Fire Inspector

CHAPTER FOUR
FIRE GROWTH

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Welcome to Chapter 4 Fire Growth.

In this Chapter we will discuss:

- The chemistry of fire
- What fire is
- States of matter
- Fuels
- Five types of energy
- Conservation of energy
- Conditions needed for fire to occur
- Products of combustion
- Fire spread
- And we will very briefly, talk about methods of extinguishment, and the classes of fire, but these, are dealt with in much greater detail, in the chapter on Portable Fire Extinguishers

We will also talk about

- The characteristics of solid, liquid, and gas fuel fires
- The phases of fire development
- The characteristics of a room, and contents fire including flameover, thermal layering, and backdrafts

We will conclude this Chapter, with a discussion, on how building construction, and the contents placed in buildings, effect the growth of fire.

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Fire inspectors need to understand how a fire occurs, develops, and spreads in order to know how to prevent or minimize the consequences of unwanted fire. In many cases fire inspectors are also charged with determining the origin and cause of fire, so they must have a good understanding of the chemistry behind fire growth.

Fire is not a new concept, the methods on how we can extinguish fires have not changed very much from back in the Stone Age, we still put the wet stuff on the red stuff. The problem is that modern fuels and construction methods have changed, and we need to understand and appreciate how these contribute to the fire problem. This is by no means meant to imply that this Chapter is a complete explanation of the chemistry of fire or fire growth. For further readings and explanations please refer to the materials section at the end of this module.

The following video, based on a series of lectures given by Michael Faraday in 1848, describes how the combustion process really works by studying a candle flame.

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Video

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Characteristics of a Flame - The fuel and oxygen mix at the base of the flame because oxygen always enters the fire at the base of the flame. The coolest part of the flame is at the base while the upper part of the flame is the second hottest place in the flame. The actual combustion takes place in a narrow bluish band that encircles the outside of the base of the flame. This blue zone is the combustion reaction zone, and it may reach temperatures of about 1400 degrees °C. The dark inner portion of the flame indicates "cooler" temperatures and a lack of oxygen.

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There are five different types of energy that can create heat that will result in a fire. These are Chemical, Mechanical, Electrical, Nuclear and Light energy.

When any combustible is in contact with oxygen, oxidization occurs. This process almost always results in the production of heat. Self-heating, also known as spontaneous heating, is a form of chemical heat energy that occurs when the material increases in temperature without the addition of external heat. If the heat cannot be dissipated as quickly as it builds, then a combustion reaction will occur.

The following video demonstrates the reaction between two chemicals; chlorine and glycerin.

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This video demonstrates the reaction between two chemicals: chlorine and glycerin.

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Mechanical heat energy is generated by friction or compression. The movement of two surfaces against each other creates heat of friction. This movement results in heat and/or sparks being generated. Heat of compression is generated when a gas is compressed. Diesel engines use this principle to ignite fuel vapor without a spark plug. Heat of compression is also the reason that self-contained breathing apparatus cylinders feel warm to the touch after they had been filled.

Electrical heat energy can generate temperatures high enough to ignite any combustible materials located nearby. Electrical heating can occur in several ways including resistance heating, overcurrent or overload, and arcing or sparking. Statistics gained from fire reports indicate that electrical heat energy is identified as the form of heat ignition in a large percentage of fires.

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Nuclear is the source of energy within the sun, the core of our earth and nuclear reactors. Most common nuclear incidents involve fires where solar heat energy was radiated from the sun. In this diagram a magnifying glass is used to focus the energy of the sun's rays.

Light energy is a kind of kinetic energy with the ability to make types of light visible to human eyes. Light is defined as a form of electromagnetic radiation emitted by hot objects like lasers, bulbs, and the sun. Light contains photons which are minute packets of energy so when an object's atoms get heated up, it results in the production of photons. There are many examples of light energy like lightened candles, flashlights, fire, stars, and other luminous bodies etc. Each act as a source of light.

The law of the conservation of energy states that energy can neither be created nor destroyed - only converted from one form of energy to another.

