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Technical Support for the Consumer Product Safety Commission 1979 Interim Standards for Cellulose Insulation

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U.S. Department of Commerce
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Washington, DC 20234

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Final Report

Prepared for:

Consumer Product Safety Commission
Textile and Mechanical Engineering Group
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U.S. DEPARTMENT OF COMMERCE, Malcolm Baldrige, *Secretary*
NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Director*

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TECHNICAL SUPPORT FOR THE CONSUMER PRODUCT SAFETY COMMISSION 1979 INTERIM STANDARDS FOR CELLULOSE INSULATION

David D. Evans and Sanford Davis

Abstract

The attic floor radiant panel test (AFRPT) and smoldering combustion test are two fire performance tests required by the Consumer Product Safety Commission (CPSC) as part of a mandatory standard for loose fill cellulosic home insulation. In providing technical support to CPSC, the sensitivity to variations in parameters of each test method were studied. Specimen density was found to have no effect on critical radiant flux values when measured with the AFRPT for two paper-based cellulosic insulations tested at densities below 48 kg/m3. A low flux exposure profile, ranging from 0.04 to 0.35 W/cm^2, was developed to extend the range of the AFRPT about the region of greatest interest. The critical radiant flux measured using the low flux profile was found to be sensitive to changes in preheat time from the prescribed two minute specimen preheat. Large scale attic fire tests verified the predictive ability of AFRPT measurements. Results from the smoldering combustion test were shown to be sensitive to test room humidity conditions over the range of 39 to 84% RH.

Key words: Attic floor radiant panel test; cellulose insulation; smoldering; fire test; flame spread; HH-I-515D.

1. INTRODUCTION

The Emergency Interim Consumer Product Safety Standard Act of 1978 (PL 95-319) [1]* required the Consumer Product Safety Commission (CPSC) to enforce the corrosiveness and flame resistance requirements of the General Services Administration (GSA) specification HH-I-515C [2] for loose-fill cellulosic insulation, and to publish all subsequent related amendments which GSA may publish. On June 15, 1978, GSA published an amendment to the specifications for cellulosic insulation and designated it HH-I-515D [3]. This amendment contains two test methods developed by the Center for Fire Research (CFR) at the National Bureau of Standards (NBS) - the attic floor radiant panel test (AFRPT) and the smoldering combustion test. Testing loose-fill cellulosic insulation in the AFRPT was proposed to assure that the material had a specified resistance to surface flame spread. The smoldering combustion test was also specified to assure that insulation materials had some resistance to ignition by a smoldering source.

The CPSC insulation standard is based on fire performance test methods developed previously for the General Services Administration (GSA). The technical rationale for fire performance sections of the GSA cellulosic insulation standard (HH-I-515D) were detailed in an unpublished paper by S. Davis. For completeness of the documentation of NBS efforts concerned with the development of the CPSC insulation standard, S. Davis' discussion of the technical rationale for the GSA standard is included as Appendix 1 to this report.

Before a final version of a mandatory standard based on HH-I-515D could be issued by CPSC, public comments were solicited. To aid CPSC in responding to the comments, NBS prepared suitable responses to technical questions about the standard; these responses were based on knowledge about the test methods at the time of publication. Experimental work was

* The numbers in brackets refer to the references listed in section 6 of the report.

necessary in some cases to gather adequate information to respond to comments on the proposed AFRPT and smoldering combustion test methods. In particular, round robin testing was conducted with the cooperation of several independent testing laboratories to determine the repeatability and reproducibility of the two test methods by testing selected loose-fill insulation materials. Round robin testing was coordinated by NBS on both the AFRPT and smoldering combustion test of HH-I-515D [7] specifications, the ASTM E 84-77a tunnel test of the HH-I-515C specifications [8], and a new method to determine the settled density of loose-fill insulation materials, the cyclone-shaker test [9].

Additional effort was directed towards modification of the measuring range of the AFRPT and verifying that the measurements were meaningful by testing materials in a simulated attic fire situation. The effects of variations in specimen density and preheat time on AFRPT results were investigated. The sensitivity of the smoldering combustion test method to changes in test room humidity conditions was also explored.

This report serves to document the various activities conducted by the NBS Center for Fire Research in technical support of CPSC's interim standards for cellulose insulation.

2. ATTIC FLOOR RADIANT PANEL TEST

The Standard Method of Test for Critical Radiant Flux of Floor Covering Systems using a Radiant Energy Source (NFPA 253, ASTM E 648) was developed for evaluating flooring systems in corridors exposed to radiation from fully developed fires in rooms. The range of critical radiant flux measurable in this test included values down to 0.11 W/cm^2 that were appropriate for simulation of the potential total heat flux to an insulated attic floor from the heated attic air, the underside roof surface, and the presence of a small ignition source. A new specimen tray was developed to hold cellulosic loose-fill insulation and to replace the standard specimen holder in the flooring radiant panel apparatus (NFPA 253). With the new specimen holder suitable for holding loose-fill insulation, the apparatus became known as the attic floor radiant panel. The minimum level of critical radiant flux for safe use of insulation materials in the attic space was established as 0.12 W/cm^2 (Appendix 1). Additional background on the development of the test method is given in the Technical Rationale for the GSA Federal Specification HH-I-515D Flame Resistance Provision included in this report as Appendix 1.

2.1 Development of a Low Flux Profile

The CPSC interim standard for cellulosic insulation [6] requires that cellulosic insulation materials have a critical radiant flux equal to or greater than 0.12 W/cm^2 as measured by the attic floor radiant panel test (AFRPT). For the flux profile specified in the standard, the AFRPT can measure critical radiant flux values from 0.1 to 1.1 W/cm^2. Since the pass-fail level of 0.12 W/cm^2 is near the low end of that range, the gas flow rate to the radiant panel was reduced to obtain a new heat flux distribution at the test specimen surface spanning the range from 0.04 to 0.35 W/cm^2. For this "low flux" profile, the pass-fail level of 0.12 W/cm^2 occurs mid-length along the 100 cm test specimen. The regular and low flux profiles are shown in figure 1.

Eight cellulosic insulation materials were selected to compare the low flux profile to the standard (regular) flux profile. These eight materials are identical to those used by Lawson in the study of the ASTM E 84-77a Tunnel Test Method as modified for testing of loose-fill cellulosic insulation [7]. Materials D and F were untreated paper-based material. The remaining materials were commercial paper-based materials, except that H was cotton-based. All paper-based materials were tested at a density of 40 kg/m^3. The cotton-based material was tested at 24 kg/m^3. Three replicates were run for each material under both conditions. Critical radiant flux values, averages, and repeatability coefficients of variation are listed in table 1.

In table 1 repeatability coefficients of variation (COV) values for materials B, C, E, and G are listed for both flux profiles. The repeatability COV as defined in table 1 is a measure of the within-laboratory variability of test results. Averaging the COV values for these four materials yields essentially equal values of 10.1% and 10.0% for the regular and low flux profiles, respectively. This compares with an average COV value of 11.7% based on the extensive testing in [8], and suggests that this is the practical limit for materials of this type.

Four the eight materials tested, could not be compared directly at both profiles. For the four materials that could be compared, the differences in average critical radiant flux were 0.01, 0.02, 0.02, and 0.04 W/cm^2 for materials B, C, G, and E respectively. For three of these four materials, there was no significant statistical difference in the averages, using the two heat flux profiles, at the 95% confidence level. But for material E, variations of test values below the 0.12 W/cm^2 critical radiant flux value would cause this material to be judged a failure in the low flux test while passing the regular flux test. For material G, the critical radiant flux of 0.14 W/cm^2 measured in the low flux test was "statistically different" from the value of 0.16 W/cm^2 measured under the regular flux profile, because of the very low coefficient of variation for this material in the test.

An alternate method of obtaining a low flux profile was considered; i.e., by lowering the surface of the specimen while maintaining the radiant source at the same intensity as used in the regular flux test. No practical testing configuration of this type was found. To obtain a heat flux of 0.12 W/cm^2 near the mid-length of the test specimen, its surface must be lowered approximately 60 cm. This is impractical since it would necessitate a total reconstruction of the apparatus frame. Figure 2 shows the flux distributions obtained at the surface of the test specimen lowered from the normal position both 47.5 cm and 63.5 cm respectively.

For most cellulosic insulation materials, no significant change in critical radiant flux rating is expected if tested using the low flux profile.

2.2 Effect of Specimen Density on AFRPT Results

The effect of density on Attic Floor Radiant Panel test (AFRPT) results was studied to support the CPSC responses to public comment on the proposed amendment to the interim cellulose insulation standard. Justification for testing insulation at the density obtained by blowing ("blown density") as specified in the standard was also sought. It was found that variations in sample density can affect AFRPT results. This was demonstrated using both the regular (0.1 W/cm^2 to 1.1 W/cm^2) and low (0.04 W/cm^2 to 0.35 W/cm^2) flux profiles. For the two paper-based insulations (F and G), critical radiant flux values were significantly greater at specimen densities above 48 kg/m^3 (3 lbs/ft^3) than below. No significant variations in critical radiant flux values were found for the materials tested at densities below 48 kg/m^3. The blown density is recommended for testing cellulosic insulation materials in the AFRPT because it is on the conservative side from the standpoint of fire risk.

Cellulosic insulation G was evaluated in the AFRPT using a two minute preheat and the low flux profile at hand loaded densities of 24, 40, and 64 kg/m^3 (1.5, 2.5, and 4.0 lbs/ft^3). To simulate installation conditions, the material was first blown from a commercial blower before hand packing into the specimen holders to the desired test density. A settled density for this material of 42.3 kg/m^3 was measured by the CPSC laboratory using the Department of Energy (DOE) cyclone-shaker test method [9]. Table 2 contains the data from triplicate evaluations of the material at each of the three densities. At the lower densities, 24 and 40 kg/m^3, the critical radiant flux was 0.15 W/cm^2. At the higher 64 kg/m^3 density, flames did not propagate as far down the samples. The material was rated at a significantly higher 0.26 W/cm^2.

