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Flammability Testing for Carpet

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Center for Fire Research
National Engineering Laboratory
National Bureau of Standards
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Final Report

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

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U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, *Secretary*

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Abstract

As use of carpet has increased in recent years, more and more attention has been focused on different test methods for measuring its flammability.

The carpet industry, as well as regulatory agencies have been working on test procedures which would provide consumer protection and not be overly burdensome.

All carpet sold in this country must pass the "pill test." The pill test provides "first-to-ignite" protection for carpet flooring systems located within rooms or undivided building spaces.

Criteria have been proposed using the new Flooring Radiant Panel Test which provide equivalent safety to that level provided by the Life Safety Code. The Flooring Radiant Panel Test is both reproducible and related to "real world" performance. This publication explains the features of this test.

Key words: Carpet systems; criteria; fire growth; flammability; flooring radiant panel test; testing.

1. BACKGROUND

1.1 Basic Building Materials

Building regulations, including building codes, fire prevention codes and the like, contain various restrictions limiting the use of flammable materials on walls, ceilings, and floors of buildings. This is essential because of the way flammability characteristics of these interior materials can affect the behavior of a fire. The less a fire spreads, the less threat it becomes to life and property and the easier it is to control and extinguish.

1.2 Floor Coverings

Floor coverings,[1] such as wood, vinyl asbestos tile, terazzo, and linoleum, which have long been used, show little tendency to affect the spread of fire.

In the late 1950's and early 1960's, production techniques were developed within the carpet industry whereby carpet became competitive in cost with conventional flooring and offered certain advantages over other materials. Along with this widespread usage came a few claims that carpet aided in the spread of fire. Noting these factors, some fire officials expressed concern that some carpet material could react significantly different in a fire situation than other commonly used flooring materials. As a result of this concern, a first attempt was made in mid-1965 to regulate the floor covering by a flammability test and much research and development work was undertaken to better understand the phenomenon of fire spread.

2. THE THREE STAGES OF FIRE

In order to understand the testing and measurement of the behavior of flooring systems in a fire situation, it is necessary to consider fire in three distinct stages.

2.1 Stage 1

Stage 1 is the "ignition and its initial growth." For example, this could be the first sign of a flame in a waste-basket or overstuffed sofa. A fire will be considered as being in Stage 1 while the fire remains in the area of the ignition.

2.2 Stage 2

Stage 2 is the growth to "full involvement" - or flashover - of the room or space of origin. The fire has progressed through Stage 2 when everything in the room is burning.

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[1] The test methods described herein do not pertain to carpet used other than for floor covering.

2.3 Stage 3

Stage 3 is after the time of "flashover" when the fire spreads beyond the room of origin and spills over into the corridor and the fire begins to spread along the passageway.

3. TESTING CARPET FOR ROOM USE

Since the purpose of interior finish regulations is to avoid rapid fire spread, the following question arises:

> What level of flame spread resistance is necessary to prevent involvement of carpet during a Stage 1 fire?

3.1 The Pill Test

Since April 1971, Federal regulations have required that all carpet sold in the United States pass the Pill Test [1][2]. The test will screen out carpet easily ignited by a small incendiary source; it measures the response of carpet exposed to a timed burning tablet in the absence of an imposed external radiation field. Carpet which passed the Pill Test will not spread flame during a Stage 1 fire. This was further demonstrated in a series of room tests conducted by the National Bureau of Standards [2]. This series of experiments reconfirmed the conclusion that:

> "Carpet systems, used in rooms, will not normally spread fire provided they meet the requirements of the DOC FF 1-70 (The Pill Test)."

3.2 Evaluation of Fire Incidents

The National Bureau of Standards conducted an evaluation of fire incidents [3] in which flame spread was reported to have occurred in, or to have involved, carpet. In all but seven cases, the analysis showed either that the carpet was excessively flammable and would not pass the Pill Test, or that the available data did not clearly show that carpet was a significant contributor. Further analysis of the seven cases revealed that in none did carpet which passed the Pill Test propagate flame during a Stage 1 exposure. The study did reveal that when a very large fire source exists it

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[2] Numbers in brackets refer to the literature references listed at the end of this paper.

could result in carpet burning. Therefore, the analysis clearly showed that flame propagation was only produced in carpet when exposed to a fully-developed room fire and then only when the carpet was located in a corridor (Stage 3).

4. TESTING CARPET FOR CORRIDOR USE

The following question must now be addressed:

What level of flame spread resistance is necessary to prevent a Stage 3 fire from spreading to other parts of the building?

