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Please note

The possible rate and extent of fire spread throughout a building once a fire has been initiated are of prime importance in fire protection. They are related to the characteristics of the individual building and its parts and can be adjusted over a wide range by the designer. The principal means at his disposal in limiting the extent of the fire is through the use of compartmentation (see CBD's **11** and **33**), by which various parts of the building, including exits, are separated by constructions having suitable fire endurance. The designer may also have to consider how best to reduce the rate at which fire will develop and spread within a compartment. This is in part related to the flame spread characteristics of exposed surfaces of enclosing construction, and is the subject of this Digest.

The nature of fire and the way it may be expected to develop within a compartment have been discussed in **CBD 31**. Fire spread is influenced by a number of factors that vary from one case to another, but experience has shown that it can be markedly influenced by the nature of the interior linings. The flammability of the materials used as interior linings often determines both the likelihood (ease of ignition) and rate of development of a fire within a compartment.

The speed with which a lining material spreads flame is frequently a major factor in determining the size of the fire that will confront a fire department upon its arrival. If lining materials are chosen that have a low rate of flame spread, the rate of development of fire in a compartment will be reduced, provided the contents are not highly flammable. If the rate of development is slow enough it may even be possible, provided there is a prompt alarm, for the fire department to extinguish a fire before it bas reached sizable dimensions within a compartment.

Slow development generally also improves the chances of escape of the occupants of the area in which the fire originates. Fires often develop slowly, but when flammable interior linings are involved they tend to speed up the development so that the flashover point is reached more rapidly. Flashover may be said to have taken place when the whole volume of a room is enveloped by flame. At this stage, survival of occupants is no longer possible as there is a rapid rise in temperature, often of the order of several hundred degrees.

Corridors, stairways and other escape routes that can be used during the early stages of a fire are also to be regarded as compartments, although they usually differ from normal occupied spaces in that they have no furnishings. Here the spread of fire is more directly dependent upon the flammability of the surface materials, and their role as escape routes merits special consideration.

Recognition of the hazard of rapid flame spread and the contribution made by flammable lining materials is a relatively recent development. Studies in this field were initiated as a result of several large fires about 1940 in which many lives were lost in the United States. Since that time quite extensive work bas been done on the development of test procedures for comparing the surface burning characteristics of building materials. Many building codes, including the National Building Code of Canada, now recognize the flame spread hazard and contain requirements designed to limit it.

Flame Spread Tests

Although the concept of flame spread is quite simple, the real situation is not. Consequently it is not an easy matter to develop a standard test to evaluate the role of interior lings in actual situations. Three flame spread tests developed on this continent enjoy varying degrees of recognition; colloquially they are known as the large tunnel, radiant panel, and small tunnel tests. The large tunnel test was developed by Underwriters' Laboratories Inc., and is at present the only one recognized by the National Building Code of Canada. This test method is described in ASTM Standard E84-61. The radiant panel test, detailed in ASTM Standard E162-60T, was developed later at the U.S. National Bureau of Standards. The third, the small tunnel test, was developed at the U.S. Forest Products Laboratories, and a standard is now being prepared by ASTM. A brief description of each is given below.

ASTM E84-61 Test for Surface Burning Characteristics of Building Materials
This is the large tunnel test, which involves the use of large specimens. The combustion chamber is approximately 25 feet long, 17½ inches wide and 12 inches deep. Two gas burners deliver gas flames upwards at one end against the surface of the test specimen, which forms the roof of the tunnel. The igniting fire is assumed to extend 5½ feet from the burner end of the combustion chamber. Measurements are made of the speed of flame travel, the density of smoke and the temperature of the outgoing gases.

The essential. feature of this test method is that following adjustment of the test equipment, flame will spread 19½ feet along select grade red oak flooring in 5½ minutes. This condition is considered to represent a classification of 100, and asbestos-cement board is assigned a rating of zero; together they provide the fixed points on the scale of rating.

The flame spread classification is determined as follows:

1. For materials on which the flame spreads 19½ feet in 5½ minutes or less, the classification shall be 100 times 5½ minutes, divided by the time (in minutes) in which the flame spreads 19½ feet.

2. For materials on which the flame spreads 19½ feet in more than 5½ minutes but not more than 10 minutes, the classification shall be 100 times 5½ minutes divided by the time (in minutes) that the flame spreads 1932 feet plus one half the difference between this result and 100.

3. For materials on which the flame spreads only part way, then ceases to continue or even recedes, the classification shall be 100 times the distance (in feet) from the igniting flame to the extreme flame travel on the sample divided by 19½ feet.

