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**Investigation of the Fire
Performance of Building Insulation
In Full-Scale and Laboratory
Fire Tests**

Wayne A. Kleinfelder

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MASTER

Part of
The National Program
for
Building Thermal Envelope Systems
and Materials

Prepared for the
U.S. Department of Energy
Conservation and Renewable Energy
Office of Buildings Energy R&D
Building Systems Division

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**INVESTIGATION OF THE FIRE PERFORMANCE OF BUILDING INSULATION
IN FULL-SCALE AND LABORATORY FIRE TESTS**

Wayne A. Kleinfelder

Part of
The National Program for
Building Thermal Envelope Systems and Materials

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FOREWORD

This is the Report of an investigation conducted by Underwriters Laboratories under Subcontract No. 7863 and Supplemental Agreement No. 1 issued by Oak Ridge National Laboratory under a project sponsored by the U.S. Department of Energy.

The work reported was performed at UL's Northbrook, Illinois facility and was conducted during the time period of May, 1980 through November, 1981.

Respectfully submitted:

UNDERWRITERS LABORATORIES INC.

WAYNE A. KLEINFELDER
Engineering Group Leader
Fire Protection Department

Reviewed and Approved by:

R. L. PARKS
Associate Engineer
Fire Protection Department

JAMES R. BEYREIS
Managing Engineer
Fire Protection Department

WAK/RLP/JRB:bg

FOREWORD

This is one of a series of reports to be published describing research, development, and demonstration activities in support of the National Program for Building Thermal Envelope Systems and Materials. The National Program involves several federal agencies and many other organizations in the public and private sectors who are addressing the national objective of decreasing energy wastes in the heating and cooling of buildings. Results described in this report are part of the National Program through delegation of management responsibilities for the DOE lead role to the Oak Ridge National Laboratory.

Ted S. Lundy
Program Manager
Building Thermal Envelope
Systems and Materials
Oak Ridge National Laboratory

William Gerken
Program Manager, Building Systems
Division
Office of Buildings Energy R&D
Department of Energy

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INVESTIGATION OF THE FIRE PERFORMANCE OF BUILDING INSULATION
IN FULL-SCALE AND LABORATORY FIRE TESTS

Wayne A. Kleinfelder

ABSTRACT

Twenty-two insulations are exposed to fire tests including the 25 ft Tunnel test, the Attic Floor Radiant Panel test and actual fire conditions of a simulated attic configuration. The insulations consisted of a number of cellulose fiber insulations, utilizing various chemical treatments, glass fiber and mineral fiber insulations. The fire performance characteristics of the insulations were measured in each of the three test scenarios and the report compares their results.

INTRODUCTION

This is a report of a fire test investigation on primarily cellulose insulation materials when exposed to two standard laboratory test methods and to actual conditions as represented by a simulated wood joisted attic. The investigation included tests on 19 samples of treated cellulose fiber, untreated cellulose fiber, a glass fiber and a mineral wool insulation.

One of the laboratory test methods was the 25 ft Tunnel test as described in "Test Method for Surface Burning Characteristics of Building Materials" (variously designated as UL 723, ASTM E-84, NFPA 255 and ANSI A.25).¹ The second laboratory test method is known as the "Attic Floor Radiant Panel Test" (AFRP) which is described in detail in "Standard Method of Tests for Critical Radiant Flux of Exposed Attic Floor Insulation Using a Radiant Heat Energy Source."² The third fire exposure was performed in a simulated wood frame attic representative of construction practices and materials commonly in use today. The performance of the materials in the simulated attic was used as a bench mark for judging the performance of the two laboratory tests.

A total of 66 simulated attic tests were performed in this investigation along with 37 tunnel tests and 57 AFRP tests. For the attic tests, two flaming ignition sources were used; alcohol spill and a propane torch and four non-flaming ignition sources were used; cigarettes, overheated electric wire, and a recessed light fixture (rated lamp and overrated lamp).

OBJECTIVE

The objective of the investigation was to: (1) determine the actual performance of the insulations in the attic environment, and (2) to compare the abilities of the laboratory tests to properly assess the performance of the insulations by comparing their results to the attic results.

