Smoke: Its Origin and Characteristics

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SMOKE

It was agreed this research paper would be on the size of smoke particles. Little did I know how sparse the information on this subject is. In fact, there is little information on the whole subject of smoke. What there is, is often redundant. Since my research on the size of smoke particles can be put into one sentence, I have expanded my topic to smoke itself.

Several organizations research the subject of fire and smoke primarily with fire prevention in mind. Some, where this information was gathered, are the National Fire Protection Association, Center for Fire Research, Factory Mutual Insurance, International Fire Service Training Association and Massachusetts Institute of Technology. Also I turned to ASCR and Society of Cleaning Technicians bulletins plus releases and training manuals from various manufacturers and experts in the restoration field.

I will discuss how smoke is generated, what it is composed of, its color, odor, temperature and other characteristics. This discussion will also provide an understanding of fire itself - the origin of smoke. With this understanding, a restorer will be better prepared to test for its presence and can quickly determine cleaning techniques with the proper chemicals.

Furthermore, the understanding of smoke, its creation, its make-up, its characteristics is a strong sales aid for fire restorers. With this knowledge a restorer can establish his credibility when he first meets with the customer at the damaged site. By being able to discuss with the customer the characteristics of smoke, the customer soon realizes he is dealing with a professional. He is less apt to doubt you when you point out what has or has not been affected by the fire. He is impressed when you tell him why you test in particular areas when looking for smoke contamination.

In order to have smoke, we must have fire and what is fire? A key discovery in the scientific effort to understand fire was made in 1774 by Antoine Laurent Lavoisier. He recognized the apparent disappearance of flames is an illusion. Lavoisier showed an invisible component of the air (which he latter named oxygen) reacts chemically with matter at high temperatures, yielding heat and a variety of combustion products.[12] By studying fire in the laboratory, fire has come to be understood chemically as an intricate network of molecular events.

Fire, therefore, normally is the combustion of oxygen, a combustionable material or fuel and heat which produces light. Take away one of the components, oxygen, fuel or heat and the fire extinguishes. Combine them again in the right proportions and you have fire again.

Fires can be classified as friendly or unfriendly. As an example, a friendly fire is a fire in a fireplace because that is where it belongs. It becomes an unfriendly fire if it escapes to some combustionable material outside the fireplace such as a rug.

To further understand fire, a combustionable material is any substance which when exposed to heat gives off vapors which will burn when combined with oxygen in the air and ignite. Some materials don't need all three elements; oxygen, fuel and heat. For instance, phosphorus and sodium can ignite merely by being exposed to oxygen or moisture. Combustible material can be solids (wood), liquids (gasoline), or gases (butane). most solids and liquids must change to vapor (gas) before they will burn. However, gases with the right mixture of air (oxygen) are ready for instant ignition.

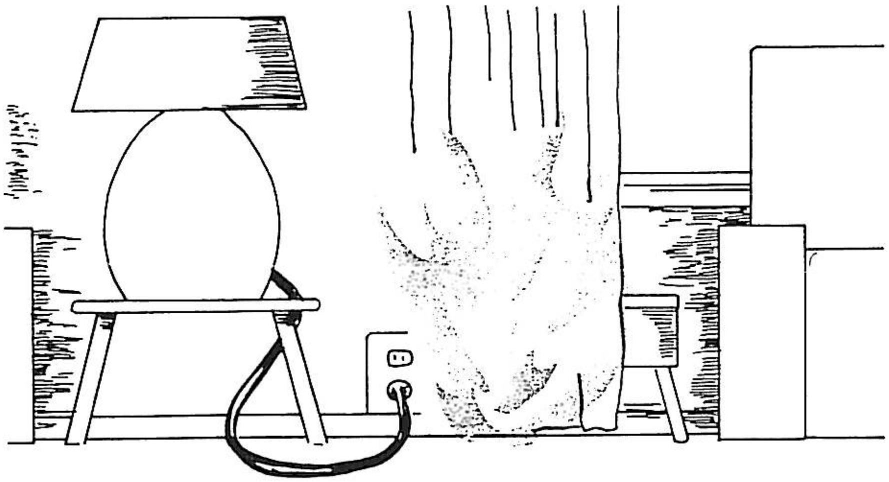
The burning characteristics of solids depend on the density and form of the solid. Sufficient heat must be applied to the solid to heat it to a point where the release of vapors and oxidation start and ignition takes place. (See Appendices A and B.) A large log needs more heat thus we start a fire by the use of kindling and/or paper. Wood dust needs much less heat and if exposed to the air can be caused to ignite by a small spark. Ignition can be so rapid an explosion takes place.