To answer this question, extensive research has been carried out at the National Bureau of Standards, as well as at other organizations. This research involved model corridor [4] and full-scale corridor [5-9] experiments. The studies were conducted to develop an understanding of the mechanisms by which fire spreads within carpeted corridors under the influence of a large fire source, a Stage 3 fire. In these studies, fire from a room which has passed flashover extended into a corridor through an open door. The test program led to the following three conclusions:

- The amount of energy radiated onto the flooring system is a significant determinant as to whether or not a carpet system will propagate flame.
- To radiate sufficient energy onto the floor to propagate flame, the fire source (in the room) must be large enough to intensely heat the air and ceiling in the corridor.
- Flammable materials mounted on walls or ceilings have a greater effect on flame spread than similar materials installed on the floor.

The assumption that carpet systems located within corridors should be regulated, raises several questions:

- Which test method provides the best information for judging relative fire hazard?
- Which test is most suitable for evaluating floor covering assemblies (such as carpet and separate underlayment)?
- Which test method provides reasonably reproducible data correlated to the "real world?"

4.1 The Tunnel Test

The ASTM E-84 "Tunnel Test" was originally developed to evaluate the fire hazards of wall and ceiling materials. When this method is used for carpet, a conditioned sample is mounted upside down on the "roof" of the tunnel. As a consequence, this method does not provide meaningful real-life information for judging the relative fire hazards of carpet. There is agreement within the technical fire protection community that the tunnel test does not yield data which predict the probable performance of flooring systems in actual building fires.

4.2 The Chamber Test

The Chamber Test (UL-992) was developed to evaluate fire behavior of flooring systems. The test is a variation of the Tunnel Test in that the sample is exposed to a high intensity burner in a tunnel. The specimen is placed on the floor, enabling floor covering assemblies, including carpet with separate underlayment, to be evaluated in this apparatus. In this test the forced draft supplying air to the flame sweeps the carpet in the opposite direction to that observed on the floor in full-scale corridor fires.

This test has technical shortcomings [3,11] in that:

- The Chamber Test generates an index which has an undetermined relevance to fire hazard.
- The degree of reproducibility of data resulting from the Chamber Test is not established.
- Indices produced by tests conducted in the Chamber tend to divide materials into two polarized groups; therefore, a continuous classification scale is not provided to categorize materials.

4.3 The Flooring Radiant Panel Test

Since neither the existing Tunnel Test nor the Chamber Test adequately evaluates flooring materials, a new test was developed, called the Flooring Radiant Panel Test [10]. This test is designed to simulate a likely set of conditions which may lead to fire spread in a carpet system.

The Flooring Radiant Panel concept evolved from information obtained from the full-scale corridor fire test programs. The full-scale tests showed that the level of energy radiating onto carpet significantly affected whether or not progressive flaming occurred. This test method determines a critical radiant flux, measured in watts per square centimeter (W/cm^2). Critical radiant flux is the lowest level of radiant energy necessary for a fire to continue to burn and spread.

The Flooring Radiant Panel Test is different from most other fire test methods in that it measures an actual property of the carpet system and is not based on an arbitrary scale. The test yields data correlated to the relative performance of materials in actual installations. In this test, the floor covering system in installed on the "floor" of the test chamber similar to a "real world" situation. The test can accomodate floor system assemblies, such as carpet with a separate underlayment.

The Flooring Radiant Panel apparatus involves a horizontally-mounted floor covering test sample which receives radiant energy from a gas-air fueled radiant panel mounted above one end of the sample and inclined at an angle of 30°. The sample and radiant panel are located within a test chamber. Air is allowed to flow in the bottom of the test chamber and exits via a stack located at the top of the chamber at the opposite end from the radiant panel.

The radiant panel generates a radiant flux profile along the length of the sample ranging from a maximum of 1.1 W/cm^2 immediately under the panel to approximately 0.1 W/cm^2 at the end of the test sample remote from the panel. A gas-fired pilot burner is used to initiate the ignition on the floor covering sample immediately below the radiant panel and the test is continued until the flooring system ceases to burn. The distance the flooring system burns to extinguishment is converted to watts per square centimeter from a calibration graph and is reported as critical radiant flux.

4.4 Critical Radiant Flux

The result of the test is reported as the critical radiant flux (W/cm^2). This is the minimum radiant energy a fire needs to sustain flame propagation in the flooring system. In this test, the lower the number, the greater is the tendency of the system to spread flame. Conversely, the higher the number, the more resistant is the material to flame propagation. This number is the average of at least three replicate burns.

The test apparatus is capable of accommodating materials which have critical radiant flux values ranging from approximately 1.1 to 0.1 W/cm^2. To relate these values to the critical radiant flux value of a traditionally used material, note that oak flooring has a critical radiant flux value of approximatley 0.35 to 0.40 W/cm^2. Carpet may have values from less than 0.1 to greater than 1.1 W/cm^2.

Data from the test have been shown to be both reproducible and repeatable, based upon a round-robin test series conducted under the supervision of the National Bureau of Standards, involving ten carpet systems and twelve laboratories.