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BACKGROUND

Cellulose loose fill insulation is required by law to conform to requirements set forth in the Consumer Product Safety Commission's (CPSC) Interim Safety Standard For Cellulose Insulations. The current version of the CPSC Standard³ provides for the use of the Attic Floor Radiant Panel Test.^{2,3} But prior to the adoption of the current version, fire performance characteristics were determined using the 25-Ft Tunnel Test⁴ method and approximately 1200 tests of cellulose insulation materials using the 25-Ft Tunnel Test were conducted by Underwriters Laboratories under a contract arrangement with CPSC.

Data provided in consideration of the proposed adoption of the AFRP Test, as a replacement for the 25 Ft Tunnel Test, was limited to 1) interlaboratory studies to investigate repeatability and reproducibility^{2,5} of the AFRP Test and 2) a preliminary study of fire behavior in a full-scale attic⁶. While the behavior of insulation in the attic fires was compared with performance in the AFRP Test, no comparison was made to the 25 Ft Tunnel Test results. Therefore, no information was presented to indicate a need to abandon the Tunnel Test Method.

In order to supplement the data in the above studies and to provide results of the 25-Ft Tunnel Test for comparison purposes, UL conducted an in-house investigation of building insulations using full-scale and both type of laboratory fire test methods. The initial work of the program concentrated on the fire performance of cellulose insulations in a full-scale test geometry which incorporated several ambient test conditions. The results of this program were presented in a report entitled "Flammability of Thermal Insulation Materials in Laboratory Tests and a Simulated Attic."⁷

The work described in the following is a continuation of that described in UL's in-house investigation, and its intent is to assess the suitability of the AFRP Test and the 25-Ft Tunnel Test for evaluating the fire behavior of cellulose and other insulations in a full size attic.

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TEST PLAN

The plan of this investigation was to compare the relationship between the results of full-scale simulated attic fire tests and the 25-Ft Tunnel Test and AFRP Test for a variety of cellulosic insulations. For comparison purposes, untreated cellulose, shredded glass fiber and blown mineral wool insulations were also examined in the investigation.

Initially, cellulose insulation materials manufactured using the same chemical formulation but varying the chemical add-on rate were evaluated by the 25-Ft Tunnel Test. The chemical add-on rate is defined as the percent by weight of chemical contained in the finished material. The chemical add-on rates of these cellulosic materials were designed to produce flame spread values of approximately 25, 35, 45, 55 and 65 as measured by the 25-Ft Tunnel Test.

These same five materials were used in a series of attic tests to bracket the flame spread value corresponding to the threshold of full fire involvement under the influence of a flaming ignition source.

After determining the flame spread values that bracketed the threshold of full fire involvement, four additional typical formulations of cellulose insulation were subjected to laboratory and simulated attic tests. These four additional formulations used different treatment chemicals than that of the first samples and were designed with chemical add-on rates to produce values of flame spread near the threshold values, both above and below. It was the purpose of these additional formulations to determine if similar flaming and smoldering conditions existed for a variety of typical chemical formulations presently being used in the industry.

Six additional samples of cellulosic insulation were added to the investigation. These samples were provided by the Department of Energy and are presently being used in other investigations to study the flammability permanency of these materials. The test data developed in this Report will be used to supplement the data from the permanency investigation.

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Two flaming ignition sources, and four non-flaming ignition sources were also utilized to produce a smoldering condition within the insulation in the full-scale attic fire tests. These non-flaming sources consisted of: 1) a recessed lighting fixture, with both rated and over-rated lamps, 2) cigarettes, and 3) overheated electrical wiring. In those experiments involving the recessed lighting fixture, the insulation materials surrounded the fixture in order to confine heat and induce smoldering of the insulation. This type of installation condition would be in violation of the National Electrical Code⁸, but in this case, the objective was to study the effects on the insulation, not the performance of the recessed fixture.

In all attic tests, the attic was preheated by either convective heating to simulate summer conditions.

It was the purpose of those attic tests that utilized the cigarette ignition source to evaluate the potential of the insulation samples to support smoldering combustion when exposed to a localized high temperature ignition source.

The experiments with overheated electric wire were conducted with a No. 14 gauge copper wire loop installed in the center of a joist cavity at mid-depth in the insulation. The copper wire was stripped of its insulation jacket at the end of the loop to provide intimate contact with the bared wire and test material. A current of 48 amperes ac was supplied from a 115 volt source through a current limiting resistor.