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In order for fire to take place fuel, heat, and oxygen must be available in the right proportions. This is graphically displayed as the fire triangle.

Once Ignited, a fourth component must also be present if the fire is to be self-sustaining thus creating what is called the fire tetrahedron. This last component, an uninhibited chemical chain reaction, provides a self-sustaining event that continues to develop fuel vapors and sustained flames even after the removal of the initial heat source. As a fire continues to burn, this exothermic reaction radiates heat back to the surface of the fuel, producing more vapors and continuing the combustion process.

All four elements must be present for fire to occur; fuel, heat, oxygen, and a chemical chain reaction. Removal of any one of these essential elements will result in the fire going out.

This subject will be dealt with in much greater detail in the chapter on Portable Fire Extinguishers.

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When a fuel burns it undergoes a chemical change. Two of the byproducts of combustion are smoke and unburned gases.

Smoke is made up of unburned particles which can be solids, liquids, or gases. This is due to incomplete combustion caused by an inadequate amount of oxygen. The unburned particles raise up from the fire in a thermal column forming a layer of smoke. Some of the particles in the smoke can enter the respiratory track and lungs with fatal results. Smoke can also contain liquid droplets that can enter the body through inhalation which can also result in death.

Smoke in a confined area like the room in a house can quickly fill the space and render the occupants unconscious.

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The term fire gases refers to the vaporized products of combustion. The more common combustible materials contain carbon which, when burned, forms carbon dioxide and carbon monoxide. The principal factors which determine the fire gases that are formed by burning are:

- The chemical composition of the fuel
- The percent of oxygen present for combustion

And

- The temperature of the fire
- Almost all the gases produced by the combustion process are toxic to humans including carbon monoxide, hydrogen cyanide, and phosgene.

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Smoke is a visible product of incomplete combustion. Smoke encountered at most fires generally consists of a mixture of:

- Oxygen
- Nitrogen
- Carbon Dioxide
- Carbon Monoxide

And

- Finely divided particles of soot and carbon

These elements are released from the burning material involved. In a burning structure smoke

builds up gradually, continuously reducing visibility, until ventilation is accomplished. People can become trapped in a smoke-filled building because of disorientation caused by reduced visibility. Because smoke is unburned particles of combustion it can sometimes ignite as seen in this video. (start video here and continue narration as follows)
This fire is in the growth stage and the black smoke is the unburned particles of combustion. If this was in an enclosed space the smoke layer would completely fill the room, but it doesn't because there is no wall at the front of the compartment to contain it so it can freely escape to atmosphere.
As the fire develops it spreads rapidly across the ceiling and starts to ignite the unburned particles in the smoke. The fire is now nearing the fully developed stage.

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Carbon Monoxide is also a product of incomplete combustion. It is an unstable gas with an affinity for oxygen. Carbon Monoxide has a chemical symbol of CO and a vapor density of 1. It is poisonous, explosive, tasteless, odorless, and is non –irritating. Carbon monoxide combines with the hemoglobin in the blood and prevents oxygen from being delivered to the lungs. This combining process means carbon monoxide is dangerous at relatively low concentrations. For example:

- An exposure to .05% for three hours is dangerous to life.
- Exposures to .15% for one hour is dangerous to life
- Exposures to .4% for one hour causes death
- Exposures to 1.3% for two to three breaths cause death.

According to the Ontario Association of Fire Chiefs, carbon monoxide poisoning claims the lives of more than 50 people each year in Canada and hundreds more are sent to hospital each year.

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Carbon monoxide poisoning is caused by inhaling combustion fumes. When too much carbon monoxide is in the air you're breathing, your body replaces the oxygen in your red blood cells with carbon monoxide. This prevents oxygen from reaching your tissues and organs.
Various fuel-burning appliances and engines produce carbon monoxide. The amount of carbon monoxide produced by these sources usually isn't cause for concern. But if they're used in an enclosed or partially enclosed space — cooking with a charcoal grill indoors, for example — the carbon monoxide can build to dangerous levels. For this reason, carbon monoxide detectors are required to be installed in residential and care occupancies by the 2020 edition of the National Building Code and most if not all Provincial building codes.
In some cases, CO detectors are required retroactively. An excerpt from the NBC 2020 is provided in the addition materials section of this Chapter. Fire inspectors should be familiar with the requirements for CO detection in their jurisdiction.
Smoke inhalation during a fire also can cause carbon monoxide poisoning.

