This procedural process assumes workers will be HEPA vacuuming items at a safe workplace (not in an unsafe building or toxic environment).

3. This procedural process assumes contents, antiques, collectibles and artwork are only soot damaged/contaminated and they are safe and secure at the spot they're located.

b. When HEPA vacuuming cannot be completed in the place where upholstery, furniture, antique and collectible objects are located for any reason:

i. Carefully handle (e.g., pick up, box and transport) soot damaged items to a safe place, such as an evaluation and cleaning table.

1. This doesn't mean furniture, antique or historically significant items can be roughly handled. In fact, extraordinary handling measures are required to identify, stabilize and carefully remove them.

7) Triage:

a. The project manager assigns supervisors and workers to complete specific work tasks such as identifying furniture, antique or historically significant items based on their value or historical significance, condition or location. For example triage (a method of prioritizing work tasks based on the severity of the fire damage or smoke and soot contamination):

i. In a home or museum, the cleaning crew may need to focus on soot cleaning and the removal of antiques and collectibles before soot cleaning and removing other items such as Oriental rugs, furniture and clothing.

ii. In an office, computers may need to be removed before file systems.

iii. In a factory, the entire finished product may need to be removed first; or the multi-million dollar computer lathes may need to be removed first.

8) Temporary Removal and Storage:

a. During fire recovery and restoration, some contents may require special attention. What this means, some contents may need to be boxed and processed to temporary storage while waiting further cleaning; or the structure must be cleaned and deodorized before contents can be placed back into it.

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b. Avoid temporary storage of contents that are not completely cleaned of smoke and soot residue because soot acids can be accidentally activated. The catch 22 is: acid activation may occur at a relative humidity above 40%; but 40% is the minimum relative humidity many antiques and artifacts should be kept at. In avoiding this dilemma, contents, antiques and artifacts should be thoroughly cleaned and dried onsite after HEPA vacuuming.

c. When contents are stored onsite, the storage area (garage, a room in the building or a PODS storage unit) must be clean, soot and odor free and secure. The storage area should be temperature and humidity controlled.

d. Contents and collectibles should be open to the storage room air to avoid moisture and condensation issues. Further, some contents should be placed on storage shelving and not placed in boxes to avoid damage. Stacking and close wrapping should be avoided so as to minimize pressure on contents, and if present, on the soot layer.

9) Poor HEPA Vacuuming Practices Can Cause Significant Damage To Some Items:

a. Note: most HEPA vacuum brushes are inexpensive (meaning, they are inexpensively made with materials that are not designed for art conservation cleaning).

   i. Hairs of a brush or vacuum can scratch some artwork and historically significant items including paper. This statement is consistent with the conservators from the Missouri Conservation Services Notes; Northeast Document Conservation Center; Chicago Conservation Center; Center for Art Conservation; McKay Lodge Conservation Laboratory; Straus Center for Conservation; American Institute for Conservation.

b. When surface scratching is an issue (e.g., scratching a photo, X-ray or an art object including pastels and paintings, and historical documents), the quality of the HEPA vacuum's brush must be evaluated (some brushes are made with natural or synthetic hair but all of them are coarse).

c. In HEPA vacuuming sensitive surfaces, only a conservation quality brush should be used to aid and loosen soot and ash instead of allowing a vacuum brush to do the job. (See below for further advice.)

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WHERE INDOOR SOOT DEPOSITS ARE MOST COMMONLY FOUND AND THE REQUIREMENTS FOR HEPA VACUUMING

Once the air cools, the greatest amount of soot deposits is usually found on flat surfaces. In buildings, soot deposits are on floors and the surface of contents. First, vacuum off soot particles before handling or moving contents and other items. In completing a hazard assessment and a procedure for removing soot the project manager will determine: (1) Can the open traffic areas be safely HEPA vacuumed first to reduce the tracking of oily soot deposits into flooring, especially carpets; (2) are contents, collectibles and antiques in any danger of being damaged from falling or from items falling on them, and if so, what must we do to immediately minimize content damage; (3) based on customer requests, remove specific items first because of their value, condition, historical significance, etc.

This section is specific to mitigating soot damage that has settled on certain types of contents: In general, once soot damaged contents are HEPA vacuumed they are either – left in place, removed to a control inspection area "called a work station" for further evaluation or cleaning, or placed in a non-smoke and soot contaminated storage room.