Liquids don't burn but the vapors of flammable liquids do. In fact, there is enough heat in the air even on a cold day to vaporize liquids such as gasoline.[15] The temperature where liquid turns into vapor is called the flash point. It is interesting to note the vapor of flammable liquids are heavier than air; therefore they tend to hug the floor and collect in low places.

Flammable gases are already vapor so they don't have to be heated to be burned. They just have to be combined with oxygen and ignited. Some gases are ~~heavier~~ lighter than air and collect under ceilings, etc.

Fires can be classified into phases which are the incipient or beginning phase, the free burning phase and the smoldering phase.[6]

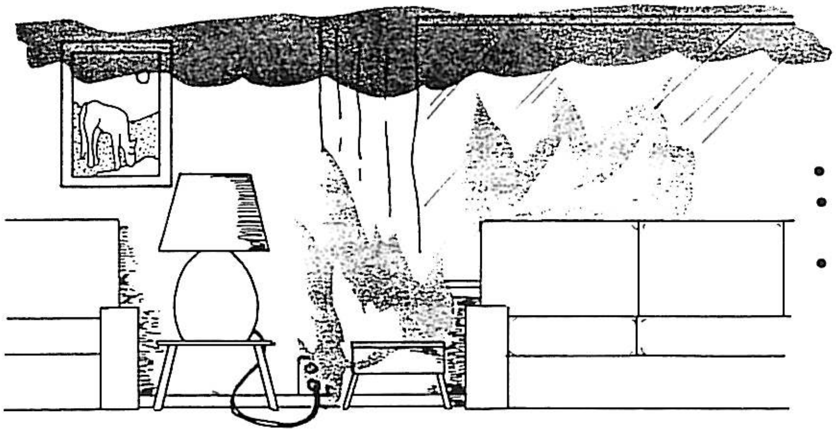
In the beginning phase the oxygen content in the air hasn't been significantly reduced so the fire is producing water vapor (H_2O), carbon diozide (CO_2) and perhaps small quantities of sulpher dioxide(SO_2), carbon monoxide (CO) plus other gases. Some heat in being produced and the amount will increase as the fire progresses.[6] In fact the flame temperature may be above 1000°F yet the room temperature has only been slightly elevated.



INCIPIENT PHASE

- Slightly Over 100°F (37.8°C) In The Room
- Rising Hot Gases
- Room Air Approximately 20% Oxygen

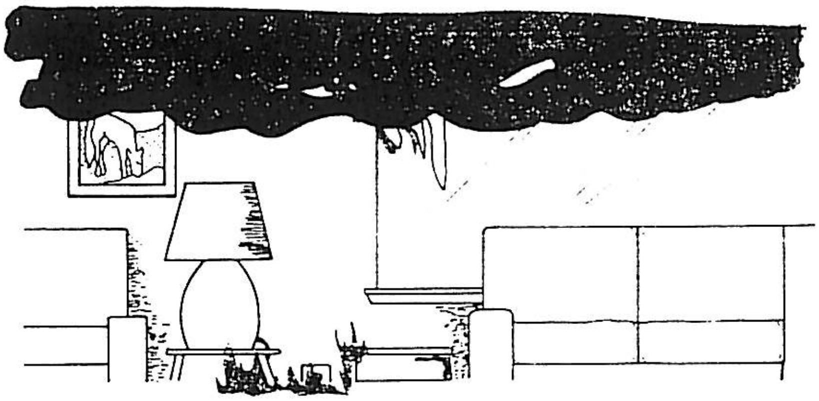
The second phase or free burning phase consists of all the free-burning activities of the fire. This phase continues until insufficient oxygen is available to react with the combustionable material and the fire is reduced to the smoldering stage. Oxygen rich air is drawn into the flame. The rise of heated gases by convection carries the heat to the uppermost regions of the confined area. Then these heated gases spread out laterally from the top downward. This forces the cooler air to lower levels eventually igniting all the combustable materials in the upper levels of the room. The temperature of the upper regions can exceed 1,300°F. During the latter part of this phase, the flame consumes the free oxygen until there isn't enough oxygen to sustain the flame, so the fire enters the smoldering phase.



FREE BURNING PHASE

- Approximately 1300°F (705°C)
- Heat Accumulates at Upper Areas
- Reduced Oxygen Supply

The flame may cease to exist in the smoldering phase if the area of confinement is sufficiently airtight. Burning is now reduced to glowing embers and the room becomes filled with dense smoke and gases which are forced from all cracks under pressure. This smoke and the combustion gases will exceed a temperature of 1,000°F.



SMOLDERING PHASE

- Oxygen Below 15%
- Temperature Throughout is High
- High CO and Carbon Concentration

Heat is transmitted by one or more of four methods. These are conduction, radiation, convection and flame contact. One law of physics is called the Law of Heat Flow. Under this law, heat flows from a hot substance to a cold substance. The colder of two bodies in contact will absorb heat until both objects reach the same temperature.