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Firefighters often think of carbon monoxide as the silent killer. More and more, however, research is showing that hydrogen cyanide, is another equally hazardous threat. Hydrogen cyanide is a chemical compound with the chemical formula HCN. It is a colourless, extremely poisonous, and flammable liquid that boils slightly above room temperature. Hydrogen cyanide is a chemical warfare agent but is also used commercially for fumigation, electroplating, mining, and in the production of synthetic fibers, plastics, dyes, and pesticides.
Studies have shown that increase quantities of cyanide are present in smoke from modern materials such as plastics, rubber, and asphalt. The reports show that firefighters are routinely

exposed to dangerous levels of cyanide at fires without realizing it.
This is another good reason to avoid the smoke at a fire scene.

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Phosgene is the organic chemical compound with the formula COCl2. It is a colourless gas and in low concentrations, its odor resembles freshly cut hay or grass. Phosgene is a toxic gas, considered a pulmonary irritant. Its structure includes a carbon, oxygen and two chlorine molecules. It was used in World War I as a chemical weapon and is an industrial chemical used to make plastics and pesticides.
Phosgene gas is also another by-product of the combustion of chlorinated organic compounds. It is slow to dissolve in water which means that when it is inhaled, it does not dissolve in the mucus membranes of the airway quickly, so it can travel into the lower airways. Once it dissolves, it turns into carbon dioxide and hydrochloride acid in a process called hydrolysis. The hydrochloric acid causes inflammation and death of cells in the lower airways and the lung itself.
If you are at a fire scene make sure you stay out of the smoke or wear self contained breathing apparatus.

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Fire grows and spreads by three primary mechanisms conduction, convection, and radiation.
Heat transferred from one body to another through a solid is known as conduction. The rate of heat transfer is influenced by the difference in temperature and thermal conductivity of the object. A good example of this is a metal pot on the stove. Heat conducts from the hot element to the bottom of the pot and through the pot to the handle. As materials are heated, the heat absorbed at the surface of the object is transferred through the rest of the object via conduction.
Materials vary in their ability to conduct heat. Metals like cooper and aluminium are good conductors of heat while wood is not.

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Convection is heat transferred from or to a surface through contact with moving air or a liquid. The air above a hot surface expands and becomes less dense so it rises spreading vertically and laterally through the space. As the hot air rises it pushes cooler air downward and convective currents are formed. This is one reason why fire separation between floor levels in buildings is critical to prevent the upward spread of fire.
Radiation is heat transferred via electromagnetic waves through the air. Heat from the sun is radiated to earth. The rate the heat is transferred between two objects is affected mainly by the size and temperature of the fire and the distance between the fire and the target. Radiated heat from a fire is transferred in a direct line away from the heat source and absorbed by cooler materials including liquids and gases.
The next five pictures are a graphic representation of fire spread.

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These photos show a graphic demonstration of fire growth.

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There are four basic methods used to extinguish fires. These are:

- Cooling
- Excluding Oxygen
- Removing the fuel

And

- Interrupting the chemical chain reaction.

Cooling the fire is most frequently done by putting water on it to absorb the heat. Water cools the surface of the burning fuel which inhibits pyrolysis. Of all the extinguishing agents, water absorbs more heat per volume than any other agent.

Excluding oxygen, or as it is often called smothering the fire, can be achieved by covering the fire with sand or other blanketing material or by using a chemical extinguishing agent. A common example of this method is extinguishing grease in a frying pan by placing the cover on the pan. In some cases, however, fires cannot be extinguished by smothering. For example, some plastics and metals cannot be smothered because they do not depend on an external air supply. In these cases, a special method of extinguishment or control is required.