1) Upholstered Furniture (e.g., **couch, arm chair, cushions**):
    a. With a HEPA vacuum crevice tool "that is kept off (up and away) of contact with the material's surface," HEPA vacuum loose soot and ash. This requires a steady hand and will remove most of the heavier loose soot and ash.
    b. As a second step, depending on the condition of the fabric and remaining amount of soot residue, carefully position a clean mesh (e.g., fiberglass window screening having large [18 x 16 mesh (0.011-0.013)] diameter holes) over the previously vacuumed surface; and with a clean crevice tool, apply minimal (very light hand pressure) on the mesh to extract additional soot particles from the fabric.
    c. As a third step, when it is required, with your clean white gloves on, carefully pick up vacuumed upholstery and deliver them to a work station or a safe, soot-free clean room.
2) Hard Surface Furniture (e.g., **table, desk, armoire, chair**):
    a. With a HEPA vacuum and short and long hair brush attachments, make the first extraction pass just above the surface of the furniture. (Depending on the vacuum's pressure, many loose soot particles will be extracted.)
    b. Once the first passes are complete, begin a series of second passes by slightly touching the surface with a clean vacuum brush. (Ensure each pass picks up a desired amount of large soot and ash particles down to smaller amounts.)
    c. When residual soot particles remain they are there for a reason. Generally they are either sticky or temperature and humidity has become a factor. In these instances:
        i. The worker should attempt to loosen surface soot and ash with an appropriate sable, squirrel, ox, camel or a goat hair paint brush. (Sable being the softest is also the most expensive brush. The sable brush is not necessary for loosening and removing soot and ash from most hardwood made furniture).

ii. Loosen surface soot with the appropriate brush, and extract with the more coarse HEPA vacuum brush.
iii. On completion of surface vacuuming, when required, carefully pick up hardwood furniture with your clean white gloves on and deliver to a work station or a safe soot free clean room.

3) Works of Art and Collectibles (**framed wall paintings, pictures and collectible objects** on shelves and mantels):
   a. Note:
      i. This particular HEPA vacuuming process is for removing loose soot and ash from the tops of surfaces that will not be further damaged by vacuuming.
      ii. This emergency soot removal process is not intended to clean, restore and deodorize smoke and soot damaged items that should only be cleaned by a certified restorer or a conservator.
   b. As a first step, do not touch the item with the HEPA vacuum crevice tool while vacuuming off loose soot and ash.
   c. Once vacuumed, works of art should be carefully removed (frame intact) from the wall and delivered to a safe place or evaluation station.
   d. Note: It is necessary to investigate how the art is attached to the wall such as hooks, screws and wire; and determine if the mounted art is attached to an alarm system.
   e. Once vacuumed, antiques, art objects, pictures and collectibles may need to be hand delivered or wrapped, boxed and delivered to a work station cleaning area or placed in a safe and soot free room.
   f. For collectible objects--not paintings or historical papers: Hold the crevice tool in one gloved hand and with a propped finger placed on a soot cleaned surface, continue removing soot using the crevice tool above the item's surface; or with a crevice tool in one gloved hand and a proper cleaning brush in the other, loosen soot with a soft brush and allow the soot to be extracted by the crevice tool.

4) Semi-Porous Objects (**books, rattan furniture, cardboard boxes and porous items** having lacquer and paint finish):
   a. The equipment for the first vacuuming pass across the surface of an item is a HEPA vacuum and brush with crevice tool attachments.
   b. Once completed, begin a series of second passes by slightly touching the surface with a clean vacuum brush.
   c. When residual soot particles remain, use a soft brush and loosen surface soot and allow it to be extracted towards the more coarse HEPA vacuum brush.
   d. On completion of surface vacuuming, when it is required, carefully pick up contents with your clean white gloves on and deliver them to a work station table for further evaluation.

5) Porous Contents (**modern quilts, Indian blankets, Oriental rugs and tapestries** that are in good condition):
    a. I preface this section because the handling and cleaning of these types of items can be rather simple to extremely difficult. Most of the complicating issues have to do with the age and quality of the piece; exposure to soot particles and acids; and temperature and humidity. That said, as a general rule:
        i. Often an *Indian blanket* or a *quilt* will be folded and only the upper exposed surface is soot damaged. HEPA vacuum loose surface soot on the soot side using a crevice tool. Upon further inspection, one may find a smoke stain on the exposed portion of the fabric when opening up the piece.
            1. When a smoke stain is not visibly present, it may be safe to wet clean the fabric following ASCR/NIDR/CUCI guidelines.
            2. When a smoke stain is present, consult with your professional cleaner.
                a. When the fabric is old, sensitive to tearing, is discolored, and/or it has historical significance, consult with a supervisor, certified restorer or a conservator before touching the item.
        ii. *Oriental wool and silk rugs* may release their dyes when wet; and they become further damaged when people walk on them after a fire. Avoid walking on and crushing soot particles and ash and their oily, acid-base residue into the rug fibers.
            1. Worst case scenario: carefully inventory the condition of the wet, sooty rug, roll it up and take it out to an inspection table.
                a. Consider creating a bath for the rug to flush out the black sooty mess. This is done by placing plastic on the ground (generally a sidewalk or driveway). With a garden hose and free running water, flush out the sooty mess until the rinse water is clear.
                b. Depending on the expertise of the restorer, some may use a detergent to wash out greasy oils then apply an acid rinse to stabilize loose dyes.
                c. Extract excess water and roll up the carpet in greaseless paper or plastic sheeting and immediately deliver it to an Oriental rug cleaning plant.
            2. In the best case scenario, spend the time to HEPA vacuum up loose soot with a crevice tool before it is ground into the fibers. Then carefully roll up the rug and take it to an inspection station.
        iii. *Tapestries* are often hung and are therefore expected to sustain some soot damage. However, they can absorb smoke odor that can cause damage to the materials.
            1. With a crevice tool, HEPA vacuum soot off the top of the tapestry and the face fabric, if necessary. If it is not framed, carefully detach the tapestry