Cellulosic insulation E was evaluated in the AFRPT using a two minute preheat and the regular flux profile at densities of 32, 48 and 64 kg/m^3 (2.0, 3.0, 4.0 lbs/ft^3). The settled density for this material of 46.8 kg/m^3 was measured by the CPSC laboratory using the DOE cyclone-shaker method. Table 3 contains the data from the triplicate evaluations of the material at each of the three densities. At the lowest density (32 kg/m^3), the material had an average critical radiant (CRF) flux of 0.12 W/cm^2. At the middle density (48 kg/m^3), the CRF was higher, but not significantly different, with an average value of 0.14 W/cm^2. At the highest (64 kg/m^3) density, a significant change in average radiant flux to 0.23 W/cm^2 was recorded.

At densities below 48 kg/m^3 (3 lbs/ft^3), no significant differences in critical radiant flux were found for the two paper-based cellulosic insulation materials. Above 48 kg/m^3, significantly higher CRF values have been demonstrated in both the regular and low flux profile tests. In other testing, AFRPT results for a cotton-based insulation material have been shown to be sensitive to density variations below 48 kg/m^3. Therefore, extension of the conclusions of this report to non-paper based cellulose insulations cannot be justified.

The Consumer Product Safety Commission Interim Standard for Cellulose Insulation [6] requires that the AFRPT be conducted with specimens loaded by blowing the insulation into the tray using the blower/cyclone apparatus. Suggestions have been made to perform the test at the settled density. For both materials evaluated in this study, the settled density was close to, but below, 48 kg/m^3. Based on the test results, no significant difference in critical radiant flux value would be expected for these small density differences. However, because the critical radiant flux values for the materials tested increased at higher specimen densities, the density as blown should be maintained as the specified specimen density for the AFRPT as the material CRF will be on the conservative side from the standpoint of fire risk.

2.3 Variation of Critical Radiant Flux with Preheat Time

The sensitivity of measurements of the critical radiant flux for insulation materials to changes in preheat time was examined. The CPSC Interim Safety Standard for Cellulose Insulation [6] currently specifies a two-minute preheat for the specimen before ignition. The sensitivity of critical radiant flux to changes in preheat time is of interest to support the ± 5 second tolerances on the two-minute value specified in the standard.

Three cellulosic insulation materials, identified as materials B, E, and G by Lawson [7], were used in this study. All critical radiant flux (CRF) values were determined using the low flux profile (0.040.35 W/cm^2). The materials were evaluated at 0, 1, 3, 6, 9 and 20 minute preheat times. Values at 2 minutes preheat were available from previous testing. All materials were evaluated at 40 kg/m^3 density.

The low flux profile was chosen for use in this study to provide better resolution at low critical radiant flux values. The low flux profile also eliminates the erratic behavior observed for some materials that may char excessively and fail to ignite using the regular flux profile with preheat times greater than five minutes.

Figures 3, 4, and 5 are graphic presentations of the data obtained. These data are also tabulated in table 4. For each material the critical radiant flux decreased with increasing preheat time. The three materials were rated above 0.12 W/cm^2 CRF with short preheat times and below with long preheat times. The critical radiant flux for a material appeared to be relatively insensitive to changes in preheat time for preheat times greater than ten minutes. Critical radiant flux values were sensitive to changes in preheat time in the range of the standard two-minute preheat. The rate of change of CRF values with respect to changing preheat time at two-minutes preheat was approximately 0.015 W/cm^2 per minute.

The test results in the AFRPT using the low flux profile have been shown to be sensitive to preheat time variations. It is expected that test results using the regular flux profile would also be sensitive to preheat time (and would also be more erratic because of specimen charring). Therefore, the tolerance on the preheat time of ± 5 seconds used in the standard is justified to limit any effect on CRF to a negligible amount.

3. FLAME SPREAD TESTS ON CELLULOSIC INSULATION IN A LARGE-SCALE ATTIC

A series of five large-scale attic fire tests were conducted to demonstrate the applicability of the attic floor radiant panel test (AFRPT) critical radiant flux ratings of cellulosic insulation to the anticipated fire performance of the materials in end-use configurations. The tests showed that materials with critical radiant flux values greater than the surface heat flux generated in the simulated summer attic conditions did not allow flame to propagate away from a small torch ignition source.

The large attic mockup (2.84 m x 3.66 m base), used in previous attic insulation tests as reported by Gross [10], was modified for these tests. A nominal 14 cm deep duct was constructed to circulate hot air over much of the exposed exterior peaked roof area. The attic space could be heated up to 82°C by heat transferred from the hot surfaces of the roof, simulating the type of heating that occurs in home attics. Figure 6 shows a diagram of the large scale attic; key features are identified in the figure. As indicated, the attic was constructed in two pieces: a base floor section and a removable peaked roof assembly. The two pieces were mated for testing and separated for installing and removing insulation.

For testing, the middle three joist spaces, each 37 cm (nominal 14.5 in) wide, were filled with cellulosic insulation to the top of the 14 cm (nominal 6 in) deep joist for a distance of approximately 1.7 meters. Three small propane torch burners, mounted on a gas manifold controllable from the exterior of the attic, were used as flaming ignition sources for the tests. Flame spread was measured from the point of ignition. As three joist spaces were filled with the same material and each ignited separately, each attic test represented three trials for the material tested.

For each test the insulation was blown through a commercial blower into auxiliary containers. This blown insulation was loaded into the joist space by hand and distributed uniformly to a pre-established density of 44.8 kg/m^3 for the paper-based materials and 24 kg/m^3 for the cotton-based material.

Over a two to three hour period before testing, the attic assembly was preheated to temperatures near the test conditions. An attic air temperature of 71°C was chosen for the conduct of the tests. This temperature was measured in air over the center of the attic floor 0.69 m below the peak in the roof. Stratification of the air within the attic produced a considerable gradient in air temperatures with distance from the peak in the roof. Typically, a drop in air temperature of 30°C was observed traversing the distance from the peak in the roof to the floor. Table 5 contains the data from one vertical traverse made over the center of the attic base.

The heat flux distribution over the area covered by the three joist spaces was uniform to within 10%. Table 6 contains the data for total heat flux measured 10 cm above the insulation surface. At test conditions the nominal total heat flux near the surface of the insulation was 0.055 W/cm^2.

Four of the five materials tested were commercial materials. The fifth material (S) was a special mixture that was a border-line failure in the AFRPT with an average critical radiant flux of less than 0.11 W/cm^2. Table 7 lists the flammability characteristics for the cellulosic insulation materials B, F, G, H, and S as determined in the AFRPT and tunnel test.

In the large scale attic tests, none of the materials allowed flame to spread a distance greater than 35 cm from the ignition source. None of the materials allowed rapid or substantial flame propagation.

Table 8 summarizes the test results and conditions. Over a period of two to three hours the attic was heated from laboratory conditions to slightly over 70°C. Then the ignition burners were ignited, raising the attic air temperature to between 75°C and 77°C at the time the burner flames were applied to the insulation surface. Peak air temperatures during the test were influenced by the extent and rate of insulation burning. Heat flux measured at the edge of the insulated joist spaces (locations shown in figure 6) increased by a maximum of 0.01 W/cm^2 during the tests.

None of the insulation materials tested permitted surface flame propagation under initial total heat flux conditions of 0.055 W/cm^2. All materials tested in the attic had critical radiant flux values at or above 0.09 W/cm^2 as determined in the AFRPT with low flux profile and using the standard two minute preheat time. (As documented in the previous section, critical radiant flux values are dependent on specimen preheat time.) Based on the standard interpretation of AFRPT test results, the measured 0.09 W/cm^2 or greater critical radiant flux values for the insulation material indicates that no flame spread would be expected in the attic tests with initial flux of 0.055 W/cm^2 regardless of preheat time. As observed in these tests, no flame spread occurred in the attic mockup.

The attic test conditions used in this study were representative of a likely exposure in parts of the U.S. during the summer. The conditions do not represent a worst case exposure. Larger ignition sources than the torch flames could raise the air temperature in the attic and heat flux to the floor to values above those found in these tests. Other attic construction methods would also influence test conditions. Flame spread over the exposed insulation surface would only be expected in cases where the incident surface heat flux exceeds the critical radiant flux of the insulation material as measured in the AFRPT.

4. SMOLDERING COMBUSTION TEST

A review of fire incident data by D. Gross [10] showed that the most likely hazard associated with cellulosic insulation stems from smoldering. The smoldering combustion test was introduced into the GSA specification and the CPSC interim safety standard for cellulose insulation to assure that cellulosic insulation would have some resistance to smoldering. In smoldering combustion test, a smoldering cigarette is placed in a pan of insulation to serve as an ignition source. The concern is whether the smoldering, once started, will continue to propagate in the cellulosic insulation. The test is intended to simulate any localized high temperature source (not limited only to a cigarette), and to determine if the smoldering will continue beyond the heated region.

The weight loss of the insulation sample after testing is used to determine the extent of smoldering. If a product does not exhibit any smoldering tendency, a weight loss of less than 1 or 2 percent would be expected. If the product is ignited by the smoldering cigarette, the expected specimen weight loss would typically be in excess of 30 percent. Because of the nature of the test results, a weight loss criterion of 15 percent was established as the maximum weight loss permitted for a material with acceptable smoldering resistance. Additional details of the test background are given in the Technical Rationale for the General Services Administration Federal Specification HH-I-515D Flame Resistance Provision included in appendix 1.

4.1 Effect of Test Area Humidity on the Smoldering Combustion Test

The temperature and humidity conditions for the smoldering test defined in the CPSC interim safety standard for cellulose insulation [6] are as follows:

1. Condition the specimens at 21$\pm$3°C and 50$\pm$5 percent relative humidity.

2. The test area shall be maintained at 21$\pm$3°C and 50$\pm$5 percent relative humidity.

The temperature and humidity criteria in the test area were examined to determine whether the specified limits are justified. Based on an experimental examination of the influence of the test area relative humidity on specimen weight loss in the smoldering test, the allowable humidity range of 45 to 55 percent is a justified restraint. In addition, the experimental data indicated that a tolerance of $\pm$ 2°C should be specified for the 21°C test area temperature to assure that variations in test area conditions do not significantly affect specimen weight loss. Although not explicitly demonstrated in this testing, variations in specimen weight loss due to changes in ambient humidity conditions could influence the pass/fail rating of the material tested.