Conduction is associated with heat transfer rather than by flame. Heat can be conducted from one body to another by heat-conducting medium between two bodies. The conductivity of the material, such as metal pipes, determines the amount of heat which will be transferred and the rate of travel. Liquid, gases and air are poor conductors of heat.

HEAT TRANSFER BY CONDUCTION

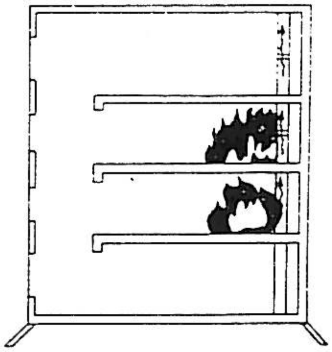
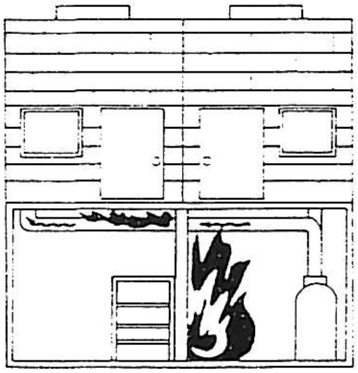


Figure 1.6 — Heat can be conducted through walls or floors by metal pipes igniting adjacent combustibles.



Although air is a poor conductor, heat does travel where matter doesn't exist. When heat travels this way it is known as the radiation of heat waves. Once radiant heat has ignited a close-by object, the heat of the new fire will radiate to other objects. It also radiates back to the original object increasing the intensity of the fire which causes the fire to grow faster and faster. Radiated heat is one of the major sources of fire spread. When the hot air layer below a ceiling reaches 650° C, there is sufficient radiation in the lower part of the room to ignite virtually everything combustible.8

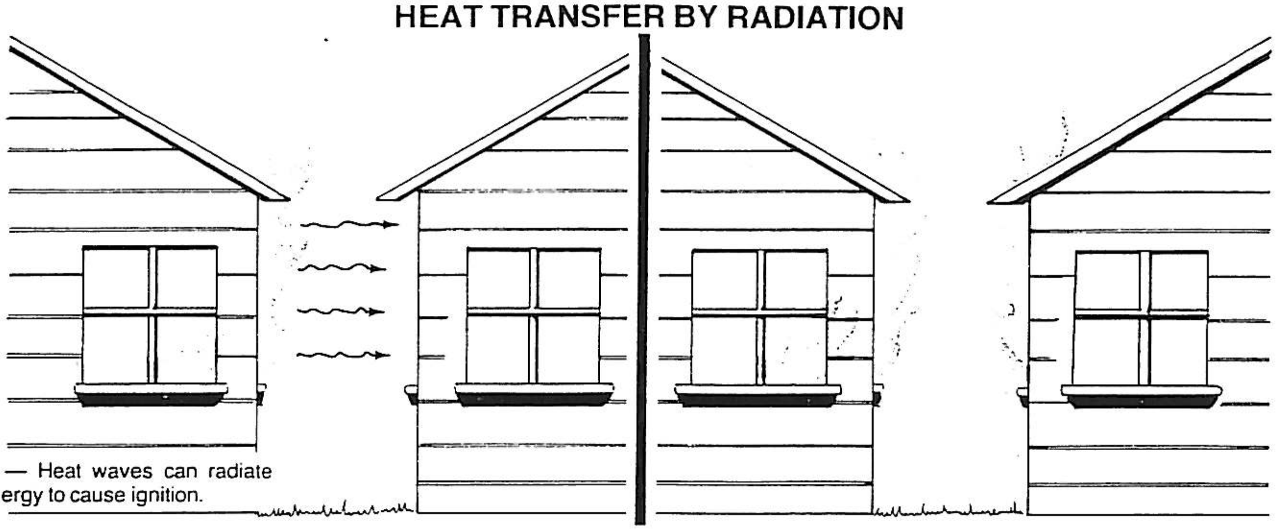
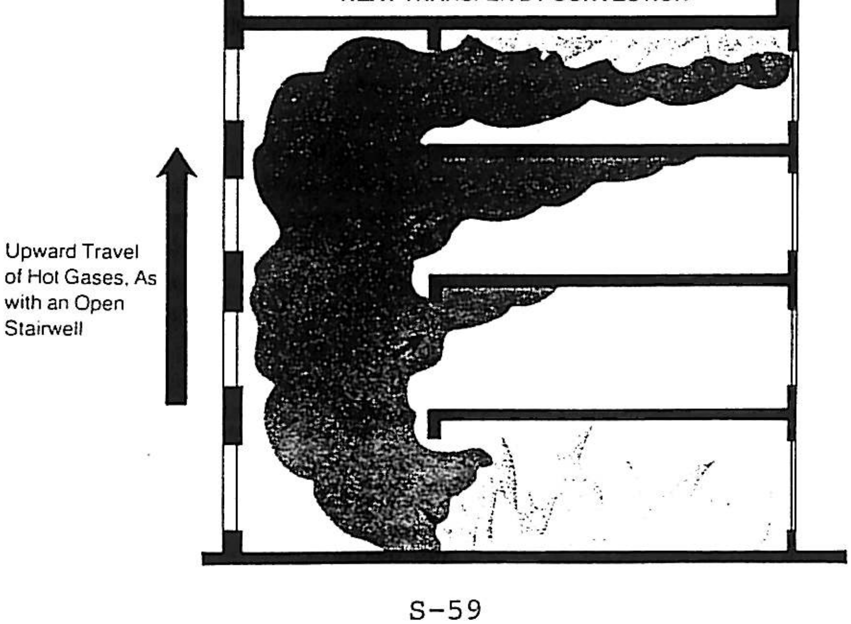