from its supporting rod. Roll up the tapestry in greaseless paper then remove it to an inspection station; or

2. Once removed, take the tapestry to subcontracted professional cleaners that are able to wet and dry clean tapestries by hand.

6) Fabric Window Coverings: (e.g., valances, cornices and shadow-boxes):

a. Draperies and other window coverings are included at the request of a restorer. Draperies, like tapestries can experience the same amount, if not a higher amount of soot contamination, because of their location. Meaning, tapestries are generally mounted on inside walls while draperies are hung on rods mounted on outside walls.
b. Also, tapestries are on flat wall surfaces while draperies are placed over windows. Flat walls do not open to the outside elements but windows do. Finally, tapestries don't easily become sun faded and damaged but draperies are more likely to become faded and damaged. One final thought: most building's ventilation systems face draperies. In a wildfire storm, smoke and soot pass through the air supply and end up as micro-fine soot deposits on draperies.
c. Now that I setup a mental picture about what can occur between tapestries and draperies, draperies act as a filter that captures soot and smoke more than almost any other material in a building. This situation becomes worse when heat convection pressures from firestorm driven wind create eddies around windows forcing even closed windows to crack open. (Open windows are worse.)
d. Soot deposits develop on closed windows at the ledge and often at the floor. No matter if windows are closed, your nose may be able to smell smoke; your eyes or a 20*x* field magnifying glass can identify whether or not soot passed through the window into and deposited on drapes, floors and casements.
e. Another trick is to use cotton balls and collect surface soot. Under the 20*x* field magnifying glass, an average person with minimal training should be able to distinguish common household dust from darker more defined wildfire soot, ash and embers.
f. Draperies should be HEPA vacuumed along with the contents of the building. With your white glove hand on one side of the drapery, HEPA vacuum the opposite side of the drape with a clean brush attachment. Start at the top of the drape and continue down. Avoid climbing up and down a step stool or ladder multiple times to vacuum panels, Clean the upper drape as far as you can safely reach, then step down to continue with the remaining panel.
g. If the result of HEPA vacuuming is not sufficient to clean them, as a second step, draperies should be professionally removed for wet or dry cleaning. Meaning, don't just take down sooty draperies and send them to a cleaner without first removing loose soot and ash particles.

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WORK STATION: INSPECTION AND CLEANING

Unlike the area where workers initially remove soot particles from furniture, contents and collectibles in soot contaminated buildings, a work station is located at a clean area (often outdoors or at a non-soot affected clean room) that has close to normal background levels of dust and soot particles in it. The work station is expected to be a safer work environment for employees thus resulting in reduced levels of PPE.

Benefits of a Work Station:

- Allows further inspection of furniture, contents and collectibles for hidden damage and contamination that could not be identified during the initial HEPA vacuuming phase.
- Items can be stabilized, wet cleaned and dried.
- It becomes a triage center for items requiring:
    - Further onsite and offsite cleaning (such as dry cleaning, immersion cleaning, spot cleaning or a special deodorization process);
    - Damage appraisal, conservation and restoration;
    - Temperature, moisture and humidity control;
    - Transition point to offsite cleaning and repair;
    - Transition point for storage;
    - Transition point where items can be placed back into a cleaned and deodorized room.

Several Words on Wet Cleaning:

- One of the goals of this paper is to provide guidelines to restorers on dry soot removal. I didn't intend to focus on wet cleaning because that is the subject for another paper. Yet, I would be negligent if I didn't talk about the need for wet cleaning since it, too, is part of the smoke and soot removal process.
- HEPA vacuuming is the first stage in the cleaning process. And depending on the amount of soot fallout and dusting, including infiltration, HEPA vacuuming may be all that is required to bring contents, artwork, collectibles, antiques and the building back to their pre-loss or pre-contaminated condition. However, in other cases, HEPA vacuuming becomes the first and most important step in the cleaning process followed by other cleaning methods including dry-particulate removal and wet cleaning to remove carbon-base soot smoke and oily substances.
- When wet cleaning is required, there must be mechanical and solvent action to clean contents and building materials. Part of the wet cleaning goal is to break up delicate agglomerations of soot into yet finer particles where cleaning solvents facilitate the suspension and emulsion of smoke and soot contaminants and flush them away.
- Cleaning techniques should be designed to avoid embedding particles into a surface either mechanically or through the use of organic solvents that are intended to extract oily components that easily can be absorbed into a content or building material surface including particles of carbon black.
- The presence of acidic soot adds to the degree of urgency in having it removed. This includes the phenomenon that soot becomes more strongly attached to surfaces over time. Conservators theorize that this effect may be due to cross-linking, but it may also be related to the physical