To study the effects of humidity on this test, a controlled environmental chamber is needed. Since a commercial chamber of that type was not available for this study, the humidity was controlled in a test module with a commercial humidifier-dehumidifier. Essentially, this work was directed towards determining whether significant variations in test results could be detected over a modest range of humidity conditions deviating from the recommended value.

The four cellulosic insulation materials chosen for study were selected from the group used in the smoldering test round robin conducted by Lawson at NBS [7]. Using Lawson's identification, the four cellulosic insulation materials were C, E, F, and G. The round robin smoldering tests conducted by NBS were performed at a specified density. For the paper-based materials, E, F, and G, the specified density was 48 kg/m^3 (3.0 lbs/ft^3). For the less dense cotton-based material C, the specified density was 24 kg/m^3 (1.5 lbs/ft^3).

These smoldering tests were performed on material packed to the settled density as specified in the CPSC interim safety standard for cellulosic insulation [6]. The settled density for each of the four insulation materials was determined by the CPSC laboratory using the DOE cyclone-shaker method. Settled density values for the four materials are given in table 9.

Prior to testing, all the material was pre-conditioned in large open bags for a minimum of 48 hours at 21°C and 50% relative humidity. The samples were transported from the conditioning room in Building 225 to the Building 205 test facility in closed bags. The sample pans were loaded and weighed outside the conditioned test room. The samples were subjected to the smoldering test as quickly as possible after being placed in the conditioned test room.

Different relative humidity levels were obtained in the conditioned test room using a commercial home style humidifier-dehumidifier. The test room temperature, typically within ± 2°C, was not controlled separately; however, the Building 205 test facility, as a whole, is temperature controlled. To obtain high and low values of humidity, it was necessary to install a polyethylene vapor barrier over the interior wall and ceiling surfaces of the room. The three conditions obtained in the room for testing purposes were: 21°C, 84% RH; 21°C, 52% RH; and 24°C, 39% RH. Originally, it was proposed to examine an additional humidity level between 50% RH and 84% RH. The data obtained in the set of three measurements were sufficiently definitive to dispense with additional tests.

Table 10 lists the test results for percent weight loss in the smoldering test for each of the five specimens of four materials tested under three conditions. Five specimens were chosen for the test because, at the time this work was performed, some thought was being given to changing the proposed standard test of three specimens to a test of five specimens. (The CPSC interim safety standard for cellulosic insulation [6] specifies three specimens.) A specimen that had a weight loss greater than 15% of its initial weight was considered a failure and is indicated by an "F" in the table. The CPSC interim safety standard for cellulosic insulation [6] specifies that all three specimens in the sample must pass the test for the material to pass. All specimens of material F passed and all specimens of material G failed under all conditions tested. Two of the materials had split test results; that is, some but not all of the five samples tested under the same conditions were failures. Material C gave one split result only at the highest humidity conditions tested.

The analysis of data resulting from the smoldering test, with the widely different weight loss values for passing and failing samples and the split test results, presents many problems. There is not a continuum of weight loss values from passing to failing in this test; therefore, extrapolation of data cannot be performed. To be explicit, the percent weight loss for samples in the smoldering test is usually in the range of either 0% to 4% or 35% to 60%. Values in the region between 4% and 35% are rare and extrapolation of test results into this region is unjustified. This type of behavior can be understood if one thinks of the smoldering test as a go/no-go ignition test. Once the cigarette causes a small percentage (by weight) of the insulation in the sample box to ignite and smolder, then the added heat generation within the well insulated center region of the sample will be enough to guarantee that the smoldering will continue. The smoldering, once initiated, will progress to the edges of the container. There heat loss or lack of fuel will cause the reaction to stop. To reach the edge of the container, the smoldering front must consume a large portion of the sample. Thus test results for percent weight loss have either very low or high values.

The critical amount of sample weight loss that can occur before failure becomes imminent is unknown. This critical value will be sensitive to the thermo-physical and reaction rate properties of the insulation material, as well as specimen density and environmental conditions. With this in mind, some caution should be exercised in generalizing the smoldering combustion results of the limited sample of data presented in this report.

In table 10, the weight loss data for each specimen tested are recorded. For both materials F and C, some trials under high humidity conditions showed negative weight loss. This indicates that, over the test time of approximately 5 hours, more weight was gained by absorption of moisture than was lost from smoldering. Just as in the standard test method [6], no attempt was made to correct weight loss data for this effect.

Each trial of material G failed, with weight losses ranging from 38 to 56.5%. Materials F and C (excepting the one failure) had small percent weight changes.

Test room humidity conditions may be quantified by use of specific humidity, the ratio of the mass of water vapor to the mass of dry air present. This parameter is preferred to relative humidity for this study because the temperature in the test room was not held constant.

As a first step in analyzing the data, the split pass-fail test results of material C under high humidity conditions must be considered. If the one unexplained trial failure at the high humidity conditions is considered significant, then a variation from the near-standard conditions (21°C, 52% RH, 0.0078 specific humidity (SH)) to the high humidity condition (21°C, 84% RH, 0.0133 SH) is sufficient to account for variations in material performance in the test. Excluding other chance variations in test conditions, a change in specific humidity of 0.0055 can produce test result variations.

As an alternative method of detecting significant changes, variations within the group of trials tested at the same room conditions may be compared to variations between conditions. This information may be used to establish a range of specific humidity conditions in which no significant variations in specimen weight would be expected. Although significant variations in weight loss do not necessarily act to change the overall evaluation of a material from passing to failure, they do show that the test measurements are influenced by the change.

The one trial failure of material C has been considered as significant abcve to establish one limit on allowable moisture changes. On the other hand, if that failure is neglected as being non-significant with respect to high humidity, the following analysis pertains.

The data for material C, F, and G on average percent weight loss and standard deviation recorded in table 10 are presented graphically in figure 7. The error bars in figure 7 indicate plus and minus one standard deviation about the average value. Table 11 lists the average weight loss and two standard deviations based on the data in table 10 for materials C, F and G tested at 21°C and 52% RH. Using the slope of the straight line fits of the data in figure 7 to assess the amount of change in measured weight loss with changing specific humidity, values of specific humidity change necessary to produce two standard deviations change in weight loss were evaluated. These calculated values of specific humidity change are listed in table 11.

The CPSC interim safety standard for cellulose insulation [6] specifies that the test area conditions must be maintained within the range of 18°C, 45% RH to 24°C, 55% RH. This corresponds to a range of specific humidity from 0.0059 to 0.0104. The change in specific humidity over the range is 0.0045. This value is above the level for significant variations in weight loss predicted for materials C and F (see table 11). Of course, the weight loss data for materials C and F cannot be interpreted to indicate that for other materials a specific humidity change of 0.0045 would change the overall evalution of from passing to failure (or vice versa).

It has been suggested by CPSC that a 50 $\pm$ 10% relative humidity specification might be substituted for the current 50 $\pm$ 5%. Under this change, the test area conditions for specific humidity may range from

0.0052 to 0.0111, corresponding to 18°C, 40% RH and 24°C, 60% RH respectively [11]. The change in specific humidity over this range is 0.0059. This value is greater than the level for significant variations in weight loss predicted for all three insulation materials: C, F and G. It is also greater than the 0.0055 SH change that may have been responsible for the trial failure of material C discussed above.

In the interest of caution, considering only the limited testing reported here, a change of the 50 ± 5% to 50 ± 10% relative humidity specification for the testing space cannot be recommended at this time. Further testing is needed to determine the effect, if any, of changing test area temperature at a fixed specific humidity.

Again in the interest of being conservative, it is suggested that the specific temperature limit variations be reduced for the smoldering test to 21°C ± 2°C and 50 ± 5% RH. This would limit the allowable range of specific humidity change to 0.0036. It should be noted that temperature tolerance of ± 2°C and a relative humidity tolerance of ± 5% for standard laboratory atmoshperes are the recommended in ASTM D-618 section 3d.

The erratic test results of material E made the data difficult to utilize in this study. Lawson in his smoldering round robin tests [8] found that material E was rated as passing in three of ten laboratories and as a failure (including split results) in the remaining seven laboratories. It is possible that material E is a border line material with respect to the pass/fail smoldering test. Lawson speculates that material composition variations may be the source of the erratic performance. In addition, for the smoldering test other testing variations, such as changes in local specimen density around the ignition source, could become important in influencing test results.

The smoldering test has been shown to be sensitive to changes in overall specimen density. As an example, material F used in this study was reported as a failure in the smoldering test in nine of the ten laboratories in the NBS round robin [8]. In the round robin, the material was tested at a density of 48 kg/m^3. In the work reported here, this material was tested at a density of 41.3 kg/m^3. At this lower density, each tested specimen passed (see table 10).

5. CONCLUSIONS

As part of the technical support for the CPSC 1979 Interim Safety Standard for Cellulose Insulation, various parameters of the attic floor radiant panel test (AFRPT) and smoldering combustion test were investigated. The low flux profile developed to extend the measurement range of the AFRPT down to 0.04 W/cm^2 was shown to produce results equivalent to those obtained using the regular flux profile for most materials tested. Large scale attic fire tests have shown that, when the heat flux to the surface of the insulation does not exceed the critical radiant flux, flame spread does not occur. The AFRPT is applicable to the prediction of resistance to flame spread for attic insulation.

No statistically significant variations in critical radiant flux values for pre-blown paper-based cellulosic insulation were found for variations of hand loaded specimen bulk density in the range of 24 kg/m^3 to 48 kg/m^3.

The critical radiant flux measurement in the AFRPT was found to be sensitive to changes in the 2 minute preheat time. A tolerance of $\pm$ 5 seconds on the standard preheat time is justified.

Smoldering combustion test results were found to be sensitive to large changes in test area humidity conditions. Limiting the tolerances on temperature and relative humidity to 21 $\pm$ 2°C and 50 $\pm$ 5 percent respectively is considered necessary to ensure that significant variations in test results are not produced by variations in test area conditions.