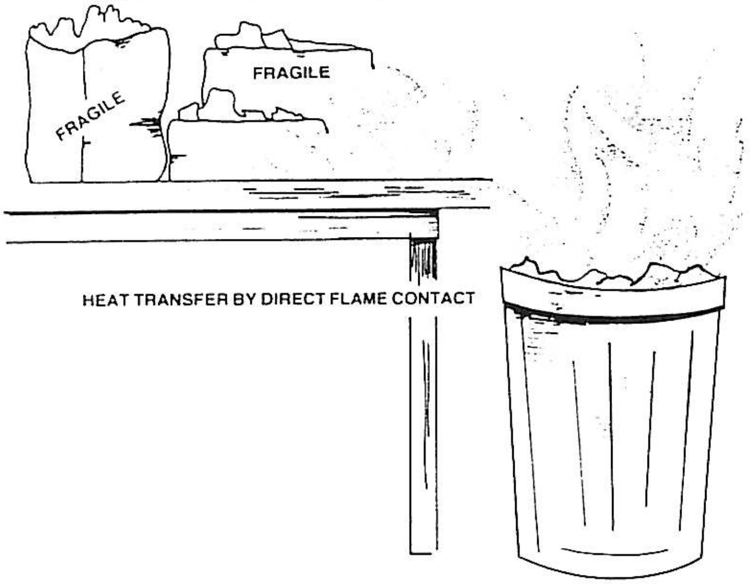
Figure 1.7 — Heat waves can radiate sufficient energy to cause ignition.

As the fire intensifies, the ambient air becomes hotter and hot gases are released into the air. The movement of these hot gases is a transfer of heat called convection. The hot gases become less dense and are lighter and rise through the heavier, cooler air above. This cycle continues as the cooler air below the rising hot air is heated and rises. The gases rise until they are stopped by a ceiling, etc. At this point the gases spread out until there is no place to go. When these hot gases can't rise or spread out any farther, the temperature of the hot gases increases. Normally the fire spread by convection is mostly in an upward direction, but air currents can carry heat in any direction. It is because convection causes heat to rise that firemen open holes in roofs to let out the hot air to reduce heat build-up inside the structure.

Convection is the reason heat moves from room to room and floor to floor. Convection carries smoke with it and is the reason smoke travels.



When flammable material is in contact with the flame of a fire, it can be heated to a temperature where it will ignite and burn. This is direct flame contact.



Other than traditional fire with flame, there is the smoldering fire or slow combustion fire.15 A lighted cigarette in an upholstered couch is an example of a smoldering fire. Such a fire can take two hours to develop until there is enough air to induce a flame. Radiation, convection and conduction help spread this kind of fire. Until this fire develops, the smell of smoke is often the only evidence of fire.

Spontaneous combustion or ignition is an example of another kind of fire. This fire develops when materials oxidize and vaporize, even in normal temperatures, in small spaces where there is little ventilation. As the material oxidizes, such as oil, it generates heat and without ventilation to carry the heat away, heat is built up until the ignition point is reached.15

When materials burn none of the elements making up them are destroyed by the fire. However, the material undergoes a chemical change and all of the matter is transformed into another state or form. The transformed form or state equals in weight and volume the material before it burned.

There are four products of combustion: Heat, flame, fire gases and smoke.6 Heat is a form of energy. It is measured by degrees of temperature. Heat is the product of combustion which is responsible for the spread of fire.