compacting of a soot layer over time (Spafford-Ricci, S., Graham, F.). (This theory is also consistent with studies and conclusions reported by Kasper, M., et al.)

- Removal of soot during recovery after the Royal Saskatchewan Museum fire became even more difficult after the soot layer had been compacted through excessive handling or movement, and if the object had been subjected to high humidity conditions, or if a prior unsuccessful cleaning attempt had been made (Spafford-Ricci, S., Graham, F.).
- Types of soot varies considerably and therefore the soot cleaning treatments can vary tremendously depending on the type of material surface being cleaned and the heat generated during fires. However, conservators and restorers alike find there is a predictable characteristic of soot that make it imperative for general cleaning guidelines be followed during the removal of soot from contents and buildings.
- Conservators find that a strict progressive cleaning procedure that begins with vacuuming and moves to dry-surface-cleaning, then to wet-cleaning, will guarantee the highest degree of soot removal for most objects [and material finishes]. This success is particularly true of soot loosely to moderately bound; for cleaning of more tightly bound layers of soot, the procedure is less critical but still applicable (Spafford-Ricci, S., Graham, F.).
- Thorough wet cleaning at a work station should limited to medium and hard contents; and when available, the day-to-day washing of clothing, bedding and linens that are washed in washing machines and dryers. Other items including the cleaning of quilts, Oriental rugs, lamp shades, and historically significant items and pictures including works of art, should be cleaned at a restoration plant or conservation cleaning facility.

The Restorer should have One or More Cleaning Stations Onsite that have:

- Contents pack out inventory control (POI) type of identification system
- HEPA filtered down-draft tables for contents to sit on that allows a more thorough cleaning
- HEPA filtered negative air machines (NAMs) with 6-mil containment plastic
- Strong folding tables covered with protective packing paper and tape
- Greaseless and soft packing paper
- New (unused) packing boxes of various sizes (including acid free boxes, tubes and paper)
- Bubble wrap clear and pink (anti-static)
- Liquid packing foam including soft Styrofoam peanuts
- Stretch (shrink) wrap and furniture blankets
- Bags or boxes of clean white cotton cloths, used clean cotton rags,
- Soft painter's type soot removal and cleaning brushes
- Camera and ruler with black felt backdrop
- Portable white flood light with tripod and a UV light
- Detergents include Dri-Pak soap flakes, Ivory, Dreft, Biz, Dawn [original blue], baking soda and Orvus and when appropriate Simple Green
- Cotton, rubber and Latex gloves
- Spotting kits
- Cotton swabs and balls
- Hair dryer
- (Optional) ultrasonic cleaning tanks
- (Optional) box and storage frame making including wood, cardboard and foam

PART IV:

PROCEDURES FOR REMOVING WILDFIRE SOOT PARTICLES IN BUILDINGS

Part IV Does Not Apply to Buildings like This One

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UNDERSTANDING THE ISSUES

Cleanup, Remediation and Deodorization Goals:

The goal is to remove soot from building framing and materials. –However, this is easier said than done. The practice of removing smoke, soot and odor remediation requires the restorer to eliminate as much of the particulate matter as humanly possible in order to return building materials free from oily, soot deposits.

The returning of buildings, their environments and contents to pre-loss conditions is every building owner's goal in mind. Let me give you an example:

> *While shopping in a food market, I overheard a lady mention to her girlfriend "…I burnt a turkey in the oven three years ago. The whole kitchen was full of smoke and we had to call the fire department. They sprayed a chemical on the stove then threw out the turkey and turkey pan on our front lawn and hosed it down. Our insurance company paid a contractor to cleanup the soot and smoke odor at a great expense. We even had part of the house repainted. However, when I open up my cabinets at certain times of the year, I still smell smoke from that turkey; the smoke smell is on my clean dishes and pans that have been washed hundreds of times."*

If I was able to investigate the situation faced by the lady who burnt her turkey several years ago, I believe I would find that the restorer did not complete the job properly. Cabinets should have been detached and cleaned. It is also possible the drywall and insulation behind the cabinet should have been removed and replaced. Properly applied, cleaning chemicals can dissolve the oily-sticky protein odors trapped behind and under cabinets.