While the number of materials, heating modes and ignition sources created one hundred seventy-six potential combinations for the full-scale simulated attic tests, the actual number of tests conducted was reduced by selective test procedures that eliminated redundant tests. For example, if smoldering combustion was present in a cellulosic sample, the corresponding sample having the same formulation but a lesser chemical add-on rate was not conducted. This approach permitted a reduction in the number of tests conducted to sixty-six.

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MATERIALS

Cellulosic loose fill materials, shredded glass fiber, and blown mineral wool products were evaluated in this project.

The cellulose samples were specifically formulated for this project by a cellulose manufacturer utilizing normal manufacturing procedures.

The various chemical formulations for the cellulose samples and installed blown density values of all samples are shown in Table 1.

Those cellulose samples used to bracket the value of flame spread corresponding to the threshold of full fire involvement in the full-scale simulated attic tests are identified as samples A through E. The four additional formulations of cellulose that were manufactured to produce flame spread values below the threshold of fire involvement are identified as samples G through J; and those above the threshold are identified as samples K through N. Those above the threshold had the same chemical formulation as those below but contained a lesser chemical add-on. The untreated cellulose, shredded glass fiber, and blown mineral wool were identified as samples F, O, and P, respectively.

In addition, the six additional samples of cellulose mentioned previously that were received from the Department of Energy were evaluated. These are identified in this Report as samples Q, R, S, T, V, and W.

All sample materials were blown through a machine designed for field application of the material. The machine consisted of a 40 lb capacity hopper, a 1 hp blower, a 1/3 hp agitator motor and 2 in. diameter plastic blowing hose. The test materials were installed in a manner commensurate with typical field practice such that the material was blown in a direction parallel to the attic joist to assure complete filling of the joist cavity and elimination of possible air spaces or voids in the insulation.

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EXPERIMENTS

Full Scale Attic Tests

The purpose of this portion of the investigation was to evaluate the fire performance of various materials in a simulated full-scale attic exposed to ignition sources representative of field conditions. The simulated attic was fabricated using typical construction practices. In order to simulate summer conditions, provision was made to conduct tests at an elevated ambient temperature.

The attic assembly was constructed of materials and methods commonly used in field construction. The assembly consists of a chamber 8 ft wide and 12 ft long with a sloping roof inclined from the level of the joists at one end to a height of approximately 5 ft at the other end, as shown in ILLS. 1, 2 and 3. Roof rafters and vertical studs were nominal 2 by 4 in. lumber, and the attic floor joists were nominal 2 by 6 in. lumber on 16 in. centers. The roof rafters and vertical sides of chamber were sheathed with 1/2 in. plywood. The underside of the joists was covered with 1/2 in. gypsum wallboard.

The attic space was preheated for several hours to an ambient attic temperature of 150 F before each test. For comparative purposes, two heating methods were used, one convective and one radiative. Although the heating of an attic space in reality is achieved by the radiant effect of the sun, the majority of the attic tests were conducted using a convective heating method. This method achieved the 150°F ambient temperature much quicker than the radiant method, and exposed the materials to the elevated temperature for a longer duration within the confines of test period.

The convective method employed a portable kerosene heater to blow hot air into the structure through a flexible supply duct. A diffusing baffle was installed at a distance of 12 in. from the outlet end of the supply duct and in a plane perpendicular to the duct. The baffle was used to uniformly distribute the hot air throughout the attic space (ILLS.1, 2 and 3). The distance between the exhaust end of the heater and the inlet end of the supply duct was adjusted to produce the desired attic temperature. This heater was allowed to operate for approximately 5 hr prior to conducting the test in order to develop an equilibrium condition. Immediately before the test, heating was discontinued.

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The radiative heating method used two 4 ft long radiant heaters with a total capacity of 1500 w, fastened directly to the rafters. A blackened baffle was positioned parallel to and approximately 8 in. below the heaters. These heaters were operated for approximately 5 hr prior to and during the test. This assisted in maintaining the desired air temperature during the early stages of the test.

The various insulation materials were installed in a blown density condition between the ceiling joists to provide a simulation of exposed insulation in an open attic of a wood frame residential dwelling.

Sample materials in all tests filled the joist cavities to the top of the joists. In most attic tests, all joist cavities were filled, but a few tests were performed for comparison purposes with only two adjacent joist cavities filled.