6. REFERENCES

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[4] Consumer Product Safety Commission, Cellulose Insulation, Proposed Amendment to Interim Standard and Certification Rule, Federal Register, Vol. 43, No. 173, September 6, 1978, p. 39720

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[7] Lawson, J.R., An Interlaboratory Evaluation of the Consumer Product Safety Commission Modified ASTM # 84-77a Tunnel Test for Cellulosic Insulation, NBSIR 79-1922, Nov. 1979

[8] Lawson, J.R., Interlaboratory Evaluation of the Attic Floor Radiant Panel Test and Smoldering Combustion Test for Cellulose Thermal Insulation, NBSIR 79-1922, Nov. 1979

[9] Lawson, J.R., Interlaboratory Evaluation of the Cyclone Settled Density Test for Loose-Fill Cellulosic Insulation, NBSIR 79-1930, Dec. 1979

[10] Gross, D., A Preliminary Study of the Fire Safety of Thermal Insulation for Use in Attics or Enclosed Spaces in Residential Housing, NBSIR 78-1497

[11] Psychometric Chart, Reprint from ASHRE Brochure on Psychometry Misc. Publications #7, 1947

Figure 1 -- Regular and Low Flux Profiles

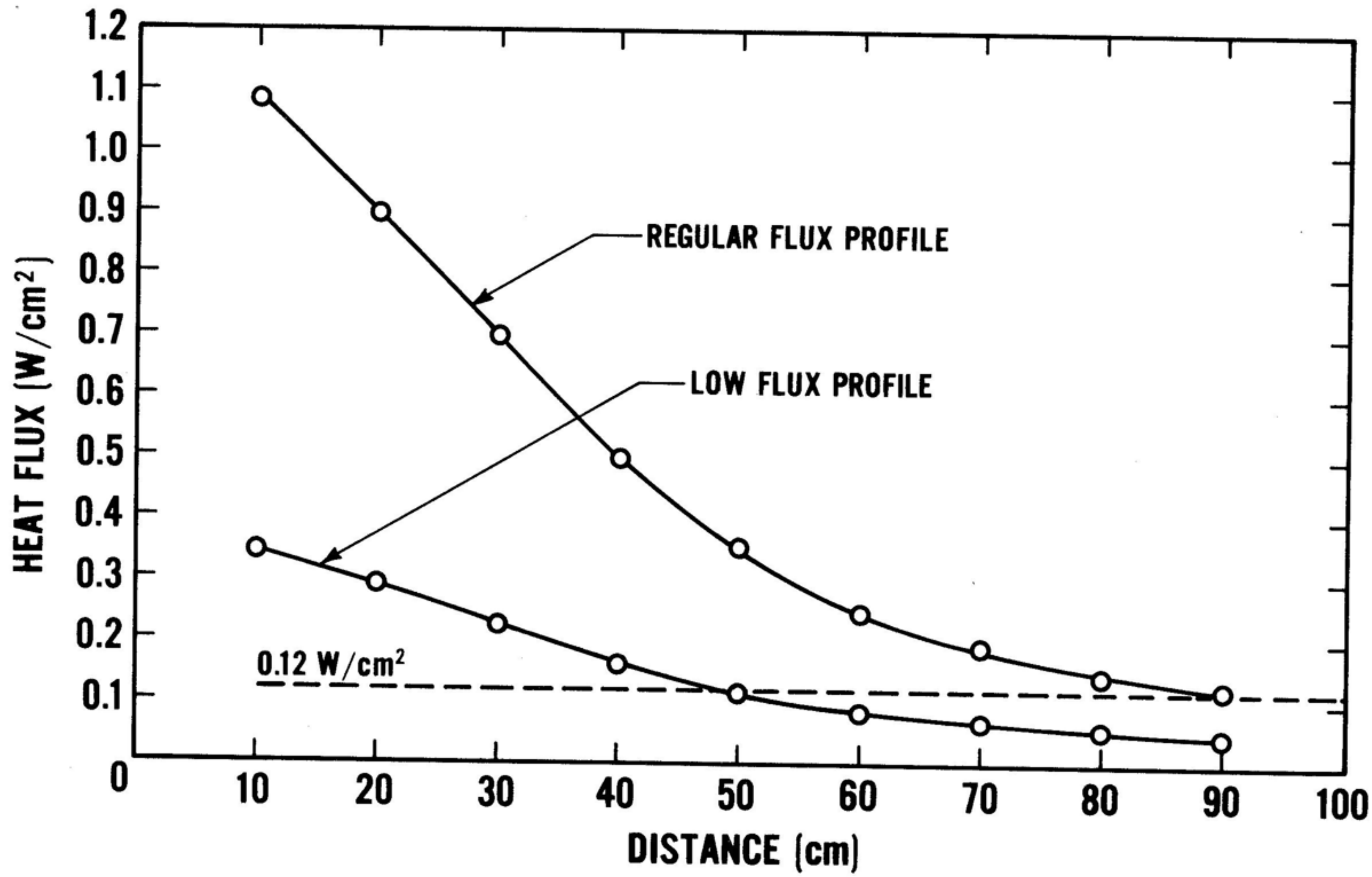

Figure 2 -- Specimen Flux Profiles with Lowered Specimen Surface

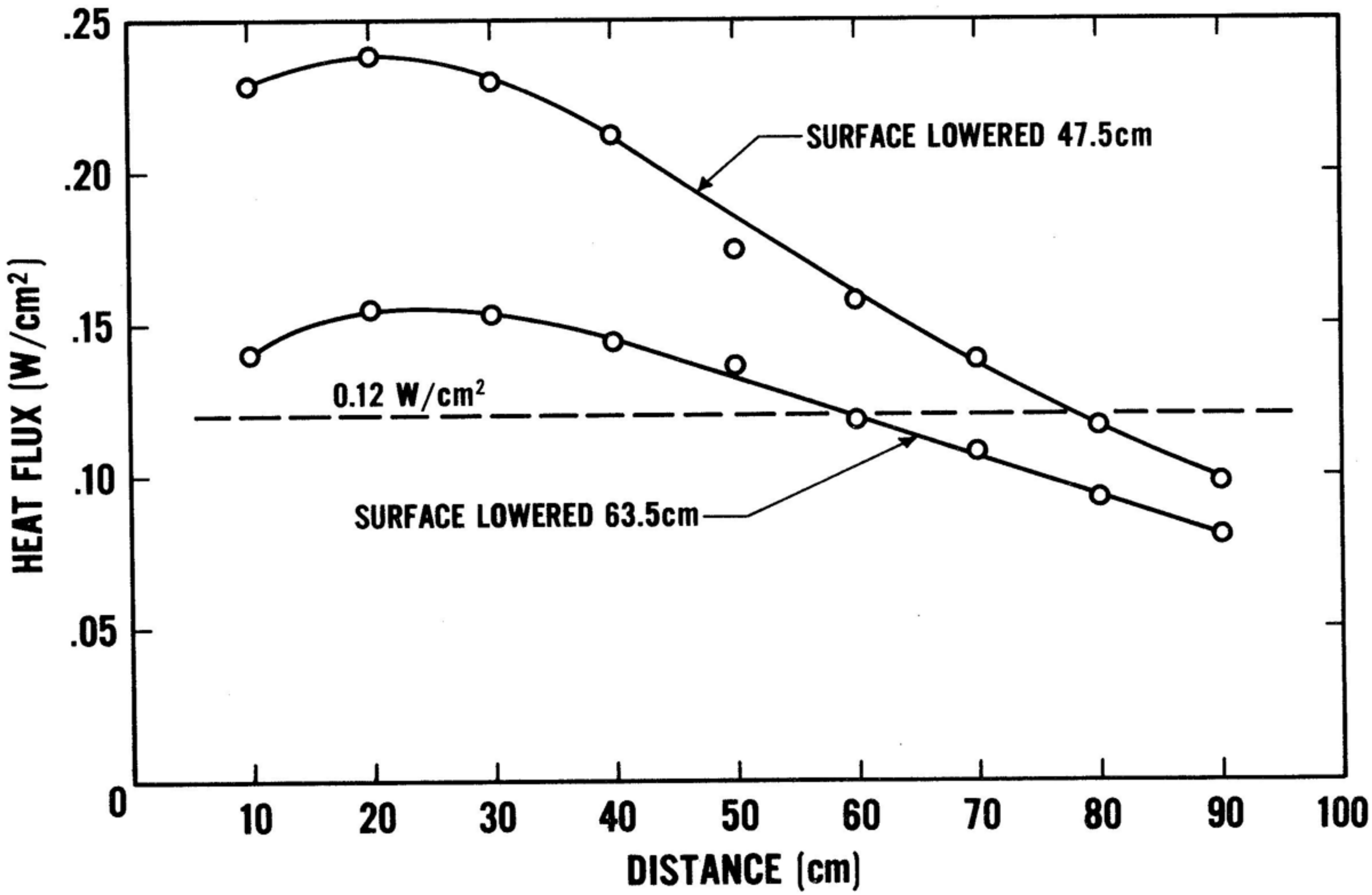

Figure 3 -- Variation of Critical Radiant Flux
with Preheat Time, Material B

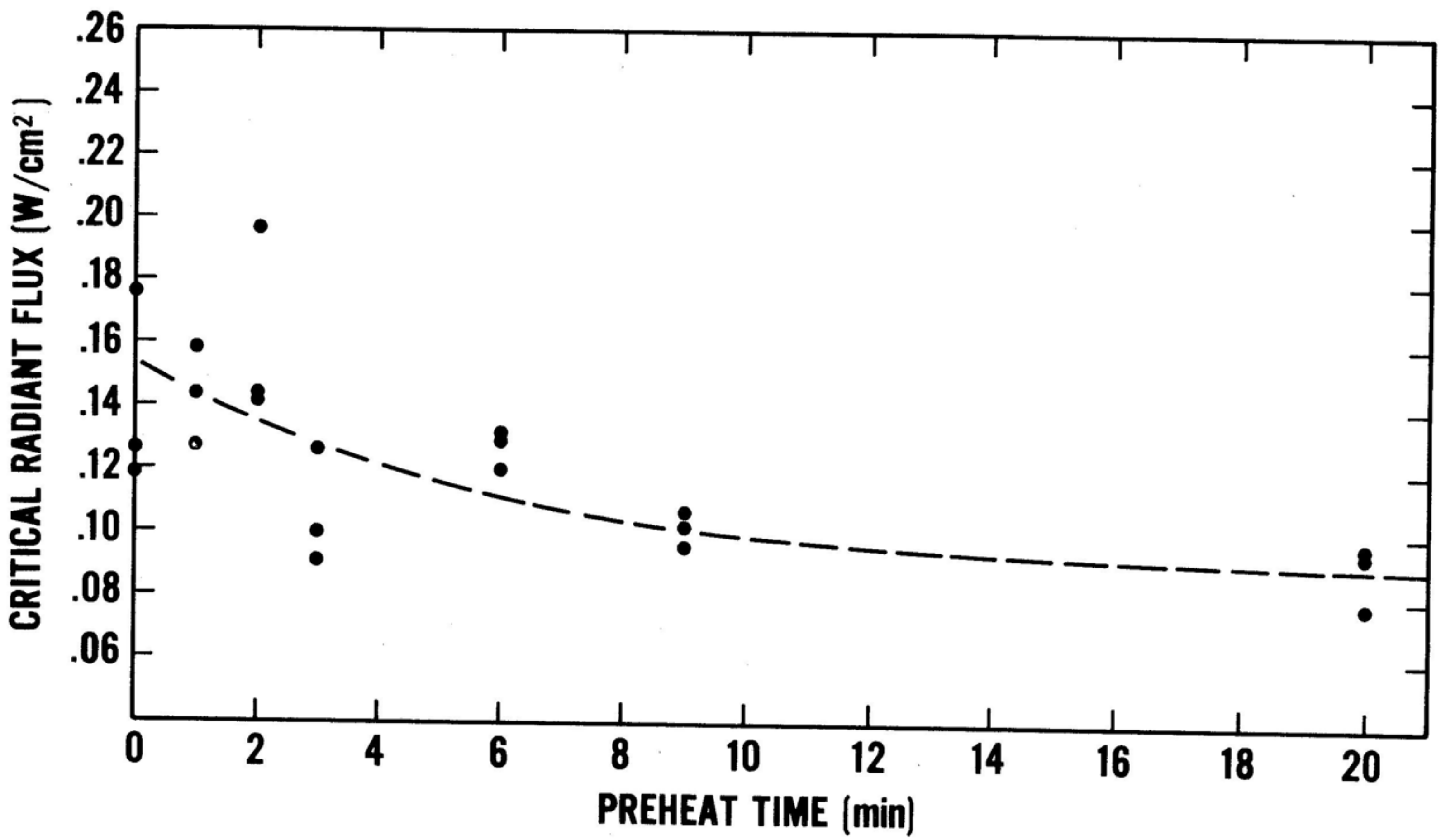

Figure 4 -- Variation of Critical Radiant Flux with Preheat Time, Material E

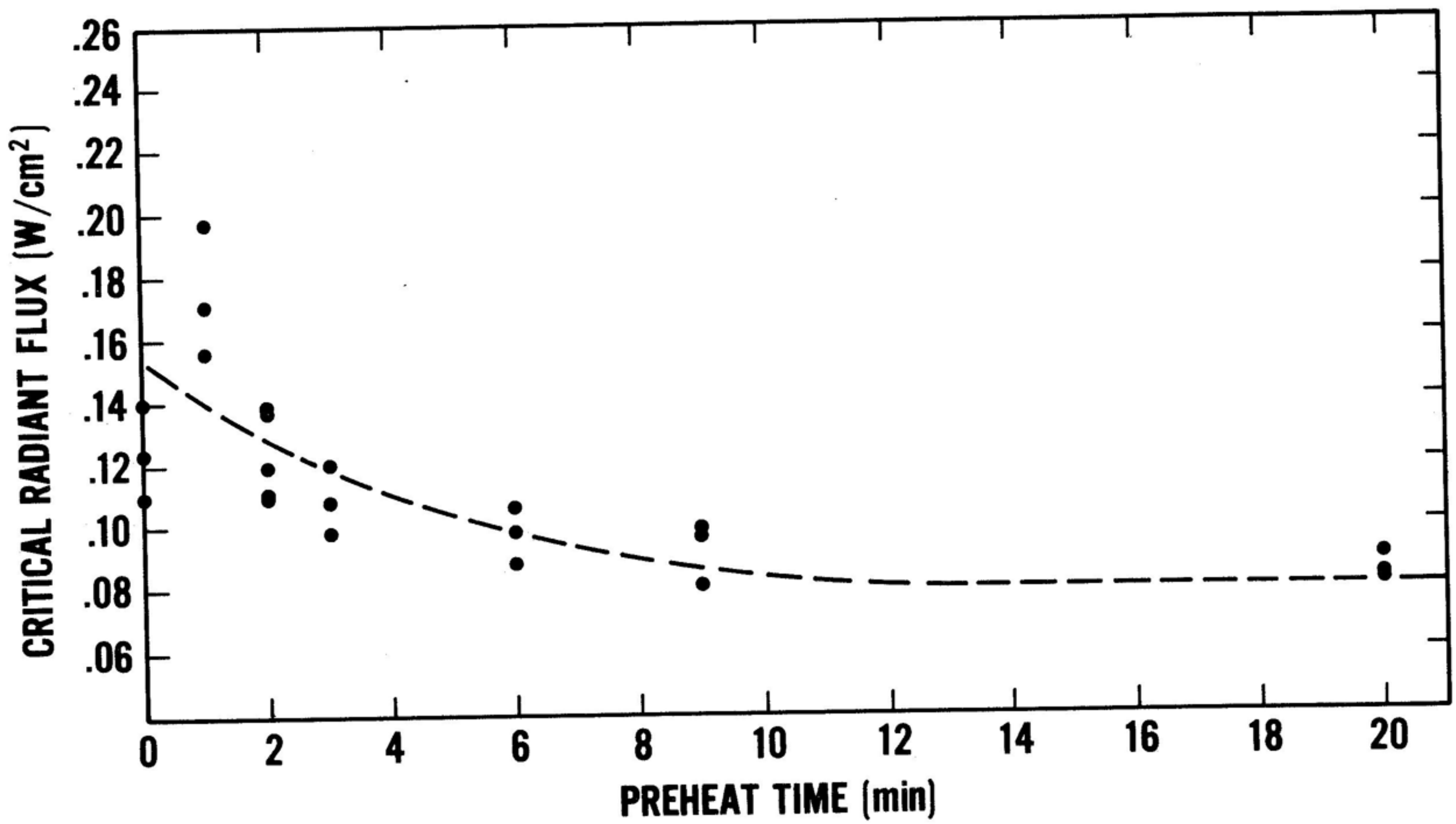

Figure 5 -- Variation of Critical Radiant Flux
with Preheat Time, Material G

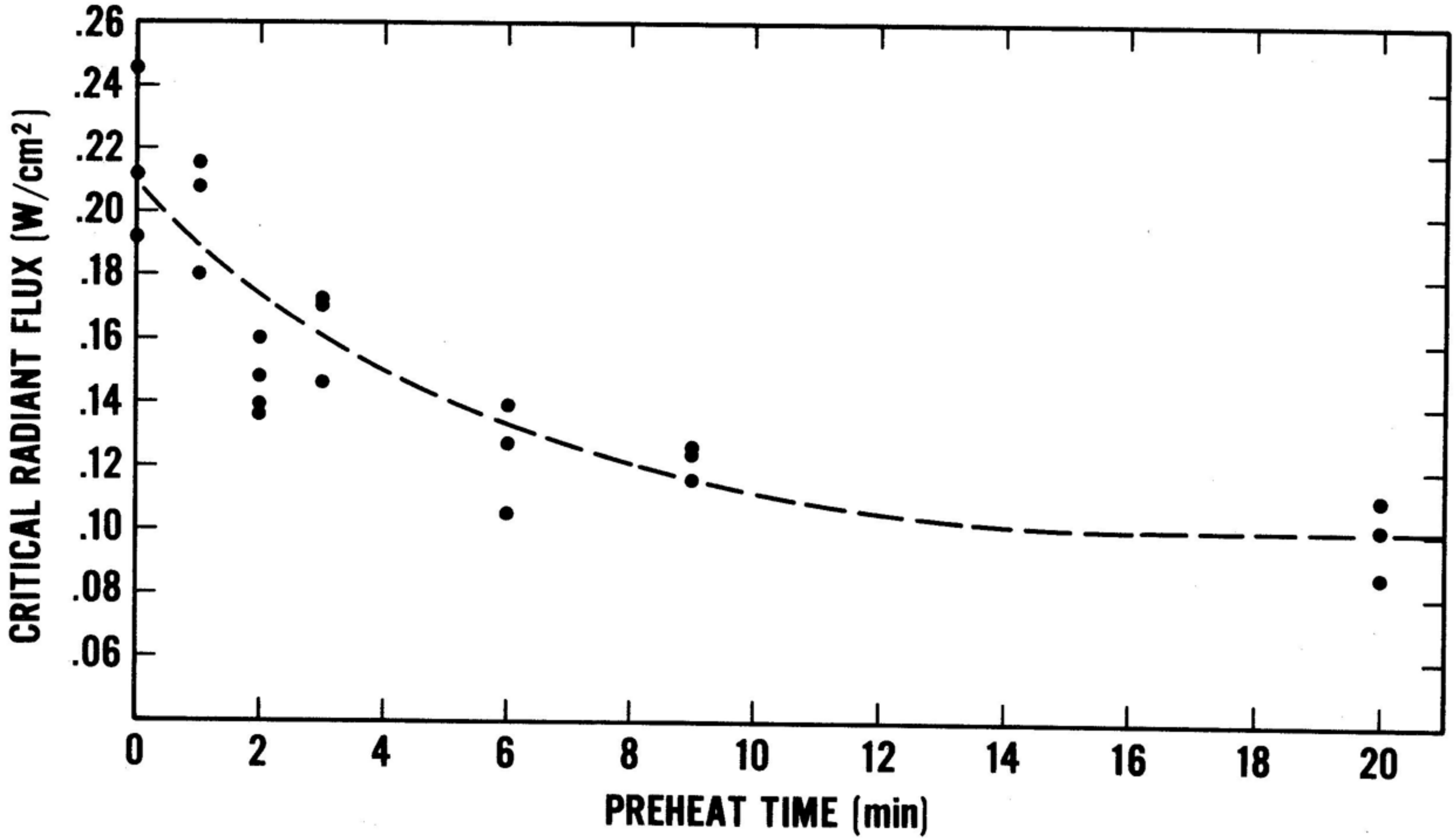

Figure 7 -- Cigarette Smoldering Test Results
Under Various Humidity Conditions

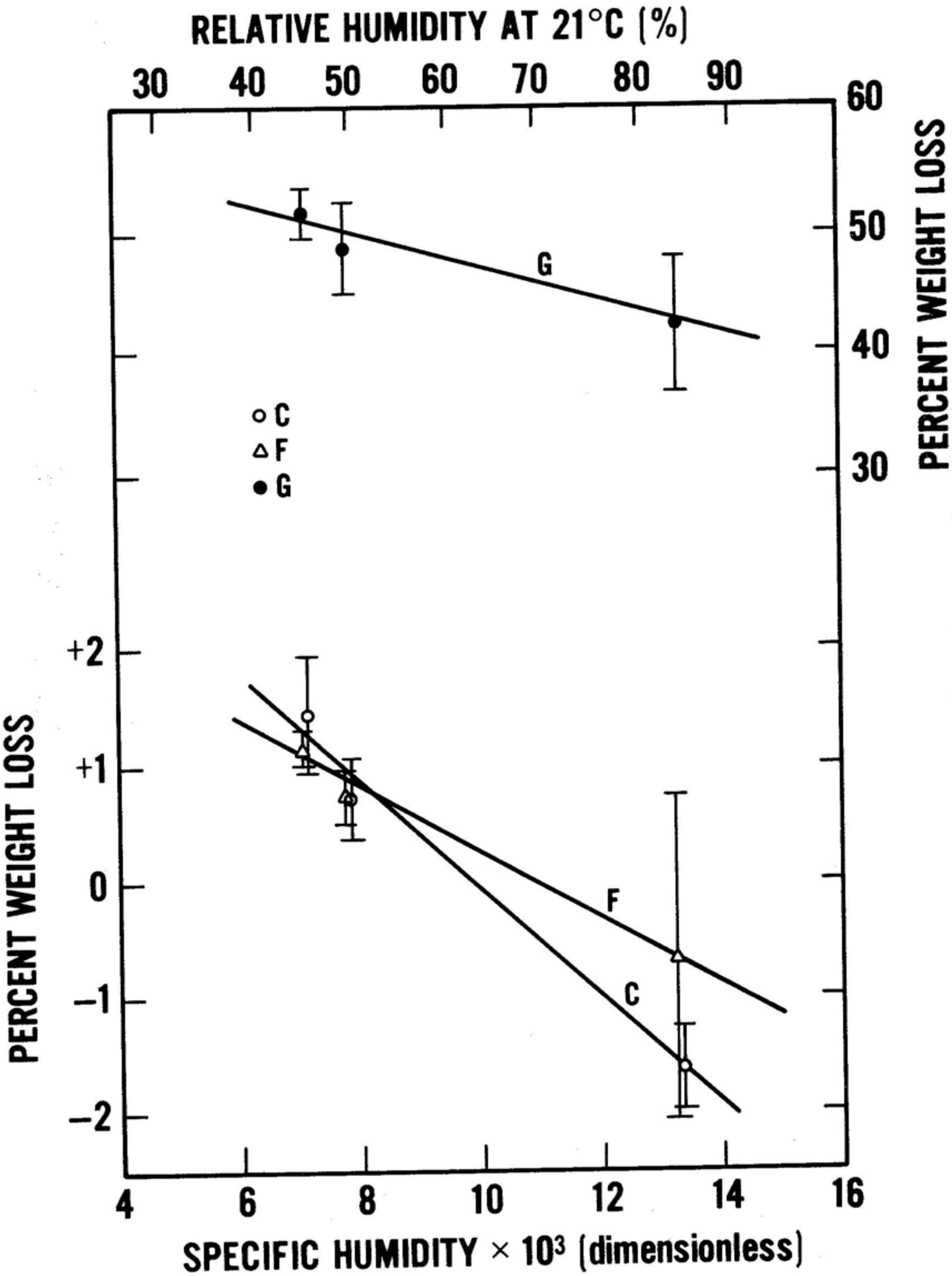

Figure 6 -- Large-Scale Attic

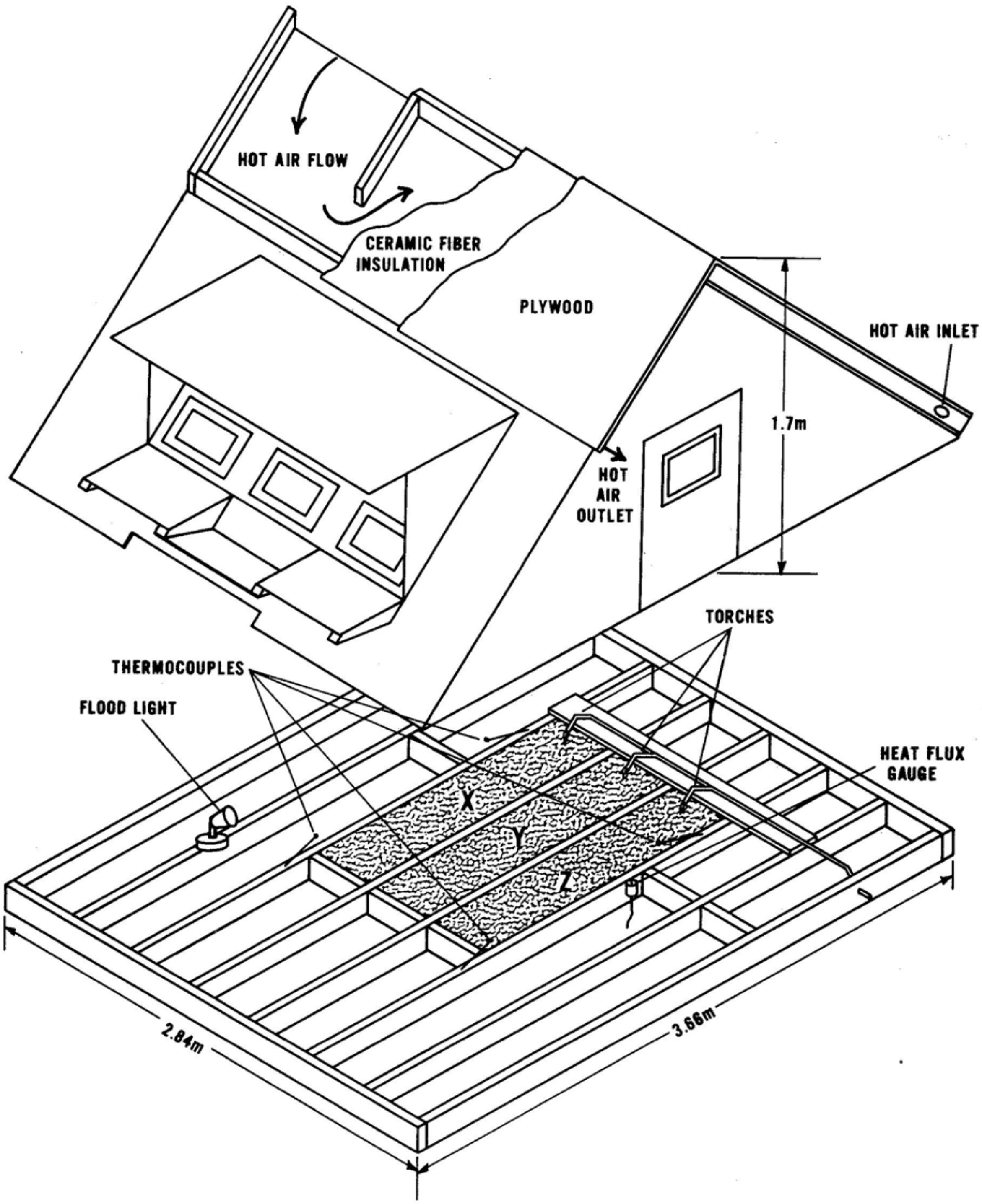

Table 1. AFRPT Test Results

Regular Flux 0.1-1.1 W/cm^2

Material	Critical Radiant Flux W/cm^2	Average	Repeatability COV
A	0.54, 0.46, 0.43	0.48	11.9%
B	0.19, 0.18, 0.15	0.17	12.4%
C	0.21, 0.17, 0.19	0.19	10.5%
D	<.10, <.10, <.10	<.10	--