What do you think is causing the smoke odor to remain? Building fires are generally classified into two groups: simple and complex.

- Simple fires result in the total or complete combustion where the residue is powdery and light and there are minimal amounts of gases and odors; while
- Complex fire results in the incomplete or partial combustion of organic and inorganic fuels. Complex fires tend to leave the most carbon-base waste behind along with chemicals, toxins and sticky residue.

Here's another story:

> *My grandfather died twenty five years ago. Yet, when I smell his pipe, it's surprising there is a lingering smell of pipe tobacco still in it. The pipe smell becomes stronger when I peel back a section of burnt residue from the bowl.*

SCIENCE 101

Air Flow Dynamics and Passive Soot Filtering Compartments

Because of wildfires and building fires, air movement and building pressure differentials can cause large to minute amounts of residual carbon-based particles to pass into walls, ceilings and voids. Solid particles and their gas vapors settle on surfaces. When disturbed by air movement, settled particles become airborne and are respirable (breathable—you can smell them).

The science behind smoke management methods includes the study of *compartmentation*, *dilution*, *pressurization*, *airflow* and *buoyancy*. CONTAM (Contamination Transport Analysis) is used to analyze many of these smoke management techniques and to simulate smoke movement in multizone facilities and to analyze the performance of smoke control systems including stairwell pressurization systems and to aid in the performance of occupant safety (NIST Multizone Smoke Management Modeling.)

- *Compartmentation* – Passive compartmentation refers to the use of physical barriers that hinder the movement of smoke from leaving the fire space and flowing into the non-fire spaces. These barriers include walls, partitions, floors and doors; and in commercial buildings – smoke dampers.
- *Dilution* – Dilution of smoke particles typically refers to the removal of smoke particles and odor from non-fire damaged spaces. The goal is to reduce airborne contamination in non-fire damaged spaces that restores and maintains acceptable levels of indoor air quality. Dilution relies on the ability of fresh and make-up air to dilute smoke and combustion gases that infiltrate non-fire spaces as the contaminated air is exhausted.
- *Pressurization* – In commercial buildings, pressurization systems are designed to reduce the spread of fire. Pressurization or *smoke control* refers to the use of mechanical ventilation systems (fans) to induce pressure differences across barriers having a relatively high resistance to airflow to control the movement of smoke between compartments. For example, stairwell and elevator shaft pressurization and zoned smoke control are typical implementations of a pressurization method. However small air gaps in building materials such as access holes in drywall, fixtures and ceiling lights; voids that cause a stack effect, attics and T-bar ceilings; plumbing, electrical and HVAC ducting, all reduce compartmentation pressurization. Small air gaps in building materials are often design and maintenance-caused defects in the building's pressurization system that are responsible for smoke and soot to enter and complicate the cleanup process.
    - *Pressure Gradients* – Smoke and fire gases disperse through positive or negative air pressure situations and become subjected to related densities of cold air and hot gases. As fuel combusts and produces heat it causes the surrounding air to expand, resulting in positive pressure. As heat cools, air pressures tends to go negative. In the fire restoration and deodorization industry, restorers use pressure gradients to create either positive pressure ventilation (PPV) or negative pressure ventilation (NPV) in venting airborne contaminants from a building.

  - *Positive Pressure Ventilation (PPV) and Negative Pressure Ventilation (NVP)* – (1) The process by which fire fighters rely on structural ventilation, blowers and fans, and natural venting techniques at the time of a fire (NIST Fire Dynamics Simulator); (2) The process by which restoration contractors use PPV/NVP from HVAC systems, mechanical use of blowers and fans, and natural venting techniques after a fire.
- *Airflow* – (1) In building design, smoke control by airflow is very similar to pressurization except that airflow typically refers to the flow of natural or ambient air through relatively large openings. (2) Airflow in fire damage restoration is designed to use PPV or NVP distribution to aid in the removal of airborne contaminants from relatively large areas.
- *Buoyancy* – (1) Buoyancy in building design refers to the venting of hot (buoyant) combustion gases through fan-powered and passive vents typically located in the ceiling of large open spaces and attics. (2) Buoyancy in fire damage restoration includes any process by which vapors and gases are vented out of a building.

Soot Gases and Vapors

Organic vapors in soot have a relatively high boiling point, requiring high temperatures. When soot settles and vapors condense on cooler surfaces they can be very difficult to remove, especially on porous building materials such as wood, drywall, plaster, acoustical finishes, and concrete and cement block framing because they bind and absorb into porous materials. Water-base washing may not remove all oily residues from the pores of materials because some oily soot compounds are not water soluble. Pyrolysis compounds (carbonization) and residues of incomplete combustion of organic fuels (generally below 800^{o}F) can lead to the formation of polyaromatic hydrocarbons (PAH) and particulate matter.