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Removing the fuel to extinguish fires is effective, but not always practical or possible. Some examples of fuel removal are:

Turning off the valve on a propane tank. In this photo firefighters are using a fog spray so they can approach the propane tank and turn the valve off.

Shutting off supply to natural gas appliances either at the gas meter or shut off cocks.

If a flammable liquid container is leaking, by pumping remaining fuel to a safe container.

By removing combustible materials from the fire area.

The last method of extinguishment is to interrupt the chemical chain reaction required for continuous burning. Scientific research has found that the simultaneous formation and consumption of certain atoms is the key to the chain reaction which produces the flame. Certain chemical substances used as fire extinguishing agents have the ability to break up this reaction.

When introduced into the fire in the proper amounts, these substances inhibit the atoms, and the fire is extinguished.

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Fires are classified into one of five classes. They are:
Class A which involves ordinary combustibles like wood, paper, cloth , houses, apartment buildings etc. Water is the main extinguishing agent for this class of fire.
Class B fire involve flammable or combustible liquids or gasses like natural gas or propane.
Class C fires involve energized electrical equipment which present a shock hazard. When the power is shut off the fire becomes a class A or B fire.
Class D fires involve the burning of combustible metals like magnesium.
Class K fires involve combustible cooking oils as found in deep fat fryers. Special class K extinguishers are available for this type of fire.

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We are now going to look at the characteristics of solid fuels as they are involved in the vast majority of fires. Solid fuels have a definite shape, for example consider wood. Wood has a definite form and is a poor conductor so heat only acts on the surface of the wood. A thin piece of wood burns much quicker than a thick piece because it has a much greater surface area exposed to the heat. The thinner the piece of wood the faster it ignites and burns. Take a campfire for example. Trying to ignite large pieces of wood often fails even if it is dry but cut that piece of wood into kindling and it burns readily.

Solid fuels do not burn in the solid state but when heat is applied they start to decompose and turn into an ignitable vapour. It is the vapour created through the decomposition or pyrolysis of the wood that burns. Consider paper as a fuel. Paper is made of the cellulose fibres from wood.

Paper ignites readily because its surface temperature increases to its ignition temperature quickly.

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Solid fuel fires develop through four phases, ignition, growth, fully developed and decay.

The ignition phase is when the fire is limited to its point of origin, in this case on the bed. This first stage begins when heat, oxygen, and a fuel source combine and have a chemical reaction resulting in fire. This is also known as "incipient stage" and is usually represented by a very small fire which often goes out on its own. If it continues to burn, it will enter the growth phase. During the ignition phase the available oxygen in the air is at 21% which is normal air content. Air is drawn in at the bottom of the flame plume as hot air escapes upward. As more of the combustibles ignite a plume of hot gases starts to rise upwards and outwards and the fire enters the growth phase where other combustibles start to burn.

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The growth phase is where the fire takes hold and starts to grow and spread to other combustibles around it. The plume of hot gases creates a convection current that carries gases upwards.

Flammable materials in the path of the plume start to ignite, contributing to the energy and spread of the fire. Many factors affect the growth phase including where the fire started, what combustibles are near it, ceiling height, and ventilation to name a few. When the flames and hot gases reach a horizontal blockage like the ceiling, they spread out across it and form a thermal layer. Radiated heat starts to ignite other objects in the room and the temperature increases and the fire grows until the fuel is consumed or the available oxygen decreases. If the doors and windows to the room are closed, limiting the amount of oxygen, the fire could start to smolder and die down.

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It is during the growth stage that the thermal layer builds at the ceiling level. The hotter gases are lighter, so they accumulate at the ceiling level and the cooler gases accumulate at the lower level of the smoke layer. If firefighters are in the room and disrupt the thermal layer with a hose stream, the water can turn to steam and fill the room resulting in burns to firefighters.

Flameover, which is often call rollover, is the flaming ignition of hot gases that are layered at the ceiling level in a developing room fire. In this photo, flameover is taking place and you can see the flames across the ceiling level.