Burning gas which is visible is flame. When burning gas is mixed with the proper amount of oxygen the flame becomes hotter and less luminous. The reason for this is a hotter flame means more complete combustion of the carbon which makes the flame less visible. In a smoldering fire it is often possible to have heat, fire, gases and smoke without flame.

Fire gases are the vaporized products of combustion. The more common combustible materials contain carbon which when burned forms carbon dioxide (CO_2) and carbon monoxide (CO). The factors which determine the fire gases created are the chemical composition of the item burning, the amount of oxygen present and how hot the fire is. The gases produced in a fire are normally water vapor and carbon dioxide. When there is a lack of oxygen and incomplete combustion takes place, carbon monoxide forms.

The fourth product is smoke. Smoke at most fires consists of a mixture of oxygen, nitrogen, carbon monoxide, finely divided particles of soot and carbon plus an assortment of products depending upon the material which is burning.

Soot consists of heavy hydrocarbon ions. After a delay period some of the initial molecules disappear and soot aerosol appears. These are spherical particles of carbon containing various amount of hydrogen and trapped hydrocarbons depending on the flame. These aerosol particles give sooty flames and their opacity is responsible for their yellow glow. The spheres can't grow beyond about a tenth of a micron in diameter because of the depletion of carbon in the flame gas. The black smoke which can form is created by the agglomeration of the aerosol particles. If there is no black smoke in flames producing a yellow glow then the soot aerosol is oxidized by the flame faster than it agglomerates.12 Examples of hydrocarbon sources are burning rubber, tar, plastics, etc. These are heavy hydrocarbon materials which can contribute substantially to the initially large surface growth rate of soot.

Soot is an amorphous substance which is rare in nature. Amorphous substances differ from crystalline substances in that their particles are not arranged to form geometric shapes.13 In other words, when the soot aerosol cools, its internal structure is shapeless so no definite shape is characteristic.

The smoke produced at a fire will vary enormously, both from fire to fire and from time to time in the same fire. Because of this it is difficult to discuss the amount or nature of smoke produced by all fires.

For instance, the plumes of hot gases above a fire consist of many parts that generally fall into three groups:

1. Hot vapors and gases given off by the burning material.
2. Unburned decomposition and condensation matter which may vary in color from light to black and sooty.
3. A quantity of air heated by fire which rises with the rising plumes. Assuming there are two temperature layers in a room fire, a hot upper layer and a cold lower layer, the fire plume carries mass and energy from the cold to hot layer.5

Smoke consists of a combination of these three groups, however, the ratio of each will vary from fire to fire and within the same fire. Therefore, the volume of smoke produced, its density, color, toxicity, will depend on the material burning and the way it's burning.

One definition of smoke is: "Smoke and fumes are dispersions of finely divided solids of liquids in a gaseous medium. The particles size range is 0.01 to 5.0 microns."3 A micron is a unit of measure equal to one thousandth of a millimeter or a particle size of .00000001 inches to .0000005 inches.

The most common measurement of smoke is light density. Mulholland and Ohlemeller obtain mass median diameters of 2-3 µm for a smoldering fire when measured near the source. Bankston, et al, National Bureau of Standards, measured diameters for 0.34-2.10 µm from a number of materials including Douglas Fir, polypropylene and urethane foam. George Mulholland states the maximum diameter of 5 µm is reasonable when allowing for coagulation in a full scale fire.1

Smoke toxicity is caused by gases in it. Even carbon dioxide which isn't toxic can cause a person to die in a fire since when carbon dioxide is produced it reduces the amount of available oxygen. This can cause a person to suffocate. It is the acetic acid in smoke that causes ones eyes to "burn".

The basic elements of a cellulose product are:

Carbon - 40.0%
Hydrogen- 7.2%
Oxygen - 50.7%
Nitrogen- .8&
Sulpher - trace
Minerals- 1.3%

When these chemicals are combined in a particular way, wood is formed. When wood is heated sufficiently these chemicals combine in many different ways and are released as smoke and gases. In fact, 50% to 60% goes up in smoke leaving 40% to 50% behind as charcoal.2

Burning wood can generate as many as 50 compounds. Synthetic materials such as plastic also can generate as many compounds, some extremely toxic.

The volatile matter in smoke is referred to chemically as pryoligneous acid consisting of alchohols, acid acetone, tars, resins and other products.2 When it cools it becomes a tarry liquid which sticks to surfaces. It also contains a strong odor.

However, soot residue is odorless.14 The high carbon content of the soot has absorbed highly odorous material on the surface of the smoke particle.

It can be assumed a smoke particle is a tear shape, damp droplet or aerosol since water vapor is one of the first compounds formed by a fire.

Because the exterior of this droplet dries first, odor is often released when odor isn't apparent, during cleaning or by disturbing the burned article. The reason for this is the dried "skin" of the droplet has been broken releasing the odor trapped within the droplet.