The general process for the formation of PHA/soot involves the breakdown of materials that fuel a fire into small unsaturated fragments, followed by a subsequent build-up to form larger multi-ring aromatics and ultimately particulate matter. The nature of the unsaturated compounds determines the quantity and presumably the nature of the soot that is formed (NIST Program: Understanding PAH/Soot Formation Chemistry).

Pyrolysis follows certain rules, depending mainly on the substances burnt. These mechanisms are presented and illustrated with practical examples of burned substrates analyzed according to ASTM standards. (*Fire Sci. Soc:* Stauffer, E. *Concept of Pyrolysis for Fire Debris Analysis*, 2003). However, materials that fuel building fires have changed over the years. In the past we thought of building fires as primarily combusted materials of wood. Now with polymers (glues and adhesives) that are holding up our buildings, and many contents being synthetic base, building materials and contents have lower melting points [where the smoke and soot becomes] more toxic. Once a fire establishes itself, interior temperatures can exceed 2,000^{o}F (*InterFire Org.,* DeHann, J. *Our Changing World: Fires, Fuels, Investigations and Investigators,* 2008).

Complicating the Building's Recovery Process

According to the Institute of Inspection, Cleaning and Restoration Certification (IICRC) and the Indoor Air Quality Association (IAQA) smoke damage from forest fires can be as harmful to your building as everyday fires. In fact, forest fires may create significantly more destruction because of the amount of smoke generated; the length of exposure; types of materials combusted; and, the widespread coverage of smoke and soot. What is often not understood is that after the smoke clears and the ash stops falling, the structural and content damage is just beginning. Further, when the indoor air quality issues affect the building and its occupants, it too must be addressed.

Quick Action is Essential: When building owners, property managers or insurance adjusters procrastinate or prolong the cleanup and restoration of soot contaminated property, they extend the effects brought on by smoke and soot contamination. Here is a general timeline on the effects of fire and smoke that can damage a home or business and its contents:

- ✓ *Within Minutes*
  - Acid soot residues can cause some plastic contents and building materials to yellow;
  - Small appliances located close to the source of combustion may discolor;
  - Highly porous materials consisting of marble and alabaster can experience discoloration damage and this condition may be permanent;
  - Air quality is affected.
- ✓ *Within Hours*
  - Collectibles and antiques that have a natural patina can become damaged;
  - Acid residues stain grout in bathrooms;
  - Fiberglass bath fixtures turn yellow;
  - Metals tarnish and some types of counter tops may yellow;
  - Finishes on appliances, particularly refrigerators that extend into the heat line may yellow including white rubberized gaskets and door seals;
  - Furniture finishes can discolor and become tarnished and pitted.
- ✓ *Within Days (*Over a Few Days to a Week Or So):
  - Acid residues cause painted walls to yellow permanently;
  - Metal corrodes, pits and rusts;
  - Wood furniture requires refinishing;
  - Wallpaper yellows;
  - Vinyl flooring may require refinishing or replacement;
  - Clothing becomes soot stained especially when they are on hangers;
  - Upholstery may stain permanently.
- ✓ *Within Weeks*
  - Cleaning and restoration costs can escalate tremendously;
  - Synthetic carpet fibers may yellow or discolor permanently;
  - Silver plating can be permanently corroded;
  - Glass, crystal, china may require replacement due to severe etching and pitting caused by prolonged exposure to acid soot residues;
  - Caulking around doors and windows, base and crown molding yellows.

IICRC, IAQA, ASCR/NIDR (now RIA) recommends cleaning up smoke and soot residue as quickly as possible to avoid secondary damage.

During combustion and shortly afterwards, soot residue is carried in air by rising vapor pressure, eddy currents, thermal properties and humidity. Soot particles are deposited on surfaces throughout the structure through chemical attraction. This phenomenon is similar to electrostatic, magnetic and electrical charges that cause certain soots to be attracted to certain materials such as plastics over wood. Soot deposition tends to occur repeatedly until combustion ends and until the air is clear of contaminants.

As air and surfaces become cooler, oily smoke and soot deposits settle faster on surfaces. Over a matter of minutes soft, oily, soot film tends to harden. In some situations, the oily aggregate and particle structure morphology is believed to result in a lacquer-like residue that becomes more difficult to dissolve as time goes on.

Antique sewing machine, stereo receiver, box and carpet heavily impacted by wildfire soot and ash.

Courtesy of Elizabeth Freedbird, Caldecon, Inc.

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COMMENTARY

The wildfire soot cleanup mitigating procedures I've outlined are consistent in principle and practice with the fire damage restoration and conservation industry that includes: …vacuuming of soot from fires is the most important cleanup process one can do to limit building and content damage.