Flashover can also occur during the growth phase. Flashover as seen in this photo, occurs when the ignition temperature of the contents of the room simultaneous reach their ignition temperature and all of the contents ignites at once. Flashover is not classified as a phase of fire development but can be described as the difference between “a fire in a room and a room on fire.”

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The fully developed phase, sometimes referred to as steady state burning, is when the growth stage has reached its maximum and all, or most of the available combustible materials, have been ignited.

This is the hottest phase of a fire and when the most energy is being released. The burning gases at the ceiling radiate heat to all the combustibles in the room and can cause even the floor coverings to ignite. Wall coverings can ignite from radiated heat causing flaming particles to drop and ignite other combustibles. On average a room and contents fire can reach the fully developed stage in five to ten minutes but many test fire we have conducted reached the fully developed stage in less time.

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In this video the fire is in the growth stage and when it reaches the ceiling you will see it start to flash across the ceiling burning the hot gases and unburned particles of combustion in the smoke.

At the same time radiant heat ignites the material on the opposite wall. As there is unlimited oxygen supply the fire continues to grow. Radiant heat from the ceiling level fire ignites the floor covering and the fire reaches the fully developed phase. Because the fire has an unlimited supply of air, the only things that will put the fire into the decay phase will be removing the heat through the application of a hose stream or consumption of the fuel.

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The decay phase is when the fire has consumed most of the available fuel or oxygen, and temperature starts to decrease, and the fire becomes less intense. The decay stage is characterized by a significant decrease in oxygen or fuel, putting an end to the fire. Two common dangers during the decay phase are first – the existence of non-flaming combustibles, which can potentially restart the fire if it is not fully extinguished which is often referred to as a rekindle, or second, there is a real danger of a backdraft or smoke explosion when oxygen is reintroduced to an oxygen deficient confined space.

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This photo also shows a fire in the decay stage. The fire was on the second floor of the building but note that there are no flames showing and the windows are black with smoke. This indicates that the fire was ventilation controlled, meaning there was not enough oxygen to support combustion, and has entered the decay phase due to a lack of oxygen. The following video graphicly displays the danger of introducing oxygen to a fire in the decay phase. It also demonstrates that fire development can move from one phase to another and is not necessarily a liner progression.

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Video

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Some important solid fuel fire behaviour principles are demonstrated in the photos and videos you have just seen. These include:

- Hot gases and flames are lighter than air, so they rise through the principal of convection

- When the flame and hot gases reach the ceiling they spread out horizontally
- Downward flame spread is usually caused by falling debris or by radiation
- Ventilation will affect the movement of the flames and the phase of fire progression
- An adequate supply of air is required for fire to burn.

In the following video Dr. John DeHaan describes what is happening in a typical room and contents fire. Dr. DeHaan was one of the leading experts in the world in the field of fire chemistry and fire investigation. He authored six editions of Kirks Fire Investigation, a leading resource manual used by fire investigators internationally. Dr. Dehaan is frequently featured in FireWise' s "Fire Origin and Cause" education programs which are also available online. Dr. DeHaan passed away in 2022 but much of his legacy is his contribution made to fire science and the scientific method of fire investigation.

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Video

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Liquid fuels are any liquids that will burn. They have some different characteristics than solid fuels. For example, liquid fuels do not have a defined shape but take the shape of their container. If they are not contained but on a level surface they spread out and pool. The also flow and pool at the lowest point.

To burn, liquids must be converted to a vapour and be mixed in the right proportion with air. The fuel air mixture must be within the flammable or explosive range to ignite. There must also be an ignition source and the ignition source, and the fuel-air mixture must come together long enough to transfer the energy required for ignition.

When liquid fuels reach their boiling point the amount of flammable vapours increase. The higher the temperature the more the fuel will evaporate creating more vapour to burn.

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Flash point is the lowest temperature at which an ignitable liquid gives off enough vapour for a fire to flash across the surface of the liquid, but sustained combustion does not result.
The fire point, which is a slightly higher temperature, is the temperature at which vapors of the ignitable liquid continue to burn after being ignited even after the source of ignition is removed.