One classification of smoke odors is as follows:14

1. Protein odors-burned meat, flesh or poultry.
2. Natural substance odors-burned wood, paper, fiber, etc.
3. Synthetic substance odors-burned plastics, synthetic textiles, etc.

We will discuss the handling of smoke odors later. During the early stages of a fire, firemen often can determine what material is burning by the prevalent odor.

How smoke travels is important to restorers. It is important in looking for contamination initially and in the actual cleaning process. Heat, as we mentioned, travels in four ways. Smoke travels primarily by convection. The only other way it can travel is by air currents-natural or man made.

The Law of Heat Flow[6] specifies that heat tends to flow from hot substances to cold substances. See Appendix C. Thus hot smoke will travel to colder surfaces such as outside walls and windows. However, it will rise first because heated gases are lighter than air. When smoke reaches a barrier, such as a ceiling, it will spread out to cooler surfaces because of the convection principle. Complicating the movement of smoke is that air currents can carry smoke in any direction.

Smoke has been referred to as driven smoke and free floating smoke.9 Driven smoke is pressurized and has a force behind it. This smoke will deposit itself on vertical surfaces due to impingment or by a magnetic attraction since smoke particles are ionized. Smoke from synthetic articles, such as plastics, have a stronger magnetic charge than natural substances, such as wood. For this reason one can inspect a room that appears to have no smoke damage and find a heavy concentration of smoke on a plastic container. Free floating smoke is smoke that has lost the force behind it. Since this smoke is heavier than air, it will fall onto horizontal surfaces. It is for this reason you will find smoke on the horizontal surfaces and not on the vertical surfaces in a room which is removed from the fire source.

Driven smoke will penetrate minute cracks and crevices, drawers, etc., due to the pressure or energy which is driving the smoke.

The quantity of smoke from even a small fire can be quite large and a building will be filled with smoke quite quickly. For example, one pound of burning wood would fill a room of 1,250 cubic feet with enough smoke to reduce the visibility to about 3 feet. Four ounces of foam rubber or one pint of kerosene would create the same effect.10

Smoke varies in appearance from light colored to black and sooty depending upon the amount and nature of the unburned decombustion and condensation products arising from whatever is burning. See Appendix D.

Smoke color and residue can give some indication of what is burning. The density and color is a direct ratio to the amount of suspended particles.6 A fire of wood, cloth and other furnishings will have no smoke or blue-white smoke of no great density. It can become darker due to the presence of larger quantities of carbon particles.

Black smoke and residue usually is produced from burning hydrocarbons such as rubber, oil and plastics. Liquid materials usually produce a darker, more dense smoke.

Visibility through smoke is a function of density. Other factors depend upon whether or not one is trying to look through smoke while trying to escape from a fire, the available natural lighting, the use of special smoke cutting lights, etc.

To elaborate, it is said, "Visibility in smoke depends on many conditions, some of which are functions of the smoke, other features of the environment and other characteristics of the observer. These conditions can be placed into three groups:

(a) Smoke: Color of smoke particles; density of smoke; physiological effect of the smoke (i.e. its irritant nature).
(b) Environment: Size and color of object being observed; illumination of object (intensity of light and whether back or front lighting).
(c) Observer: Physical and mental state of observer; whether in the controlled conditions of a laboratory investigation or whether in the panic or near-panic state of a real fire.

Information about the last group is the most difficult to obtain and indeed it must be recognized that all the information generally available relates to the 'laboratory investigation'."10

As a restorer we need to know how to test for the presence, the type and the quantity of smoke and soot. Without this ability it is practically impossible to accurately price a fire or soot job. It is first necessary to determine the type of fire, where it started and where the insured believes the damage is. This is done by asking the insured. Next we begin our actual investigation. We should be guided by our knowledge of how fire and smoke behave as outlined in this paper. Also see appendices C and E.

If the fire source is unknown, observe the window glass. Glass with heavy, dark smoke accumulation is probably remote from the point of origin because the heavy smoke indicates a slow build-up of heat in that area. Glass with a light smoke accumulation might be near the point of origin because the light smoke indicates there was intense heat in the area. A window with small crazing (minute cracking), and perhaps with light smoke accumulation, is probably near the point of origin, its condition suggesting intense and rapid heat build-up. Large crazing and heavy smoke accumulation suggests slow heat build-up and remoteness from the point of origin.4

The presence of smoke is determined by sight, touch and one's nose. However, the nose becomes immune to odor after being exposed to smoke after a period of time. It is important to go outside into fresh air if you are using your nose continuously to locate smoke. The same is true for any other odor.