For this reason my paper attempts to stay focused on the topic of proper soot removal. As I've repeatedly stated, soot removal is the first cleanup process that must be completed, because without it, further damage can result.

Where to Start?

Part III, page 24, touched on this issue in dealing with building and content issues. The initial cleanup issue for buildings is a little more complex:

- ✓ Does the restorer remove the gross amount of wildfire soot particles affecting the outdoor yard, patio, walkway and driveway first or does the restorer's project manager focus attention on the building's interior?
- ✓ Is the building's interior wildfire soot damage severe enough that soot contaminated contents must be removed first?
- ✓ The ventilation system and attic insulation is wildfire soot contaminated and because of these issues, do I mitigate this damage first?
- ✓ Building owners and tenants do not want to close their business and move out for a couple of days. What should I do in working around them; and, how does their presence complicate the soot cleanup process?

All things being equal to where there is no chance of structural damage affecting the building or its occupants or physical harm to contents (e.g., falling, breakage), I would focus my cleaning crew's initial attention to where the least amount of work provides the maximum benefit which is:

- ✓ Remove wildfire soot and ash from around the building where cleanup and restoration crews must have access to.
- ✓ Remove wildfire soot and ash from the surrounding lawn, walkways, driveways and parking and any other area that can cross-contaminate or affect the building's cleanup process.

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MITIGATING WILDFIRE SOOT IN BUILDINGS: A PRESCRIPTIVE APPROACH

Training and Equipment:

1. Restorers should have ***certified workers*** in fire damage restoration and the appropriate use of PPE.
    a. Workers must wear ***appropriate PPE*** at all times while on the job.
2. Restorers are expected to have an appropriate amount of ***clean and sanitized "cleanup and remediation equipment"*** with them at all times while on the job.

Agreements and Contracts:

This section is not legal advice. Restorers must consult with their attorney and not rely on this paper. However, I've consulted with attorneys and provided expert testimony on some of the items listed below. These comments are consistent with industry standards of care and remember--all agreements should be in writing.

1. Written agreements should incorporate:
    a. An estimate of costs per service or job;
    b. A rate sheet describing time (labor and supervision costs) and material costs;
    c. A rate sheet of daily and weekly equipment rental costs;
    d. Scope of work;
    e. Start and anticipated finish date;
    f. Miscellaneous anticipated costs including but not limited to permits and fees;
    g. Profit and overhead;
    h. Warrantee and disclaimer provisions, if any;
    i. Who is the responsible party that agrees to pay for the completion of work? It may be a homeowner or their insurance company. In another loss it may be a commercial building owner or their property management company.
    j. Provisions that establish progress payments, material payments and final completion payment.
    k. Provisions that provide for collection, interest and attorney's fees.
2. It is expected that the restorer will write their estimate based on the scope of work. The scope of work is established between the restorer and customer. However, when the restorer and customer disagree on a method or procedure, the restorer should write a full scope of work as they expect the work to be done in returning the building, contents and environment back to a pre-loss condition.

a. When the customer disagrees with a scope of work item, the customer should initial and signoff that they do not want that item completed (e.g., contents pack-out, ventilation system cleaning or insulation removal).

b. Once the contract is signed, all changes (additions and deletions) to the contract should be in writing on a change order. Both the customer and restorer sign and date the change order form.

Site Assessment and Documentation:

1. Restorers are expected to complete a ***job hazard analysis*** (JHA) that identifies hazards that exist or are anticipated to exist (including electrical and gas, unsafe buildings and asbestos).
    a. The restorer is expected to eliminate hazards or use appropriate engineering controls that protect life and property.
2. Document building and content conditions before, during and after the completion of work.
3. Document the methods and procedures used to clean, sanitize and deodorize building materials and finishes.

Process Management: A Procedural Guide

1. Keep the outside of the building clean of wildfire soot that can cross-contaminate the building's cleanup work.
2. Inspect materials and finishes that can immediately be damaged by soot.
    a. Take all necessary steps to remove soot particles and residue and provide an appropriate treatment that stops damage.
3. Install sticky-type ***walk-off mats*** at all entrances (e.g., Sticky Mat, TacMat.)
4. In buildings that remain occupied during the soot cleanup and the building remediation/ restoration phase, determine with the building owner:
    a. Are there ***occupant complaints*** such as smoke odor and soot fallout? When these conditions exist:
        i. Assess and inspect the damage/contamination and determine if a fresh air source should be established for this area or if one or more ***HEPA filtered air scrubbers*** should be installed.
        ii. Hire and consult with an ***indoor environmental professional*** (IEP), an industrial or environmental hygienist or a health expert.
        iii. Determine if ***cleaning of the ventilation system*** must be completed at the beginning of the job instead of at the end of the job.