The test results for fuel contributed and smoke are plotted, using the same coordinates, and comparison of the areas under the respective curves establishes a numerical classification by which the performance of the material can be compared with that of asbestos-cement board and select-grade red oak flooring.

ASTM E162-60T Test for Surface Flammability of Materials Using a Radiant Heat Energy Source
This method of measuring surface flammability of materials employs a radiant heat source consisting of a 12- by 18-inch panel in front of which an inclined 6 by 18-inch specimen of the

material to be tested is placed. The specimen is oriented so that ignition is forced near its upper edge and the flame front progresses downward.

The factor derived from the rate of progress of the flame front (ignition properties) and another relating to the rate of heat liberation by the material under test are combined to provide a flame spread index. Provision is also made for measuring the smoke evolved during tests. In general, the classification of materials using this test method corresponds to that obtained with the large tunnel test.

Small Tunnel Test

The equipment includes three main parts, a fire box, an 8-foot specimen combustion chamber, and a hood and stack. The fire box contains a T-head gas burner burning gas at the rate of 3400 Btu per minute. The specimen combustion chamber bas insulated walls, floor, and cover, and a horizontal partitioning hot plate located a few inches above the bottom of the chamber. The hot plate bas a number of holes of varying diameter along the full length of one side. A specimen 13¾ inches wide by 8 feet long is secured to the under side of the insulated cover, which is placed so that the short dimension of the specimen slopes upward at a 30-degree angle and its lower edge is slightly above the side of the hot plate. A small pilot burner is located under the sloping edge of the specimen.

In a typical test the main gas burner produces hot gases that heat the under side of the hot plate and flow through the holes along the edge of the plate. The specimen is thus subjected to both hot gases and radiant heat from the hot plate. When the specimen is sufficiently heated by this exposure, it is ignited by the pilot burner. The rate of flame spread along the specimen is observed through ports in the tunnel, and temperatures and smoke density are recorded in the flue.

Flame spread, fuel contributed and smoke density are reported as numerical ratings that can be related to red oak at 100 and asbestos cement board at 0. It normally takes 18.4 minutes for red oak to burn to the end, so that the test duration is that value or less.

National Building Code Flame Spread Requirements

In the 1960 revision of the National Building Code of Canada detailed flame spread requirements appeared for the first time. General considerations leading to the introduction of these requirements were as follows:

1. In corridors of all public buildings every effort should be made to render them tenable for as long as possible in the event of fire. Sharply limiting the flammability of lining materials, particularly on the ceiling, should assist in prolonging a corridor's tenability.

2. In areas used for public assembly particularly where care bas been taken to reduce combustible content, it would be logical to exclude highly flammable interior lining such places as auditoria and theatres is essential to avoid panic in the event of fire.

3. Care should be exercised in the selection of lining materials for occupancies where people are restrained (e.g., penal institutions) and where people are infirm (e.g., hospitals). Every effort should be made to retard the development of fire because greater lengths of time are often necessary to evacuate the occupants safely.

4. Consideration should also be given to residential occupancies such as hotels where large numbers of people may be sleeping. Again it seems desirable to restrict to some degree the flammability of lining materials.

The National Building Code of Canada, 1960, established the following flame spread requirements based on ratings obtained from ASTM E84 tunnel tests.

Corridors. The flame spread on ceilings shall be less than 25 and on walls less than 75. An alternate provision allows a rating of up to 150 on the lower half of walls if that of the -upper half is not greater than 25. If sprinklers are installed a flame spread of up to 150 on all surfaces is acceptable.

Assembly, Institutional and Residential Occupancies. All interior finishes shall have a flame spread rating of less than 150.

Flame Spread Ratings

The majority of tests using the ASTM E84 method have, been performed by the American and Canadian Underwriters' Laboratories on proprietary materials generally having ratings of less than 75. Ratings from these tests are found in the Building Materials List, Underwriters' Laboratories Inc., and in the List of Inspected Appliances, Equipment and Materials, Underwriters' Laboratories of Canada. Only a limited number of tests, the majority on untreated lumber, have been performed on other than proprietary materials.

