# Behaviour of Materials in Fires

## Fire Safety

Textiles, carpets and all other products made from fibers will burn if subjected to the right conditions. Depending on the physical size, orientation and chemical nature of the fibers, differences may occur in such important fire characteristics as ease of ignition, rate of flame spread, and heat release.

## Factors Affecting Fiber Flammability

How easily does a fire start, and how rapidly will it grow? One property of a material that is central to these questions is its surface to mass ratio. Items that have a large surface area for a small amount of material tend to ignite easier and burn faster. Thus, a twig is easier to ignite than a log. A heavy, tightly woven fabric is more resistant to ignition than a light, sheer fabric made of the same material. Igniting a fabric edge is usually easier than igniting a flat surface — fabrics with raised surface fibers, such as fleeces or terrys. Their raised fibers have a very large exposed surface and they can ignite easily with a very rapid flash of fire across the fabric surface. In some cases, these surface flashes may cause the entire fabric to burn, but in others the surface flash may not produce enough heat to ignite the base fabric.

Another important characteristic in determining the ease of ignition of an item is its thermoplasticity. Many synthetic fibers are thermoplastic; that is, they melt when heated. Fabrics made from these fibers tend to melt and shrink away from small flames. Thus, they are usually more difficult to ignite with a match or cigarette lighter. Non-thermoplastic fibers, such as cotton or rayon, do not melt and may be more susceptible to ignition by small flames. Mixtures of thermoplastic and non-thermoplastic fibers, such as cotton / polyester blends, tend to behave more like non-thermoplastics since the non-melting cotton can prevent the molten polyester from withdrawing from the flame.
Garments that are loose and flowing may present a greater risk of ignition because they are more apt to come in contact with a flame. If they are made of sheer, non-thermoplastic fabrics, they may present a real danger to the wearer.
The chemical nature of a fiber can also affect its burning characteristics in ways not related to thermoplasticity. In general, the more carbon and hydrogen that is present in the chemical structure, the more heat the material will give off when it burns. Thus many synthetics have a potential to give off more heat when they burn than an equivalent amount of a cellulosic material. In addition, to become involved in a flaming fire, the polymeric material which makes up the fiber must break down into small volatile fragments. Fibers from polymers with very high thermal stability, such as aramids and PBI, exhibit greatly reduced flammability. Other fibers, such as the modacrylics and FR (flame resistant) polyesters, contain chemical structures which can act as flame retardants. These inherent flame retardants can be very effective in preventing fabrics from becoming involved in fires from small ignition sources. However, they are frequently overwhelmed in larger fires, such as a burning building.

The orientation of an item can also influence its flammability. An item in a vertical configuration will usually burn faster than the same item in a horizontal position. This is one reason that curtains, drapes and wall coverings may become involved in fires. Similarly, if a carpet is ignited, the flame usually does not spread rapidly, partly due to the horizontal orientation. However, if an item which was designed to function safely as a floor covering is misused as a wall covering, it may present an unusual fire hazard because of the combination of a raised surface and vertical orientation.

## Smoke and Toxic Gasses from Fiber Product Fires

Unlike garment fires, where the primary hazard is heat release, building fires can generate both heat and toxic gasses. Often the primary human hazard is smoke and toxic gases. When cellulosic materials, either textiles or wood products, are burned the only gases formed are CO, (carbon monoxide), $CO_2$ (carbon dioxide) and $H_2O$ (water). Although carbon dioxide can cause suffocation, the dangerous material is carbon monoxide, which poisons the bloodstream in much the same way as cyanide. The relative amounts of CO and $CO_2$ produced in a fire depend primarily on the amount of oxygen present. Well ventilated fires produce mostly $CO_2$. However, in well-developed building fires, there is almost always a shortage of oxygen and larger amounts of the much more toxic CO are produced.
Some synthetic fibers, such as polyester and polyolefins, also produce only these three gases when burned. Other fibers, such as polyamides (nylon) or acrylics, contain nitrogen and are thus theoretically capable of producing other toxic gases during burning. While small-scale tests of nitrogen-containing textiles frequently show the evolution of toxic materials, such as HCN (hydrogen cyanide), these gases are probably not a major factor in real fire situations. Work at the Center for Fire Research of the U.S. National Institute of Standards and Technology has shown that the primary toxicant in most structural fires is CO, regardless of the presence of a wide variety of synthetic fiber products. Thus most common synthetic fibers usually behave no better, nor worse, than other organic materials in large fires.

## Burning Melts from Synthetic Fibers

As noted above, many synthetic fibers melt when exposed to heat. In some cases, this can be an advantage in preventing ignition by small flames. Also, as thermoplastic fabrics burn, pieces of the flaming material may melt and drop away, in some cases taking the fire with it and the fabric self-extinguishes. This effect can reduce the risk of serious injury in clothing fires.