The Fire Hazard

Fire can create and destroy. From ancient times, fire has been a tool that generated the energy which allowed humanity to warm themselves and their surroundings, illuminate the darkness and prepare food. More recently, the energy generated by fire powers transportation, manufacturing and research. While fire is indispensable to civilized society, if not properly controlled, it can kill and destroy.

The same features that make modern life possible can also cause or contribute to unwanted fires if not controlled. The top two causes of fires in homes are cooking equipment and heating equipment. In buildings other than homes, cooking equipment, electrical distribution equipment and heating equipment are the leading causes of accidental fires. Arson is the leading cause of fire in buildings other than homes, but arson is not a major cause of fires in homes.
Once a fire begins, it can spread on the items that are used to construct a building or are kept inside it. Many items that are contained inside of buildings are flammable. While flammability tests are used to assure that many types of items that are commonly found inside of buildings are not too hazardous, it is not possible for them to be completely fire proof.

Therefore, all buildings have fire hazards within them. The key is to design ways to protect people and property if fires occur. This is what fire protection engineers do.

Fire Ignition

Fire is simply a chemical reaction between a fuel and oxygen in the air. Like all chemical reactions, fire requires “activation energy” to get the reaction started. This activation energy is typically provided from a heat source, like a spark from defective wiring, failure of heating equipment, or a dropped cigarette.
Additionally, fuel must be in a form that supports combustion to burn. With the exception of smoldering combustion (the type of combustion associated with burning charcoal or the glowing portion of a lit cigarette), fuel must be vaporized before it can burn. Gaseous fuels, like natural gas, only require a relatively small activation energy to ignite.

Liquid fuels must be heated to a temperature where they release a sufficient amount of vapors to support combustion. The temperature at which a liquid fuel releases a sufficient amount of vapor to support combustion is called the “flash point.” The “flash point” is typically lower than the boiling point of the liquid.

For some liquid fuels, such as gasoline, the flash point is below normal room temperature, which means that the fuel could be ignited when it is at a normal temperature. However, other fuels have flash points that are above normal temperatures, so they require heating before they can be ignited. Motor oil is an example of such a fuel. Fuels that have flash points above normal temperature could also be ignited if they were atomized in a spray.

Solid fuels must also be heated to a temperature that is high enough that sufficient vapors are released to support combustion. This can occur in one of two ways: the fuel can be heated so that it first melts and then vaporizes, or such that the fuel decomposes and releases vapors.

Whether a fuel melts or decomposes when it is heated depends upon the type of fuel. Some plastics melt and then vaporize as they are heated. The vaporized fuel is simply
the original substance in a gaseous form. Fuels such as wood will decompose and release vapors that are chemically different from the original solid.

Heat Transfer

Fires release energy as they burn. The energy can heat the air and other items near the fire in three ways: conduction, convection and radiation. Conduction is the transfer of heat through solids. Pots and pans work through conduction, as heat that is applied to the bottom of a pot or pan is transferred through the pot or pan to the food inside it through conduction.

Convection is the transfer of heat from a gas or a liquid to a solid. Most of the energy released from a fire heats the flame and smoke. If the flame or smoke comes into contact with other items, these items are heated through convection. Because heated
air is less dense ("lighter") than normal air, heated air rises, just as oil, which is less dense than water, floats. Convection is the primary mode of heat transfer from fires that are smaller than about one foot in size.

Radiation is the transfer of heat through electro-magnetic waves. These electro-magnetic waves are transferred in the same way as light. As with light, electro-magnetic waves travel in a straight line until they reach an object. Radiation is the primary mode of heat transfer from fires that are larger than about one foot in size.

A campfire or a fire in a fireplace can be used to illustrate these types of heat transfer. If a hand were placed above the fire, heating would be from hot gasses and convection. Placing a hand beside the fire would result in heating from radiation. Touching the ground near the fire would result in heating by conduction.
Fire Growth

Whether a fire that has started will grow or die out depends upon the quantity of fuel that is available, the type of fuel that is available, the configuration of the fuel, and how much of the energy that is released is able to heat the available fuel such that it is able to support combustion. The quantity of fuel is important because once all of the fuel is consumed, the fire will not be able to sustain itself any longer.

The ease at which a fuel is ignited and the ease at which fire will spread on the fuel are closely related, in that fire spread is essentially continuous ignition of a fuel. The fuel surface that is adjacent to the flame is heated and ignites as the fire spreads.

The type of fuel is important because some fuels require more energy to vaporize and ignite than others. A fuel that is a gas at room temperature will ignite more easily than a fuel that is a solid. Fires will spread more quickly on fuels that require less energy to vaporize and ignite.

As every Boy Scout is taught, the configuration of the fuel will affect how easy it is for fire to grow and spread. Fuels that are finely divided will ignite more easily than thicker fuels. For example, it is much easier for fire to spread on a wooden match than a wooden log. This is because the match has less mass than the log does, and therefore it takes less energy to heat it to the point where it releases flammable vapors.