Test Building

All full-scale simulated attic tests were conducted in a fire test building approximately 60 by 60 by 16 ft high and equipped with afterburners for smoke abatement purposes. Atmospheric conditions were not controlled in this fire test room but were recorded as part of the test record and are shown in Table 2.

Ignition Sources

The application of the various ignition sources was located near the center of the instrumented joist cavity approximately 12 in. from the 4 ft high end wall.

The flaming ignition source in most of the simulated attic tests used 15 ml of absolute ethyl alcohol ignited with a match. The alcohol was applied to the test material over a circular area approximately 50 mm in diameter. The alcohol was selected because of the ease of handling and application, reproducible burning rate, and the ability to develop a surface burning fire without prolonged contribution from the ignition source.

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Two attic tests were conducted in which the ignition source was a propane burner flame applied continuously to the surface of the insulation at the same previously noted location.

The recessed electric ceiling fixture was purchased on the open marketplace. It was rated for a 60 watt incandescent lamp, and measured 6-3/4 in. square and 4-1/2 in. deep. The housing was made of steel and incorporated a white 8 in. square opaque glass. To produce the over-rated lamp condition, a 150 W incandescent bulb was inserted into the fixture without any modification. In all attic tests that utilized the recessed fixture, all insulation materials were blown to completely surround and cover the fixture. As in previous tests, the attic enclosure was preheated for approximately five hours. The fixtures were electrically activated at the start of the preheating phase and continued for a minimum four hours after the heating was discontinued. Measurements were made of the extent of insulation material discoloration and smoldering rate if present.

The cigarette ignition source consisted of cigarettes without filter tips, made from natural tobacco and were approximately 85 mm long with a tobacco packing density of approximately 0.27 g/cm³ and a total weight of approximately 1.1 gm. The cigarette was inserted vertically, with the lit end up, into the test sample at the center of the joist cavity. The burning of the cigarette and the smoldering of the sample material were allowed to proceed undisturbed in the attic for a minimum of 4 hr. The rate of smoldering in in./hr was recorded for each material.

Attic test with overheated electric wires was conducted with a No. 14 gauge bared copper wire loop installed in the center of a cavity at mid-depth in the insulation as shown on ILL. 5. The current load of 48 amperes was selected to represent the upper range that would be anticipated in residential dwellings. The temperature rise of the bare wire buried in the insulation was monitored during the test and measurements made of discoloration and/or any smoldering that developed.

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Instrumentation

In the attic tests, temperatures were monitored by a grid of Type K Inconel-sheathed thermocouples located in the air, at the insulation upper surface and internally within the test material as indicated in ILL. 5. Thermocouples were also positioned on the steel housing of the recessed lighting fixtures and on the overheated electrical wire.

Laboratory Scale Tests

25 Ft Tunnel Test

The 25-Ft Tunnel Tests were conducted in accordance with UL 723 (ASTM E84) - "Tests For Surface Burning Characteristics of Building Materials."¹ The apparatus consists of a chamber measuring approximately 18 in. wide, 13 in. deep, and 25 ft long. The test samples are placed in the ceiling position spanning the width and length of the chamber. The test samples are exposed to a controlled ignition flame from the floor of the chamber with an induced air velocity across the surface of the sample such that an area of approximately 7 sq ft is under direct impingement of the ignition flame. Observations are made on the propagation of the flame along the length of the sample.

It is the purpose of this test to determine the comparative burning characteristics of the sample under test by evaluating the spread of flame over its surface. The values for flame spread are compared with a combustible material (red oak lumber) as approximately 100, and a noncombustible material (asbestos-cement board) as 0 on the classification scale. During the tests, all materials were supported in the ceiling position by an angle-iron frame with a 100 mesh steel screen stretched over the bottom of the support frame. As indicated in the Guide to Mounting Methods described in Appendix A of UL 723.¹ Since the wire screening retards flame propagation, the observed results were adjusted using a correction factor that has been previously determined experimentally. The correction factor used was 1.30. This technique is presently described in the Appendix of the above Standards.

