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Control of Ignition in Building Materials

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Abstract

Strategies are discussed for avoiding the dangers of the ignition process in fires.

Introduction

If ignition can be prevented, there will be no fire. This, then, is the line of first defence against fire in buildings. Although the National Building Code (NBC)[1] contains few restrictions regarding ignition of building materials, the National Fire Code (NFC)[2] does place limitations on the placement of textiles such as carpets, furniture, and drapery materials. Flammable liquids and gases are special cases and there are provisions for controlling their location. In general, however, it is difficult to predict where combustible materials might be located, particularly in large buildings.

Even buildings constructed of non-combustible materials will almost without exception contain materials that burn under certain circumstances. On the other hand, materials that are designated combustible according to tests may be of negligible significance in fires.

Wood is a good example of a common material for which fire performance is difficult to predict. It ignites if its surface reaches about 300°C in the presence of a flame or perhaps 400-500°C in its absence. It may also ignite, however, at much lower temperatures if the time of exposure to heat is longer. Charring, a process related to ignition, has been recorded when the temperature was not much above 100°C. Table 1 defines the terms that are commonly used to describe the ignition process and its various aspects.

Table 1. Definitions

Ignition	The initiation of sustained combustion.
Combustibility	The propensity of a material to burn. It is tested[3] by placing a small sample of material in a furnace (typically at 750°C) and monitoring any increase in temperature. A material des defined as combustible if it raises the temperature of the furnace interior by 30 C deg or more when it burns. Concrete, steel and gypsum are non-combustible; most other materials are combustible.
Ignitability	The ease with which a material can reach the point of combustion in a specified test regime. The relative ingnitability of one material to that of others has meaning only for a specified test condition and is not applicable to all test conditions or even to real fire.
Ignition	The lowest temperature at which a sample of material will ignite spontaneously

temperature (auto-ignition)	without a spark or flame. This value is often used to assess whether a material could have been a source of ignition. For liquids and gases it is a reasonably well established characteristic of a substance, but it is less well defined for solids.
Flash point	The temperature at which a liquid or solid ignites and sustains combustion when a small flame is brought near the sample surface. There are several methods of measuring flash point, but they are not generally reliable enough to give the same results for the same material. Flash point is used most commonly to describe the hazard associated with storage of liquids; a flash point of 0°C, for example, indicates that the material will ignite in the presence of a small flame even when the temperature of the liquid is 0°C.
Lower explosive limit	The minimum concentration of a gas in air at which explosion or flame propagation occurs when a heat source such as a spark is applied. This term is employed in the NFC in relation to ventilation systems in which combustible gases are expected to be a problem; for example, in paint spraying booths, dip tanks for finishing operations, and other special processes involving flammable liquids with substantial vapour pressures.

Causes of Ignition

Flammable materials may ignite in many ways, some familiar, some less so. Knowledge of the most important ignition scenarios is essential for designers seeking to reduce the likelihood of fire in buildings. The common element is heat transfer. Heat may be transferred by radiation through space, by conduction, upon direct contact with a heat source, or by convection (where air, or other heated fluid, moves to carry heat from source to sample). All ignitions are caused by a version of heat transfer, although other factors may influence them.

Flames

The most common ignition source is flame. A match flame transfers heat primarily by convection and may be simply represented in laboratory testing. Larger flames, 0.5 m high or more, transfer heat primarily by radiative transfer and may ignite objects without coming into direct contact with them. The larger the flame the more probable radiative ignition becomes.

Hot Surfaces

Hot surfaces can also cause fire. A heated metal block can transfer sufficient heat (by conduction) to raise the temperature of some materials above their ignition temperature. The most common case of ignition by this means is probably the kitchen fire in which a towel is ignited by contact with a cooking element.

Sparks

Sparks generate very high temperatures in a very small space, but except when flammable gas mixtures are involved it is rare that a spark will cause ignition in the absence of other factors.

Exposure Time

This can be critical. An intense heat source may cause a fire in a very short time, but so also may a much less intense heat source over a longer period. Thus fire in a waste paper basket may ignite a sofa very quickly, but a carelessly dropped cigarette may also cause ignition given more time.

Configuration

It is difficult to ignite a sample in intimate contact with an efficient heat sink such as the metal hull of a ship in contact with the sea. At the other extreme is an insulated material that may not be able to dissipate heat sufficiently fast to prevent a temperature rise high enough to cause ignition. Thus spontaneous combustion can occur by mild self-heating caused by very slow oxidation (as in coal dust) or the effects of biochemical attack (as in damp hay).

Secondary Ignition

The propagation of fire beyond the site of primary ignition will almost inevitably involve secondary ignition of surrounding materials. Now the ignition source is most often larger than before and may present an exposure different from the original. A lit match may not set a room on fire, but if it ignites the contents of a waste paper basket the room may become vulnerable.

When a fire has generated sufficient heat to make the upper reaches of a room very hot, there can eventually be sufficient radiation from this hot layer to ignite essentially all of the remaining unburnt materials in the area. This is termed flashover. Survival in the room would not now be possible.