E	0.18, 0.14, 0.15	0.16	13.2%
F	<.10, <.10, <.10	<.10	--
G	0.16, 0.17, 0.16	0.16	4.4%
H	<.10, <.10, <.10	<.10	--

Low Flux 0.04-0.35 W/cm^2

Material	Critical Radiant Flux W/cm^2	Average	Repeatability COV
A	>.350, >.350, >.350	>.35	--
B	0.196, 0.144, 0.142	0.16	19.2%
C	0.221, 0.196, 0.224	0.21	7.6%
D	<.040, <.040, <.040	<.04	--
E	0.111, 0.138, 0.119	0.12	11.8%
F	<.040 <.040, <.040	<.04	--
G	0.138, 0.139, 0.139	0.14	1.2%
H	0.113, 0.072, 0.073	0.09	26.6%

* Repeatability coefficient of variation (COV) as defined in Interlaboratory Evaluation of the Attic Floor Radiant Panel Test and Smoldering Combustion Test for Cellulose Thermal Insulation, J.R. Lawson, NBSIR 78-1588

Table 2. Effect of Density on Critical Radiant Flux Material G

Low Flux Profile

Specimen	Density kg/m^3	Critical Radiant Flux W/cm^2	Average ± Standard Deviation
G-1	24	0.161	
G-2	24	0.146	0.153 ± .008
G-3	24	0.152	
G-4	40	0.144	
G-5	40	0.160	0.147 ± .012
G-6	40	0.136	
G-7	64	0.278	
G-8	64	0.255	0.262 ± .014
G-9	64	0.254	