How much of the heat that is released by the fire is able to heat adjacent fuel is also an important factor in whether or not a fire will spread. As a fire burns, energy is released from the area of flaming as radiation and convection. If this energy is lost to the
surroundings, then it is not available to support fire spread. However, if the energy is able to heat fuel that is not burning, it will assist with fire spread. An example of this is a fire in a fireplace. It is almost impossible to ignite a single wood log. However, if there are multiple logs placed in the fireplace, it is much easier to ignite them and for the fire to grow. This is because heat that is released from one log might heat one of the other logs instead of being going up the chimney or into the adjacent room.

Smoke

Most fire deaths and injuries are not caused by heat or burns, but rather from smoke. Smoke is mostly air, although it also contains substances that are created by fire, such as carbon dioxide, water vapor, soot, and carbon monoxide. Carbon monoxide is the primary cause of death and injury due to fire. Smoke can also make it more difficult to see due to irritation of the eyes or obscuration of vision.

How dangerous the smoke is mostly depends upon the ventilation that is available to the fuel. If a fire has an ample supply of oxygen, then the amount of carbon monoxide
that is present in the smoke will be minimal. Examples of cases where a fire would have sufficient oxygen would be a fire that is burning in the open or a fire that involves most or all of a room.

If the fire involves most or all of a room, then significant quantities of carbon monoxide can be produced due to the limited availability of oxygen. Thick, black smoke or flames emanating from a building fire are usually signs that these is limited oxygen available to the fire and that the smoke contains a significant amount of carbon monoxide.

**Fire Temperatures**

The most common form of fire is what is caused a “diffusion flame.” Diffusion flames exist in cases where fuel and air are not mixed before they burn. Candle flames and fires in fireplaces are examples of diffusion flames.
The temperatures of diffusion flames are generally in the range of 1500 – 1700 degrees Fahrenheit if the fire is in the open. The temperature above the flames quickly decreases as the height above the fire increases.

If the fuel and air are mixed before they are ignited, as is the case with torches, much higher flame temperatures are possible. However, premixed flames are rare in accidental fires.

If the fire is confined, such as because it is in a room, higher temperatures are possible. This is because radiation and convection from the flame are not lost – the energy is absorbed by smoke in the room and the room itself. Temperatures as high as 2500 degrees are possible for fires that are inside rooms, although this temperature is rarely seen in building fires. Typically the fire temperatures are lower.

A common misconception when a structure collapses in a fire is that the structure melted at these temperatures. While steel melts at a temperature of approximately 2500 degrees, and this temperature is possible in fires, what typically causes building collapse is the weakening of the steel or concrete structure. This weakening can occur at temperatures as low as 1200 degrees. It should be noted that it takes time for the structure to heat to these temperatures in a fire, just like it takes time for a roast to heat when it is placed in the oven.
Flashover

If sufficient fuel is available, a fire in a room will typically grow. As the fire grows, it heats portions of the fuel that are not yet burning and other objects via conduction and radiation. Eventually, if there are no actions taken to extinguish the fire, it will become hot enough to simultaneously ignite all of the items in the room that are not yet burning. This is called “flashover.”

When a flashover occurs, the fire rapidly grows to a maximum size. At flashover, the entire room fills with flame. After flashover, fire can usually be seen projecting from doors and windows.

When flashover occurs, the ability for people still inside the fire area to survive decreases significantly. This is because the temperature in the room can increase to as high as 2500 degrees. Additionally, once flashover occurs, the concentration of carbon monoxide in the smoke can increase to levels that can overcome people within seconds, and the smoke can become so black as to reduce visibility to almost zero.

Because the smoke can travel to areas of the building that are remote from the fire area, flashover can also affect people that are in the same building as the fire, but hundreds of feet away.

Example of Fire Growth

The following example shows how a fire could grow inside a building. It is presented to illustrate how a fire could grow. Actual building fires may be similar to or significantly different from this example.
A cigarette is carelessly dropped between the cushions of a sofa as the occupant of a home leaves to run errands. There are no other occupants at home. The fire smolders between the cushions for several minutes, producing a small amount of smoke. This smoke collects at the ceiling, and is sufficient to activate smoke detectors that are located in the home. As the fire smolders, the size does not significantly increase.

Eventually, flames are produced and the amount of smoke produced increases. The smoke continues to collect in the upper portion of the room, but as more smoke is produced the interface between the smoke and the cool air below it decreases and the smoke that has collected gets hotter. This is why people are taught to stay low in smoke – because the air near the floor contains much less smoke than near the ceiling.

The flames from the fire heat portions of the sofa that are close to the fire, which causes the fire to grow more quickly. It is at this time that residential sprinklers, if installed in the home, would activate.

Since there are no actions taken to extinguish the fire, it continues to grow until it involves the entire sofa. Radiation from the fire would heat adjacent objects, such as carpeting, tables, and other furniture. Additionally, the smoke that has collected near the ceiling continues to get hotter, and it also radiates heat to items in the room that are not yet burning. Eventually, all of the items in the room that are not burning are ignited, and flashover occurs. If there were any people in the room, it would be very unlikely that they would survive following flashover.

Following flashover, the heat in the room causes the glass in the windows to break. People outside of the building can see thick, dark smoke and flames projecting from
windows. Smoke fills other areas of the home. If there were people in other areas of the home, their chances of survival would rapidly decrease.

As the fire continues to grow, it spreads to other portions of the building. The flames that project from the windows ignite siding, and eventually break windows that are above the fire. The walls and floors in the home are also breached allowing the fire to spread to adjacent rooms.