Measurement of Ignition

There are no general procedures for assessing ignition in use in Canada, although tests exist for specific products. In recognition of the common fire scenario[4] in which a smoker drops a cigarette on a mattress, the Federal Hazardous Products Act[5] calls up a test in which a mattress is actually exposed to a burning cigarette. Cigarettes also cause many carpets to burn; the same Act has a test procedure simulating this event as well.

The problem with such tests is that conditions in the real world are difficult if not impossible to simulate in the laboratory. With mattress fires, for example, the effect of bedding can be profound. In the carpet test the ignition source is a small methenamine pill that burns in a way similar but not identical to that of a cigarette; the hot zone in a cigarette moves, but that of the pill does not. Yet these tests are probably the closest simulations of fire scenarios of any tests available.

The results of tests related to other fire properties can provide useful information about the tendency of a material to ignite. In Canada the surface flame spread test, or tunnel test,[6] is designed to rate materials by their propensity to spread flame or generate smoke. This test also gives information on ignitability. A material with a high flame-spread rating by this test is often easy to ignite. No assurance can be given, however, that the relationship will always hold. The tunnel test results should therefore be used with considerable caution in predicting the ignition behaviour of materials.

Consider, for example, how to rate a large wall hanging of textile fabric. A tunnel test may be of little value since the test uses long, thin samples (7.0 m by 0.66 m) attached horizontally to the roof of a test tunnel. A large flame is applied and the time taken for it to pass down the tunnel is measured. The conditions of burning are most unlike those to he expected of a textile hanging on a wall and probably represent a far less severe condition than the most likely fire scenario.

Laboratory versus Scenario Testing

The majority of tests are tied to the definitions of ignition-related characteristics (for example, combustibility, flash point, and lower explosive limit, Table 1). Often it is not possible to identify all the factors involved in practical ignitions. Regulators rely mainly on the results of test procedures that simulate the actual application. These demonstrations, however, can be far more expensive than the more controlled, laboratory test procedures and they are often less informative.

Fire behaviour is influenced by so many uncontrolled variables that prediction is extremely difficult. A useful technique is the worst case scenario. As serious a set of circumstances as can be envisaged is selected and material performance is assessed under those conditions. If the result is satisfactory, there is a high probability that the material will perform well in less severe fire conditions. The technique, however, encourages expensive overdesign that results in unnecessary use of highly fire-resistant materials.

Alternative Strategies

In addition to controlling ignition by material selection, the designer may use active or passive fire protection measures, or both.

Active Fire Protection

Active techniques sense a primary ignition either manually or by automatic means to evoke a response. Automatic sprinkler systems are the most common. Where they are not desirable, substances that quench flames chemically may he used, for example, halon gases or dry powders. Carbon dioxide is also effective, displacing the oxygen necessary to sustain fire.

Passive Fire Protection

Passive techniques rely on built-in fire protection measures and do not require activation. Fire-resistant compartmentation of rooms, for example, is an important element of the fire protection of buildings.[7]

Protective coatings. A very simple technique for protecting combustible material from unwanted ignition is to cover the surface with a non-combustible protection. Metal sheathing is used to protect some combustible insulation products. The wall closest to a wood stove installation should be protected from thermal radiation by a suitable non-combustible cover sheet. A similar form of protection is available for a wide variety of surfaces by applying a chemical coating (intumescent coating) like a paint; it has the useful property of expanding and hardening when exposed to heat, thus presenting a fire-resistant and heat-insulating barrier. This technique is used to protect combustible walls and to afford useful fire resistance to structural columns and non-combustible surfaces made of steel.

Fire retardants. The addition of chemicals to combustible materials can control fire behaviour. Fire retardants may simply absorb heat, often by causing the liberation of steam from chemicals that contain water; alumina is often used in this way. Others may form a char through which heat has difficulty passing; many fire retardants containing phosphorus work in this manner. They may enhance melting at a low temperature, thus causing a material to flow away from a heat source; many additives to synthetic polymers have this effect. They may evolve a flame-inhibiting gas; poly(vinyl chloride) is a polymer containing chlorine that on heating liberates hydrogen chloride, a gas that inhibits combustion. Lastly, on heating they may assist the transformation of the material to a less flammable material, usually by cross-linking the polymer chains (from which many materials are made) into a hard, thermally resistant solid.

Material location. Unwanted ignitions are more than an engineering problem. Their control is a social problem too. Attitudes towards fire differ widely from one country to another. Canada, with one of the world's worst fire loss records, could with advantage adopt some of the principles of fire protection used in other countries. Responsibility for the location of combustible materials is properly that of the building occupants, owners and users, since they are the prime risk takers. In some countries this responsibility is a civic duty, and any dereliction is a punishable offence; the owner of a building that suffers a fire may be prosecuted.

Conclusion

Ignition prevention remains the primary means of avoiding fires. While no single method of evaluating materials is specifically directed to ignitability, the common fire test methods often provide useful indication of successful ignition control.

The damage caused by unwanted ignition can be minimized by appropriate choice and use of materials. Where caution outweighs cost, protection against the worst of all conceivable potential ignition cases should be considered. If material choice has been exhausted as a method of control, active and passive fire protection measures must be considered. The avoidance of fire is a social responsibility, and the cooperation of building occupants is the most powerful asset a fire protection strategy can have.

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