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5. Determine with the customer if the interior soot contamination is severe enough where ***contents must be packed out to a safe place*** while building cleaning and restoration takes place.
    a. In these situations, contents must be ***HEPA vacuumed*** before handling, wrapping, boxing and removing. (See Section III)
6. Determine with the customer if it is necessary to remove ***soot contaminated attic insulation***.
    a. When attic insulation must be removed, the removal process should begin as soon as possible followed by HEPA vacuuming the attic.
        i. "As soon as possible" generally means within the next day or two. Other cleanup and remediation work can continue while the attic insulation is being removed.
        ii. During attic insulation removal and the cleanup and deodorization of attics, the ***attic mounted HVAC systems*** should be turned off and sealed closed; or have the fresh air supply mechanically redirected to it from an outside source.
7. Change out soot contaminated ***HVAC filters*** with clean filters.
    a. It may be necessary to run the ventilation system while the building's cleanup and remediation work is in process.
    b. It may be necessary to replace soot contaminated filters more than once including after ventilation system cleaning.
8. Because of the degree of ***wildfire soot imbedded in carpet***, it may be necessary to remove and dispose carpet and pad.
    a. When carpet is saved and cleaning is expected to remove soot particles, the carpet must be thoroughly HEPA vacuumed "before" workers start walking on the carpet.
        i. In some instances it may be appropriate to ***steam or dry-foam clean*** carpet after the initial HEPA vacuuming and again at the end of the job.
9. **Window coverings** including valances, shadow boxes, levelors and other blinds are considered contents. Yet, they are important to talk about in the building cleanup and remediation section as well. Window coverings, like carpet, act as filters for wildfire smoke and soot.
    a. Generally the sooner these items can be HEPA vacuumed and, if necessary, removed and cleaned, the quicker the building may smell better. There often is a positive change in the building's indoor air quality when curtains are cleaned.
10. **<u>General HEPA Cleaning Guidelines:</u>**
    a. Start the HEPA vacuum cleaning of the building from the furthest point such as a back office or bedroom and end up at a front or side door. In other words, have a game plan in mind on how you are going to begin and end.
    b. Begin HEPA vacuum cleaning at the ceiling, then continue from the upper to the lower walls (including windows and doors) and finally the flooring.

11. <u>Unique Problem Solving Issues:</u>

a. HEPA vacuum, then clean chandeliers and ceiling fans, wall sconces and built-in shelving next.
    i. Electrical appliances including chandeliers, fans and sconces require careful hand HEPA vacuum cleaning. Use appropriate cleaning methods for metal finishes and crystal.

b. Don't make the assumption that contents, appliances and vehicles only have wildfire soot contamination on the surface.
    i. Further investigation often shows: micro-fine soot deposits (that can cause secondary damage and corrosion) are inside the casings of grandfather clocks, computers, stereos, TV's, printers, hair dryers, phones, cameras and light fixtures; under and behind cushions and skirting of upholstered furniture; refrigerator coils and motors, stoves and dishwasher insulation; and engines and mechanisms in vehicles, such as electric windows, and inside seat belts.

c. HEPA vacuuming silk fabric walls with batting requires special HEPA vacuum cleaning tools and cleaning processes.
    i. Consult with the material's fabricator or decorator before proceeding when this is the first time cleaning these types of finishes.

d. Remove drawers of built-in cabinets and shelving. The goal is to inspect behind the access areas to observe whether or not wildfire soot is deposited behind them.

Closing Comments:

Micro-fine soot filters and settles into nooks and crannies, voids and crevices where HEPA vacuuming cannot reach, thus leaving soot particulate matter behind. In some cases after a thorough HEPA vacuuming, an environmental professional may be able to turn on a high velocity fan (e.g., electric leaf blower) and end up having high particle counts indoors at the $PM_{2.5}$ and PM_{10} harmful to human exposure level. Does this condition mean the HEPA vacuuming process was incomplete and insufficient, or the HEPA vacuuming cleanup process is limited in what it can do? Probably yes.

HEPA vacuuming is only one tool and process that must be relied upon for the cleanup of soot contaminated buildings. However, HEPA vacuuming is not an end-all or cure-all for what is ailing the building. Often a thorough cleaning must follow after the HEPA vacuuming cleanup phase.

I hope you enjoyed reading this paper as much as I enjoyed researching it.

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Since 1984, Patrick has been a participant on many standards writing taskforces including IICRC and ASTM. Patrick has published over 50 articles and 6 books.

To contact Patrick about this paper, call his office or feel free to email him.

Note: Not all reference or research materials were used in publishing this paper. I'm citing all my references including further areas of research you may want to do on your own.

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Restoration Industry Certifications:

1. IICRC: *Certified Odor Control Technician*
2. IICRC: *Certified Fire & Smoke Restoration Technician*
3. RIA/ASCR: *Certified [Fire] Restoration Technician*

Remember: "Only You Can Prevent Forest Fires!"

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