The twelfth edition of the NFPA Handbook (1962) in Table 8-143 lists flame spread ratings for a number of different materials all based on tunnel test results. Some ratings taken from this table are given below. Untreated lumber varies from 60 to 215, and, when treated, varies from 10 to 60. Untreated plywood varies from 100 for Douglas fir to 260 for a walnut-faced plywood. Treated Douglas plywood varies from 15 to 60, with about the same ratings for various facings on a Douglas fir core. Fire retardant coatings applied to Douglas fir can reduce its flame spread from 100 to from 10 to 60, and when it is applied to untreated cellulose board surfaces can reduce flame spread from 225 to from 10 to 60. It can thus be seen that certain fire retardant treatments, including surface coatings, will modify the flame spread characteristics of cellulosic boards to such an extent that they can have a flame spread of less than 25. Plaster wall board (½ to 5/8-inch gypsum core board, surfaced both sides with paper) has a rating of 10 to 15.

Information is now being developed for use with the National Building Code of Canada on flame spread ratings for common materials that can be adequately identified by class or description. It will still be necessary to establish ratings by tests, as required for other materials including those that are proprietary.

General Comments

When discussing the flammability of building materials reference is usually made to the term "flame spread." The "Tentative Definitions of Terms Relating to Fire Tests of Building Construction and Materials," prepared by ASTM defines flame spread as follows: "Flaming combustion along a surface; not to be confused with flame transfer by air currents." The precise mechanism by which flame spreads on a surface is at present not fully understood. Certain general comments, however, can be made regarding factors that exert an influence on the flame spread characteristics of materials.

Smooth hard surfaces normally will not spread flame as fast as soft or fuzzy surfaces. Thick surfacing materials will usually spread flame more slowly than thin materials, but studies indicate that flame spread is relatively independent of thickness for most materials thicker than ¼ inch. The absorption of heat by base materials to which a finish material may be applied will tend to reduce the rate of surface burning, provided there is intimate contact between the two surfaces. This is most significant where thin surfacing materials are concerned. The method of fastening the surfacing material to the base material is most important. The moisture content of a material also can affect the rate of surface spread of flame, particularly with cellulosic materials, as can the proportion of combustible matter contained in it.

In general, materials having a low combustible content will exhibit low flame spread (ratings under 25). Examples of such materials are stone, glass, most metals, masonry products, ceramic tile, plaster, asbestos products and stucco. It is generally recognized that thin surface coatings, such as two or three coats of conventional paint or a few layers of printed wallpaper, will not raise the flame spread ratings significantly when applied to such materials. Exceptions, of course, are highly flammable coatings such as nitrocellulose lacquers.

Substantially combustible materials such as untreated lumber and cellulosic products will have flame spread ratings normally ranging from 75 upwards. Most species of lumber and a number of plywoods have ratings between 75 and 150. In order to bring the ratings of these materials below 75 it is necessary either to treat them by impregnation or apply a fire retardant surface coating. The permanence of the protection offered by either method, however, is questionable. With impregnation, the salts may leach out under humid conditions, and maintenance procedures may reduce the effectiveness of a surface coating. Use of interior finishes incorporating varying amounts of combustible components often prompts the question of their influence on the fire endurance of the building element to which they are applied.

Interior finishes even of a combustible character will generally increase the over-all fire endurance of an assembly to the extent that such materials afford additional heat insulation. A supplementary fire problem may be created, however, when flammable lining materials are installed on furring strips or studs or are suspended with an open space behind or above them. A fire that originates in such a space can often spread undetected, and if proper fire stopping has not been employed can spread from compartment to compartment. In addition, this type of fire is difficult to extinguish because it is often not readily reached by hose streams.

Of recent years concern has been expressed in many quarters about the effect of the smoke produced during the burning of surfacing materials, and the toxicity of the products of combustion on life safety. Various organizations are now carrying out studies in this field. Reduction of visibility, rather than physiological effects, is generally regarded as the major smoke hazard to occupants attempting to evacuate a building in the event of fire. Although all flame spread test methods include measurement of the smoke produced during the test, there is the question of whether a severe test for flame spread is also appropriate for evaluating smoke production. In addition, there is the problem of relating the figures obtained during a test to actual conditions in a building fire. A number of the studies being undertaken are related to an individual's ability to see an exit sign at the end of a corridor while the corridor fills with smoke.

Conclusion

It is recognized that factors other than flammability of lining materials-ventilation, the nature and distribution of the contents and geometry of a compartment can materially affect the development of a fire. When these are equal, however, fire will develop more rapidly in the compartment having the more flammable lining. The selection of materials for the interior linings of buildings is therefore an important consideration; it affects not only the safety of property but also the safety of the occupants. The hazard exists, as well, for those in other areas who may be trapped by a rapidly spreading fire. This aspect of fire protection definitely merits the attention of building designers in order that buildings now being designed will not pose a serious life hazard in the future.