While smoke can often been seen, it can be difficult to determine the amount of smoke on a surface. For instance, a light residue of smoke evenly deposited on a wall, etc. may not be apparent to the eye. In this case we may have to locate the residue by contact. For example, by wiping the surface with a chem sponge, white paper or towel, we can determine the presence of smoke since the wiped area is lighter than the contaminated area. Also the contaminate probably will be apparent on the wiping medium.

Remember the following points when testing for smoke:

1. Smoke rises-in light smoke situations it won't be near the floor.
2. Smoke travels to cold surfaces-therefore look for it on outside walls and cold surfaces, i.e. toilets.
3. Smoke is attracted to metal.
4. Smoke is attracted to plastic.
5. Smoke is carried by ductwork
6. Smoke follows metal pipes.

In addition, protien fires often leave an oil residue which is pinkish in color but isn't readily apparent.

The removal of smoke odors is a separate subject. It is important to realize smoke odors can be found in the air and in the smoke residue or char. Eliminating the odor from the air will provide temporary relief. In order to completely elimonate the odor whatever is causing the smoke odor must be eliminated. This can be accomplished by removal, cleaning or by containment such as sealing. After eliminating the source it may still be necessary to remove the odor from the air. This can be accomplished by using ozone, thermal fogging, cold fogging or by the introduction of fresh air.

The cleaning of smoke residue is one of the reasons being a restorer is personally rewarding. Because the real restorer has to be able to identify the type of smoke and soot. He must know the characteristics of smoke from the different types of materials which burn. He needs to know how smoke affects various kinds of surfaces and substances. Lastly, and perhaps most important, he must know what cleaning methods and chemicals to use to restore the various surfaces he is working with.

The excitement of being a restorer is being faced with a new material or situation which challenges our ability to restore it.

Few other professions provide as much personal satisfaction.

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4. Specific Engineering
5. Fire Journal

Appendix A

Ignition Temperatures of Wood

The ordinary ignition temperatures of wood are between 450°F and 800°F (230°-430°C). For example, here is a list of the ignition temperatures of some common woods:

Wood	Ignition Temperature	
Douglas fir	500°F	260°C
Paper birch	400	200
Spruce	500	260
Western red cedar	380	190
White oak	400	200
White pine	500	260

However, it is important to note that when wood is exposed to prolonged heat it undergoes a chemical change and becomes pyrophoric carbon with an ignition temperature that can be as low as 300 F (150 C). The prolonged heat will also greatly reduce the amount of time required for ignition. For instance, the leaf pine will ignite when subjected to:

356F	(180C)	for	14.3	minutes
392F	(200C)	"	11.8	"
437F	(225C)	"	8.7	"
482F	(250C)	"	6.0	"
572F	(300C)	"	2.3	"
662F	(350C)	"	1.4	"
752F	(400C)	"	.5	"

A Pocket Guide to Arson Investigation, See Bibliography, Item 1.

Appendix B

Ignition Temperatures of Common Combustibles

Dry wood (approximately)	500°F	(260°C)
Paper (newsprint)	451°F	(232°C)
Cotton cloth	439°F	(226°C)
Pyroxylin plastics	275°F	(135°C)

Fire Ventilation Practices, See bibliography, Item 6.

Appendix C

Look for the Direction of Heat Flow

Heat Colors will be found on chromium and other shiny metals subjected to the fire (check surfaces of ovens, toasters, irons and other appliances). The progress of the fire can be traced by comparing the color-indicator temperatures on various shiny metals at different locations within the area of origin. Lighter, higher temperature colors may not be present after cooling but will be indicated by circles of darker colors still to be found on the metal.

Heat Colors	Temperature	
Yellow	450°F	230°C
Brown to purple	550	290
Blue	600	320
Faint red	900	480
Dark cherry	1100	590
Full cherry	1400	760
Salmon	1600	870
Lemon	1800	980
White	2200	1200
Sparkling white	2400	1320

A Pocket Guide to Arson Investigation, See bibliography, Item 1.

Appendix D

Color of Smoke

Combustible	Smoke Color
Hay/Vegetable compounds	White
Phosphorous	White
Benzine	White and grey
Nitrocellulose	Yellow to brownish yellow
Sulpher	Yellow to brownish yellow
Sulfuric acid, nitric acid, hydrochloric acid	Yellow to brownish yellow
Gun powder	Yellow to brownish yellow
Chlorine gas	Greenish yellow
Wood	Gray to brown
Paper	Gray to brown
Cloth	Gray to brown
Iodine	Violet
Cooking oil	Brown
Naptha	Brown to black
Lacquer thinner	Brownish black
Turpentine	Black to brown
Acetone	Black
Kerosene	Black
Gasoline	Black
Lubricating oil	Black
Rubber	Black
Tar, coal, foamed plastics	Black

Fire Cause Determination, See bibliography, Item 4

Appendix E

Indicators of Slow or Fast Burning Fires

Overhead damage - Uniform overhead damage usually indicates a slow and smoldering fire, whereas extensive damage in one place on the ceiling indicates an intense, rapid buildup beginning below this spot

Fire pattern - A wide angle "V" pattern indicates a slow burning fire. A narrow angle "V" pattern indicates a fast burning fire.