4.5 Why Test?

Experience has shown there is no way to predict the performance of a carpet system without conducting a test. The resistance of carpet to the spread of flame is a function of:

- The generic type of face yarns used,
- The type of construction, including yarn texture,
- The density of the pile, and
- The presence of an underlayment, attached or separate.

Also, the presence of a separate underlayment may significantly affect the performance of carpet compared to tests conducted on the same carpet without underlayment [10]. Therefore, carpet tested without an underlayment may not be acceptable if used with an underlayment. Emphasis should be given to conducting tests based upon the type of assembly contemplated for use.

4.6 Recommended Criteria

The most widely noted fires in which carpet has been reported as a contributor to early fire growth essentially involve the Harmer House Nursing Home, the Baptist Towers, and Pioneer Hotel fires. In each of these instances, carpet taken from the buildings was determined to have a critical radiant flux of less than 0.1 W/cm^2.

The minimum critical radiant flux limits (based upon the average of three replicate tests) being recommended [11,12] are:

- 0.45 W/cm^2 within corridors and exitways of hospitals and nursing homes, and

- 0.22 W/cm^2 within corridors and exitways of other occupancies except one- and two-family dwellings.

These values should provide a level of safety for the carpeted corridor which is equal to or in excess of that now required in the NFPA 101 Life Safety Code [13].

These limits are based upon:

- Comparison to performance of traditionally used materials,

- Performance of flooring systems under full-scale corridor tests, and

- Evaluation of carpet systems which have been reported as significantly contributing to flame spread in actual fires.

The higher level of critical radiant flux of 0.45 W/cm^2, recommended for health care facilities, is based on the assumption that non-ambulatory occupants (patients) require a higher level of protection than do occupants who are mobile and are capable of rapid escape.

4.7 Sprinklered Buildings

The radiant flux limits suggested for regulating floor coverings are based upon the possibility of a Stage 2 and Stage 3 fire. In a building completely protected by an automatic sprinkler system, the likelihood of a Stage 2 fire developing becomes remote. The need for regulation of floor coverings under these circumstances diminishes. Therefore, the criteria suggested above could be reduced or eliminated in the case where automatic sprinkler protection is provided [12].

5. REFERENCES

[1] Standard for the Surface Flammability of Carpets and Rugs, DOC-FF-1-70; Federal Register, Vol. 35, No. 74, p. 6211 (April 16, 1970).

[2] Tu, K.-M. and Davis, S., Flame Spread of Carpet Systems Involved in Room Fires, Nat. Bur. Stand. (U.S.), NBSIR 76-1013 (June 1976).

[3] Quintiere, J. and Huggett, C., An Evaluation of Flame Spread Test Methods for Floor Covering Materials, Nat. Bur. Stand. (U.S.), Special Publication 411, pp. 59-89 (Nov. 1974).

[4] Denyes, W. and Quintiere, J., Experimental and Analytical Studies of Floor Covering Flammability with a Model Corridor, Nat. Bur. Stand. (U.S.), NBSIR 73-199 (May 1973).

[5] Fung, C. W., Suchomel, M. R. and Oglesby, P. L., The NBS Program on Corridor Fires, NFPA Fire Journal (May 1973).

[6] McGuire, J. H., The Spread of Fire in Corridors, National Research Council of Canada, Division of Building Research (December 1967).

[7] Christian, W. J. and Waterman, T. E., Fire Behavior of Interior Finish Materials, IIT Research Institute, Fire Technology (August 1970).

[8] Fung, C. W., Suchomel, R. and Oglesby, P. L., NBS Corridor Fire Tests: Energy & Radiation Models, Nat. Bur. Stand. (U.S.), Technical Note 794 (October 1973).

[9] Quintiere, J., The Application and Interpretation of a Test Method to Determine the Hazard of Floor Covering Fire Spread in Building Corridors, International Symposium, Fire Safety of Combustible Materials, Edinburgh, Scotland, pp. 355-367 (October 1975).

[10] Kashiwagi, T., Experimental Observation of Flame Spread Characteristics Over Selected Carpets, JFF/Consumer Product Flammability, Vol. 1, pp. 367-689 (December 1974).

[11] Benjamin, I. A. and Adams, C. H., Proposed Criteria for Use of the Critical Radiant Flux Test Method, Nat. Bur. Stand. (U.S.), NBSIR 75-950 (December 1975).

[12] Benjamin, I. A. and Adams, C. H., The Flooring Radiant Panel Test and Proposed Criteria, NFPA Fire Journal, Vol. 70, No. 2 (March 1976).

[13] Life Safety Code 1976, NFPA No. 101, National Fire Protection Association, Boston, Mass.

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17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*
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