Table 3. Effect of Density on Critical Radiant Flux Material E

Regular Flux Profile

Specimen	Density kg/m^3	Critical Radiant Flux W/cm^2	Average ± Standard Deviation
E-1	32	0.13	
E-2	32	0.11	0.12 ± .01
E-3	32	0.13	
E-4	48	0.14	
E-5	48	0.15	0.14 ± .01
E-6	48	0.13	
E-7	64	0.23	
E-8	64	0.23	0.23 ± .01
E-9	64	0.24	

Table 4. Critical radiant flux values

Material	Preheat Time (min)	CRF W/cm^2	Average CRF W/cm^2
B	0	0.126, 0.119, 0.176	0.140
	1	0.127, 0.158, 0.144	0.143
	2	0.196, 0.144, 0.142	0.161
	3	0.100, 0.091, 0.126	0.106
	6	0.130, 0.130, 0.120	0.127
	9	0.102, 0.096, 0.107	0.102
	20	0.096, 0.096, 0.078	0.090
E	0	0.140, 0.110, 0.124	0.125
	1	0.156, 0.197, 0.171	0.175
	2	0.111, 0.138, 0.119	0.123
	3	0.120, 0.098, 0.108	0.109
	6	0.088, 0.106, 0.098	0.097
	9	0.097, 0.099, 0.081	0.092
	20	0.082, 0.082, 0.089	0.084
G	0	0.192, 0.212, 0.246	0.217
	1	0.180, 0.216, 0.208	0.201
	2	0.144, 0.160, 0.136	0.147
	2	0.138, 0.139, 0.139	0.139
	3	0.171, 0.172, 0.146	0.163
	6	0.127, 0.105, 0.119	0.117
	9	0.124, 0.116, 0.126	0.122
	20	0.110, 0.101, 0.086	0.099

Table 5. Traverse of air temperature from the roof peak

Distance Below Peak, cm	Air Temperature, °C
18	83°C
31	83°C
46	77°C
61	72°C
91	61°C
119*	56°C

* Average of four thermocouple at corners of insulated sections of the attic base as indicated in figure 6.

Table 6. Total heat flux 10 cm above insulated joist spaces at test conditions

Distance from Ignition Point in Center of Joist Space (cm)	Total Heat Flux W/cm^2 Joist Space		
	1	2	3
0	.053 ± .002	.053	.055
30	.055	.053	.055
61	.053	.057	.057
91	.053	.055	.057
122	.053	.053	.057

Table 7. Flammability measurements on test materials

Material	CRF AFRPT	FSC by ASTM E 84 Tunnel
F	0.15	Not Measured
G	0.16	32.7
B	0.17	31.3
H	0.09	22.1
S	<0.11	35.8

Measured with low flux profile (0.04-0.35 W/cm^2)
Data from reference 7

Table 8. Large-scale attic test results

Material	Air Preheat Temp	Air Temp** at Ignition	Peak Air** Temp	Flux to Floor at Ignition	Peak Flux	Max Spread Along Three Joist Spaces*
	°C	°C	°C	W/cm^2	W/cm^2	
F	73	NM	102	NM	NM	35 cm
G	71	76	79	0.055	0.060	10 cm
B	72	75	78	0.054	0.059	10 cm
H	72	76	90	0.055	0.065	> 15 cm < 30 cm
S	72	77	86	0.052	0.059	30 cm

NOTE: NM - Not Measured

* Distances were judged from video tape recordings of the test. For material H, the maximum spread was difficult to determine because of excessive smoke production. The maximum spread for material H was between 15 and 30 cm. All other measurements are accurate to within 5 cm.

** Point of measurement 0.69 m below peak in roof

Table 9. Blown and settled density values for the test insulations

Material	Blown Density* Kg/m^3	Settled Density* Kg/m^3
C	19.10	26.80
E	32.52	49.33
F	27.08	41.30
G	29.59	44.39

* Average of three samples. Data supplied by CPSC laboratory.

Table 10. Smoldering test data percent weight loss

	Laboratory Conditions		
Temperature	21°C	21°C	24°C
Relative Humidity	84%	52%	39%
Specific Humidity	0.0133	0.0078	0.0071
Cellulose Insulation			
C	35.8 (F)	0.28	0.84
	- 1.31	0.84	1.77
	- 1.40	0.47	1.40
	- 1.59	0.93	2.14
	- 2.14	1.12	0.93
	Av = - 1.61*	Av = 0.73	Av = 1.42
	σ = 0.37	σ = 0.34	σ = 0.55
E	50.4 (F)	57.5	52.2 (F)
	51.7 (F)	52.0 (F)	54.5 (F)
	- 1.01	0.10	54.0 (F)
	- 1.12	52.9 (F)	0.41
	- 1.22	53.7 (F)	57.8 (F)
	----	----	----
	----	----	----
F	- 2.24	0.66	1.21
	1.63	0.97	1.15
	- 0.85	0.91	1.21
	- 1.03	0.42	1.27
	- 0.79	0.73	0.91
	Av = - 0.66	Av = 0.74	Av = 1.15
	σ = 1.40	σ = 0.22	σ = 0.14
G	39.2 (F)	52.1 (F)	53.1 (F)
	44.5 (F)	48.1 (F)	50.7 (F)
	41.0 (F)	51.9 (F)	51.6 (F)
	51.4 (F)	43.2 (F)	56.5 (F)
	38.3 (F)	51.0 (F)	50.9 (F)
	Av = 42.9	Av = 49.3	Av = 42.4
	σ = 5.32	σ = 3.75	σ = 1.99

(F) - Weight loss greater than 15%, failing result under HH-I-515D
* - Average and standard deviation calculated neglecting (F) data

Note: Negative weight loss values represent weight gain (due to moisture absorption)

Table 11. Predicted change in specific humidity to produce a significant change in test results at 21°C, 52% RH

Materials	Average	Two Standard Deviations	Change in Specific Humidity
C	0.73	0.68	0.0038
F	0.74	0.44	0.0016
G	49.3	7.50	0.0054
		Average	0.0036

Appendix 1

TECHNICAL RATIONALE FOR THE GENERAL SERVICES ADMINISTRATION FEDERAL SPECIFICATION HH-I-515D FLAME RESISTANCE PROVISIONS

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December 1, 1978

Prepared for:

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1. Introduction

When consideration was being given to revision of GSA Federal Specification HH-I-515C for cellulose loose fill insulation, three questions were asked about the flammability requirements: (1) Were the existing test methods relevant to the real world? (2) If not, what test methods should be introduced in their place? and (3) What would be reasonable levels of acceptance in terms of fire safety of occupants? Recognizing the typical combustible nature of single family home construction, the basic premise was that the addition of insulation should not increase the normal and expected level of fire risk to the occupants. It is important to remember that the concern here is whether the cellulose insulation is the first item to ignite or is the cause for flame spread and not whether it becomes involved in the later stages of a fire. The effectiveness of any test method should be a function of how well it predicts the performance of a product in the real world and how well it evaluates the criteria for which it was developed.

2. Smoldering Test

A review of fire incident data (NBSIR 78-1497, A Preliminary Study of the Fire Safety of Thermal Insulation for Use in Attics and Enclosed Spaces in Residential Housing, D. Gross, July 1978) showed that the most likely hazard associated with cellulose insulation was smoldering. More than 80 percent of the fires associated with insulation involved cellulose insulation started from overheated electrical light fixtures and other electrical sources, heated flues, etc. When exposed to a heat source, whether in an attic or in side walls, cellulose insulation could be induced to smolder unless properly treated. Sufficient evidence was available to demonstrate that temperatures in excess of 260°C (500°F) could be obtained in contact with insulation, such as in attics from recessed light fixtures [(a) Final Progress Report, Detection of Exothermic Reactions in Cellulosic Insulation, D. D. Evans, September 30, 1978, Center for Fire Research, NBS; (b) Test Report NR 8TS026, Lighting

Fixture Temperature Survey, for Tinker AFB Fire Department, February 17, 1978, Engineering Laboratory, Oklahoma City ALC; (c) Testing of Cellulose Insulation, performed by the Consumer Product Safety Commission Engineering Laboratory, July 31, 1978] and from glowing wire connections in side walls (NBS Building Science Series 103, Exploratory Study of Glowing Electrical Connections, W.J. Meese and R. W. Beausoliel, October 1977) and that this temperature was sufficient to induce smoldering. However, neither of the tests for flame spread referenced in HH-I-515C or D address the smoldering problem.

The smoldering test introduced into HH-I-515D utilizes a smoldering cigarette as the ignition source. The cigarette specified has a maximum temperature of about 700°C in the very small glowing region (NBSIR 78-1438, Back-up Report for the Proposed Standard for the Flammability (Cigarette Ignition Resistance) of Upholstered Furniture, PFF 6-76, J. J. Loftus, June 1978), which is sufficient to initiate smoldering if it is going to occur. (There are also cases where cellulose insulation has been ignited by a cigarette.) What is of concern is whether the smoldering will continue to propagate in the cellulose insulation once it has been started. This condition simulates the behavior of a material which is heated to a sufficiently high temperature to initiate smoldering and then continues smoldering beyond the heated region. A review of some available smoldering data, e.g., Gross (Ref. cited) and Lawson (NBSIR 79-1588, Interlaboratory Evaluation of the Attic Flooring Radiant Panel Test and Smoldering Combustion Test for Cellulose Thermal Insulation, J. R. Lawson, February 1979), shows that if a product does not exhibit smoldering tendency the weight loss of the specimen would be of the order 1 or 2 percent. On the other hand, if the product is ignited by the smoldering cigarette, the weight loss of the specimen would be upwards of 30 to 35 percent. Because of the nature of the test results, it is reasonable to impose a weight loss criterion midway between these values, hence the 15 percent weight loss requirements. Although no instances of flaming combustion have been observed from a smoldering specimen, it seemed appropriate to impose this requirement also. The test as currently defined will screen out many, but probably not all, materials which will permit the propagation of smoldering in the common insulation-covered recessed light fixture scenario which might be encountered in residential use.

Research is continuing to determine the feasibility of carrying out the test at elevated temperatures or by other modifications to better simulate real world occurrences.