Crazing of glass - Large cracks and heavy smoke generally indicate slow burning while irregularly shaped cracks and slight smoke film generally indicate rapid burning.

Alligatoring - A fast, intense fire will cause heavy alligatoring and shiny, smooth blisters on exposed wood surfaces while a long, low heat source will produce flat alligatoring.

Line of demarcation - Examine a cross-section of a piece of wood found near the point of origin. A distinct line between charred and uncharred portions of the wood indicates a fast, intense fire. A gradation in charring and an overall baked appearance usually indicates a long, slow fire.

Spalling - Surface pieces of concrete, cement or brick may break off when exposed to an intense heat source.

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Appendix F

Color of Flame

Flame Color	Temperature	
Faint red	900°F	480°C
Red-visible in daylight	975	525
Blood red	1050	565
Dark cherry red	1175	635
Medium cherry red	1250	675
Cherry red	1365	740
Bright red	1550	845
Salmon red	1650	900
Orange	1725	940
Lemon	1825	995
Light yellow	1975	1080
White	2200	1205
Blue white	2550	1400

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Appendix G

Melting Point of Metals

Metal	Melting Point	
Aluminium	1218°F	659°C
Brass	1570-1900	854-1038
Bronze	1290-1890	699-1032
Cast iron	2000-2800	1093-1538
Chromium	3407	1875
Copper	1981	1083
Gold	1945	1063
Iron	2795	1535
Lead	625	329
Magnesium	1202	650
Nickel	2651	1455
Platinum	3216	1769
Silver	1761	961
Solder	varies	varies
Stainless steel	2462-2822	1350-1550
Steel	2522-2882	1400-1583
Tin	449	232
Zinc	787	419

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Appendix H

Incandescent Lamp Temperature

Wattage	Bare Bulb Temperature	
	°F	°C
25 Watts	110	43
40 Watts	252	122
60 Watts	260	127
100 Watts	261	127
200 Watts	307	153
300 Watts	374	190
500 Watts	389	198

Note: The above temperatures are based on mounting with base up in a 77°F (25°C) ambient. The temperatures vary, however, depending on the mounting position and the particular point on the bulb. For example: A 200 watt bulb would reach 307°F (153°C) with a base up mounting; with a side mounting the bulb would reach 493°F (256°C).

Temperature of filaments in the globe:

40-100 Watts	4424-4676°F (2440-2580°C)
150-200 Watts	4712-4730°F (2600-2610°C)
300-500 Watts	4784-4838°F (2640-2670°C)

Light bulbs may swell in a fire and lose their shape at 900°F (480°C) when exposed to heat for ten minutes or more. The side of the bulb exposed to the fire initially may melt and come to a point.

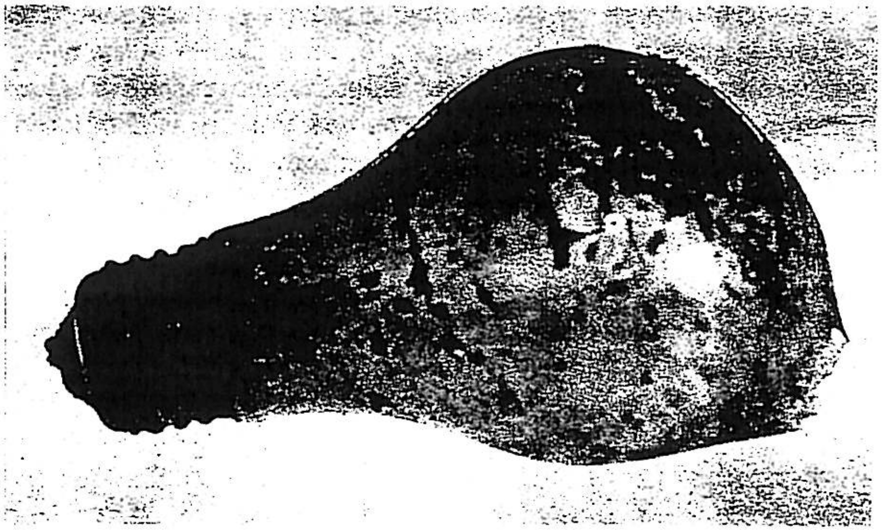

Figure 5.8 Incandescent light bulbs swell toward the greatest heat. *Courtesy of Michael Wood.*

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