As a fire inspector you should also be aware of the difference between flammable and combustible liquids when dealing with the storage and handling of these commodities. Flammable liquids are liquids that have a flash point below 37.8 degrees C or 100 degrees F. Combustible liquids have a flash point at or above 37.8 degrees C.

So, gasoline is a flammable liquid because its flash point is -43 degrees C while diesel is a combustible liquid because its flash point is around 52 degree C.

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Fire inspectors should also be aware of the characteristics of gas fuels so they can help to prevent fires by identifying potential problems during their inspections. Gases are the most dangerous of the three physical states of fuel because they only need an ignition source for combustion to occur. The most common gas type fuels you are likely to encounter are natural gas, propane, acetylene, and butane, but if you work in an industrial or manufacturing area you may run into others.

When released from a container, gases will rise or sink, depending on their vapour density compared to the weight of air. Air has a vapor density of one. Natural gas which has a vapor density of less than one is lighter than air and will rise. Propane which has a vapor density of more than one is heavier than air and will sink. This is vitally important information when considering the use and occupancy of a building where these products are used or stored.

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Gaseous fuels can be the most dangerous of all fuel types because they are already in the state required for ignition.

Explosive or flammable limits are the upper or lower concentration of the flammable gas, or the vapor of an ignitable liquid expressed as a percentage of fuel by volume that can be ignited.

The explosive limits are commonly referred to as UEL for upper explosive limit and LEL for the lower explosive limit.

Mixtures of flammable gases or vapors with air will combust only when they are within a specific range or concentration. When a gas is present at a concentration below its lower explosive level, or LEL, it is too lean a mixture to burn and cannot ignite. At concentrations above its upper explosive limit, or UEL, the fuel air mixture is too rich to burn and will not ignite. The explosive range between these two limits is called the flammable range.

Upper and Lower Flammability Limits are terms that are interchangeable with upper and lower explosive limits. They are sometimes referred to as UFL and LFL but more commonly UEL and LEL.

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An ignition source is anything that can initiate combustion and includes open flames, sparks, static electricity, heat generated by friction, and hot surfaces to name a few. The energy required to initiate flame is defined and/or measured in multiple ways, including ignition temperature, autoignition, and minimum ignition energy.

Most fuel gases commonly encountered require very little energy to initiate a fire. The energy, although minute, must be present in the area where the fuel/air mixture is within the flammable range. It is possible to pass small electric sparks through an explosive gas without producing ignition. When the spark energy is increased, a threshold energy is eventually obtained at which the spark becomes incendiary.

Reference: Fire Dynamics by Gregory E. Gorbett & James L. Pharr

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One potentially deadly event involving liquid and gas fuels is the Boiling Liquid Expanding Vapour Explosion often referred to as a BLEVE. A BLEVE is an explosion involving a container of liquid under pressure at temperatures above its atmospheric boiling point. The containers may range in size from a small aerosol like that in this photograph to a much larger container like this propane tank.

In the case of the propane tank, there was direct flame impingement on the tank which caused the propane liquid inside the tank to boil. The boiling liquid expands as it turns to a vapour and eventually the vapour pressure inside the container is greater than the container can withstand, and it ruptures. The key to preventing a BLEVE is the application of water to cool the tank.

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A major consideration for the fire inspector is the potential for fire growth within a structure. If a fire starts, are there measures in place to stop the fire spread? The growth of a fire is influenced by the construction of the building and the contents within the building. It is obvious from this photograph, if fire separations and fire compartments were in place, they did not prevent the spread of this fire.

Rapid fire growth has been responsible for many fires involving loss of life. The Station nightclub fire that occurred in 2003, in West Warwick, Rhode Island, killed 100 people. The fire was caused by pyrotechnics which ignited flammable acoustic foam on the walls and ceilings surrounding the stage. The blaze reached flashover within one minute, causing all combustible materials to burn which created intense black smoke. Video footage of the fire showed its ignition, rapid growth, and the billowing smoke that quickly made escape impossible. Blocked exits further exacerbated the situation. Many of the contributing factors to this tragic fire could have been avoided through proper fire inspections.