3. Flammability Test

The basic test for flammability in HH-I-515C in the ASTM E-84 Standard Test Method for Surface Burning Characteristics of Building Materials (tunnel test). A fixed orientation and exposure is used for all materials: wall and ceiling linings, plumbing and electrical piping, adhesives, all types of insulation, etc. Since different products are exposed to ignition sources and to different levels of fire exposure depending on their end-use configuration, due consideration should be given to an appropriate exposure. In the retrofit insulation market, in particular for residential occupancies, cellulose loose fill insulation has two major applications: (1) on the floors of attics in an exposed condition and (2) in exterior side walls. It was felt that the attic floor application was more critical and this problem should be addressed first.

Examination of the fire test methods in HH-I-515C shows that the E-84 is inappropriate for testing cellulose insulation installed on the floor of an attic. Cellulose loose fill insulation is not normally applied over a metal screen nor is it likely to be exposed to flames from below. In a typical fire situation in the attic, the cellulose is not subjected to a 5000 BTU/min fire and/or a wind velocity of 240 ft/min. It is apparent that none of the above factors which are all part of the E-84 tunnel test have any relation to evaluating insulation on the attic floor. Gross (ref. cited) points out that the tunnel test has been shown to be invalid for low density fire retardant treated plastic foams; its applicability to and appropriateness for other low density insulation materials may also be seriously questioned. For example, a flame spread classification of 25 for a 2 pcf. insulation has no relation to a flame spread classification of 25 for 40 pcf. treated lumber. It should also be noted that untreated cellulose insulation, which would be considered to be totally unacceptable, has been reported to have flame spread classifications from about 50 to 120; however, in real fire situations, these materials burn more rapidly than plywood having flame spread classifications of 150 to 200.

Having discussed above the shortcomings of the E-84 test, it remains to be shown how the insulation, in its end-use configuration in an attic, could become involved in a fire. The insulation is applied between and over floor joists in an attic, where the air is relatively still and the temperature and humidity vary depending upon the season, the geographical location, the geometrical arrangements, the extent of free or forced attic ventilation, etc. The most severe exposure is likely to develop during periods of elevated outdoor temperatures plus solar radiation. A small ignition source, such as an electrical failure causing an arc or a carelessly applied propane torch, would be typical ignition sources.

This scenario, insulation on the floor of the attic in still air exposed to radiation from the roof and subjected to a small ignition source, is modelled by the conditions of the Standard Method of Test for Critical Radiant Flux of Floor Covering Systems Using a Radiant Heat Energy Source (NFPA 253, ASTM E-648) which was originally developed for evaluating flooring systems in corridors exposed to radiation from fully developed fires in rooms. The test method involves a graded radiant exposure varying from 0.1 to 1.1 W/cm^2, corresponding approximately to the differences between direct solar radiation in the summer to the irradiance on the floor from a moderately severe flaming fire on the ceiling. However, it also has been shown that the test method is applicable to flooring systems exposed to small fires in rooms (NBSIR 76-1013, Flame Spread of Carpet Systems Involved in Room Fires, K.-M. Tu and S. Davis, June 1976). This test, commonly known as the Flooring

Radiant Panel Test, was adapted to accommodate insulation specimens and was introduced into the GSA HH-I-515D standard as the Attic Floor Radiant Panel Test. In the attic floor radiant panel test, the material under evaluation is exposed to a graded irradiance and ignited with a pilot burner at the high flux end of the specimen. The flux at the farthest point where the flame extinguishes is known as the critical radiant flux.

In order to obtain an estimate of attic temperatures for some of our preliminary work, temperatures were measured in the attic of a private home in the Washington, D.C. area during July 1977. Daytime temperatures as high as 140°F were measured. A temperature of 160°F is used as a design value for attic fans by the American Ventilation Association (The Handbook of Moving Air, Houston, Texas, 1977). This temperature would correspond to the underside of the roof acting as a black body radiator imposing a flux level of 0.08 W/cm^2 onto the insulation. A 50 percent safety factor would bring the flux level to 0.12 W/cm^2; for comparison purposes, the solar radiation reaching the surface normal to the sun's rays on a clear summer day in Florida is 0.11 W/cm^2 (350 BTU/ft^2 hr). This means that a fire would not propagate in the attic insulation if the energy delivered to the insulation is less than 0.12 W/cm^2. The critical radiant flux for plywood, wood joists, etc. is 0.35 to 0.40 W/cm^2; the test requirement of $\geq$ 0.12 W/cm^2 represents a minimum level for safety, not an equivalent to existing materials.

The Gross report describes some large-scale attic mockup tests in which several cellulosic products were exposed to temperatures of 160 and 180°F. These experiments supported the use of the attic floor radiant panel test and the criterion chosen for recommendation to GSA. In addition, we are aware of some tests run at Underwriters Laboratories from which they concluded: "Cellulosic insulation with a (critical) radiant flux level of 0.12 W/cm^2 or greater, as determined by the floor and attic (sic) radiant panel test, resisted flame propagation under the highest ambient temperature conditions of the attic simulation fire test." The highest temperature used in their study was 160°F. There is no correlation between critical radiant flux and flame spread classification by ASTM E-84; low flame spread classifications may be either above or below a critical radiant flux of 0.12 W/cm^2.

4. Flame Resistance Permanency

Another aspect of the HH-I-515C standard which needs to be mentioned is the flame resistance permanency test referenced in ASTM C-739 [Standard Specification for Cellulose Fiber (Wood-Base) Loose Fill Thermal Insulation]. This test requires that a cellulose insulation product be evaluated in the E-84 Tunnel before and after the following prescribed temperature and humidity cycling program:

24 hours at 180°F and 96% relative humidity
24 hours at 80°F and 50% relative humidity
24 hours at 180°F and 96% relative humidity
24 hours at 80°F and 50% relative humidity

Under some circumstances, the use of a two-foot tunnel is permitted in place of the 25-foot tunnel; the current CPSC requirements would permit this only if the flame spread classification of the product was 20 or less. The two-foot tunnel test is not a standard ASTM method and its use does not imply that there is a correlation with the E-84 method (ASTM C-739-77). Some limited work was carried out at NBS to evaluate the cycling process; the HH-I-515D flammability test methods were used to evaluate the effect of temperature and humidity cycling on the flammability of cellulose insulation. Three conclusions came from this work. (1) Immediately following the last 24-hour period at 80°F and 50% relative humidity, the specimens appeared to be too wet to test; the specimens were conditioned for 10 days additional at 21°C and 50% relative humidity, (2) the cycling process appears to improve the flame retardance of the cellulose insulation slightly by causing the soluble salts to be "driven" into the cellulose fibers, and (3) the cycling procedure appears to be an attempt at an accelerated aging test but does not appear to take into account the following:

(a) possibility of liquid water dropping on top of the insulation (from condensation or ice formation in winter, or roof leakage) and removing the fire retardant salts from the surface layer,

(b) a relative humidity gradient versus a uniform relative humidity, and

(c) final cycle to a low relative humidity level (20 to 30 percent relative humidity) typical of a dry season.

It was not convincing that this test from ASTM C-739, or any slight modification or it, was an appropriate measure of flame resistance permanency; hence, it was not considered for inclusion in HH-I-515D. It must be emphasized, however, that such a test should be required and that research is needed to define a suitable test.

One aspect of flame resistance permanency which was not addressed in HH-I-515C is the problem of physical separation of flame retardant chemical from the cellulose fibers. The accumulation of chemical at the bottom of the bag has been observed on several occasions. During the recent interlaboratory program evaluating the HH-I-515D flammability tests described by Lawson (ref. cited) it was noted that there was considerable separation of chemical in one of the products; this material gave the most erratic results in the smoldering test. In the future consideration of a permanency test, this problem will be examined.

5. Smoke

It was presumed that there was no need for a smoke test unless smoke (toxic gases or obscuring particulates) was shown to be a problem. In the attic, the principal problems are smoldering ignition or rapid flame spread on the exposed surface. If both processes are prevented by appropriate tests and criteria, then the smoke generated will be limited. Therefore, it was considered inappropriate to impose any requirement for smoke determination.

6. Test Method Precision

As part of the development of the flammability test methods for HH-I-515D, an interlaboratory program was conducted to evaluate the repeatability and reproducibility of the methods for cellulose insulation. Details of this study are described by Lawson (ref. cited). The results for the critical radiant flux determination showed that the pooled coefficient of variation for repeatability (within laboratory) was 12 percent and the average coefficient of variation for reproducibility (between laboratory) was 25 percent; these values were not significantly greater for loose fill cellulose insulation than for other materials and compare favorably with precision estimates available from other standard fire tests.

Because of the split test results (some pass and some fail) for the smoldering combustion reported by several of the laboratories, it did not appear practical to put the data through a rigorous statistical analysis. Agreement among the laboratories was relatively good; it appears that some variation in laboratory procedures contributed to the scatter of data.

Based on the work of this study, there is reasonable assurance that results from different laboratories evaluating the same material for compliance with Federal Specification HH-I-515D will be consistent.

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Bethesda, Maryland 20202

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)*

The attic floor radiant panel test (AFRPT) and smoldering combustion test are two fire performance tests required by the Consumer Product Safety Commission (CPSC) as part of a mandatory standard for loose fill cellulosic home insulation. In providing technical support to CPSC, the sensitivity to variations in parameters of each test method were studied. Specimen density was found to have no effect on critical radiant flux values when measured with the AFRPT for two paper-based cellulosic insulations tested at densities below 48 kg/m^3. A low flux exposure profile, ranging from 0.04 to 0.35 W/cm^2, was developed to extend the range of the AFRPT about the region of greatest interest. The critical radiant flux measured using the low flux profile was found to be sensitive to changes in preheat time from the prescribed two minute specimen preheat. Large-scale attic fire tests verified the predictive ability of AFRPT measurements. Results from the smoldering combustion test were shown to be sensitive to test room humidity conditions over the range of 39 to 84 percent RH.

12. KEY WORDS *(Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)*

attic floor radiant panel test; cellulose insulation; smoldering; fire test; flame spread; HH-I-515D

13. AVAILABILITY

☒ Unlimited
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