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Building construction is a major factor that can contribute to fire growth that you should consider when doing your inspection. Renovations in particular can hide a number of sins and create concealed spaces where fires can start, spread, and be difficult for firefighters to access. Often do-it- yourself or even professional renovations can create fire hazards like improper electrical installations or terminations and heating ducts and vents to close to combustibles as shown it these photos.

In this case, the fire resulted from inadequate clearance from combustibles for this solid fuel chimney. Investigators recreated pre-fire conditions by placing the chimney back in its original location which clearly shows the lack of clearance.
In this case, a short circuit in electrical wiring in a concealed space, caused a significant amount of damage to this recently renovated building.

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Building contents and furnishings is also a major factor that can contribute to fire growth that you should consider when doing your inspection. In the case of the fire in this photo, the fire investigator concluded that the fire cause was officially undetermined, but he suspected the fire originated in the concealed space above the ceiling in one of the units. A polyurethane foam filled chair, and two love seats were located directly under the area of heaviest burning. The investigator believes that the fire burned through the ceiling and dropped down onto the polyurethane upholstered furniture which in turn ignited and contributed greatly to the heat release rate of the fire and the total destruction of the five units in this strip mall.

Most new furniture is made of synthetic materials which can produce two, three, or more, times the heat energy that older furnishing made of natural products like cotton and kapok produced.

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The chemical composition and density of the furnishings is another factor that must be considered. The cotton fiber construction of the mattress at the top of the photo is high density and the composition of the material limits the energy release and speed of the fire. The cotton mattress can be expected to burn for a long time, often hours depending on ventilation, and produce a peak heat release rate of under 1 Mega Watt.

The mattress burning freely is low-density polyurethane foam with a cotton cover. This produces a much higher heat release rate and more rapid fire spread. The peak heat released from this mattress can be expected to be 800 kilowatts to **2.8 mega watts**. Total consumption of the mattress took less than ten minutes.

This is a good example of the difference between heritage fuels and the fuels of today.

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In this Chapter we discussed:

- The chemistry of fire
- That fire is a rapid chemical process that produces heat and light
- We talked about the characteristics of a flame
- The five different types of energy being chemical, mechanical, electrical, nuclear and light
- Fire requires fuel, heat, oxygen, and a chemical chain reaction to sustain combustion as described by the fire tetrahedron
- Fire produces smoke and unburned gases which can sometimes ignite, occasionally with explosive force
- Almost all the gases produced by the combustion process are toxic to humans including carbon monoxide, hydrogen cyanide, and phosgene.
- Fire grows and spreads by three primary mechanisms conduction, convection, and radiation.

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In this Chapter we discussed:

- Conduction is transfer of heat through solids
- Convection transfers heat through air or liquids
- Radiation is heat transfer through electromagnetic waves
- The four basic methods used to extinguish a fire are cooling, oxygen exclusion, fuel removal, and interrupting the chemical chain reaction
- There are 5 classes of fire A,B,C,D, and K
- The characteristics of various fuels including solids, liquids, and gases.
- The phases of fire development which include ignition, growth, fully developed and decay
- Flameover or rollover, is the flaming ignition of hot gases that are layered at the ceiling level

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In this Chapter we discussed:

- Flashover occurs when all the contents ignite at once. Flashover can be described as the difference between “a fire in a room and a room on fire”.
- The common dangers during the decay phase are rekindle of the fire and potential for a backdraft or smoke explosion

- Hot gases and flames are lighter than air, so they rise through the principal of convection
- When the flame and hot gases reach the ceiling, they spread out horizontally
- Downward flame spread is usually caused by falling debris or by radiation
- Flash point is the lowest temperature at which an ignitable liquid gives off enough vapour for a fire to flash across the surface of the liquid
- The fire point is usually a few degrees higher than the flash point
- Gaseous fuels can be the most dangerous of all fuel types because they are already in the state required for ignition.
- UEL stands for “upper explosive limit” and LEL stands for “lower explosive limit”.

And

- Modern furnishings made from synthetics such as polyurethane foam burn much faster and with more energy than natural products like cotton and kapok.