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Attic Floor Radiant Panel Test

All test materials were subjected to the Attic Floor Radiant Panel Test. Tests were conducted in accordance with the method entitled "Standard Method of Test for Critical Radiant Flux of Exposed Attic Floor Insulating Using a Radiant Heat Energy Source," as currently specified in the GSA HH-I-515D Specification for "Insulation Thermal (Loose Fill for Pneumatic or Poured Application): Cellulosic or Wood Fiber,"² and the Consumer Product Safety Commission Interim Safety Standard (16 CFR Part 1209 dated July 6, 1979).³

The apparatus operated with a gas fired radiant panel inclined at a 30° angle above a horizontal sample. The radiant panel generates a radiant energy flux distribution ranging along the approximate 100 cm length of the test sample from 1.2 W/cm² at the end near the radiant panel to 0.10 W/cm² at the other end.

Results

25 Ft Tunnel Test

The flame spread results by the 25 Ft Tunnel Test are summarized in Table 3 and graphically represented in ILL. 6.

Attic Floor Radiant Panel Test

Values of Critical Radiant Flux (CRF) measured with the AFRP Test apparatus are summarized in Table 3 and graphically displayed in ILL. 7.

Full Scale Attic Tests

The results of the sixty-six simulated attic tests are summarized in Table 4. Voice records made during the conduct of each of the attic tests have been transcribed and edited for clarification, and appear in Appendix A. Typical photographs taken during the tests are included as Appendix B.

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DISCUSSION

For the treated cellulose materials investigated, as the loading or add-on rate of the chemical was reduced, the resulting flame spread values increased, as shown in Table 3. This is demonstrated by samples A through E, which incorporated the same chemical formulation but different chemical loadings. The relationship of chemical add-on and the resulting flame spread values are graphically shown in ILL. 6. This graph displays a linear relationship of flame spread versus percent chemical add-on. It may be noted that the resulting flame spread values were substantially influenced by the percentage of chemicals utilized. However, the flame spread values exhibited by the materials were less affected by the type of chemicals incorporated. It may also be noted that a percent chemical add-on of 16 or greater resulted in flame spread values at or below the threshold values.

The AFRP Test produces radiant heat flux on the sample which varies from 1.2 W/cm^2 at the end nearest the radiant source to 0.10 W/cm^2 at the other end of the sample. The majority of the cellulose materials used experienced burning the length of the sample, and thus the reported CRF would be 0.10 W/cm^2 . This is shown by the relationship between CRF and percent chemical add-on in ILL. 7. It is noted that 8 percent of the measurement range of the apparatus was utilized, and 11 of 18 cellulosic samples tested developed the lowest possible value of CRF, 0.10 W/cm^2 . Thus, for this application, the AFRP Test is used near the limit of its measurement range, and it is incapable of making any distinction among those materials whose CRF are only slightly less than the acceptance limit of 0.12 W/cm^2 . This condition exists because the sample was not long enough in relation to the level of radiant energy imposed, or the level of radiant energy was too great for the size of sample being tested.

Comparison of the flame spread values and the values of CRF (Table 3) suggests that materials having flame spread values of 25 or less usually show a CRF of 0.12 W/cm^2 or greater. Materials having flame spread values of approximately 30 or greater exhibited values of CRF of 0.10 W/cm^2 . Since the AFRP Test method is unable to indicate values of CRF less than 0.10 W/cm^2 , it was not possible to establish the relationship between CRF values and flame spread values for materials having flame spread values generally greater than 25. This is graphically displayed on ILL. 8. It is not known why sample T, as shown on ILL. 8, developed poor CRF values as compared to other samples having flame spread values of 25 or less. However, it should be noted that sample T contained the least amount of borate chemicals and the highest amount of sulphate chemicals than any other sample evaluated.

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Although all cellulosic loose fill materials supported flaming combustion in the attic tests, those materials that exhibited a flame spread of 40 or greater, propagated flaming combustion to a much greater extent than did the materials with flame spread values of 35 or less. Six of the ten attic tests conducted on the 40 or greater flame spread materials resulted in full flaming involvement. The remaining four tests developed results, in terms of affected area, in the range of 31 to 44 sq ft. The eight attic tests conducted on the 35 or less flame spread materials resulted in affected areas of 4.7 ft² or less.

A graphic representation of flame spread and the affected area of flaming by the alcohol spill in the attic tests, is shown on ILL. 9. From this graph, it is shown that samples having a flame spread value of 35 or less restricted the affected area to less than 5 ft². This identified the threshold for full flame involvement as occurring between the flame spread values of 35 to 40.

The corresponding threshold value of CRF appears to be less than 0.10 W/cm², which is beyond the measurement range of the AFRP Test. Seventeen tests were conducted utilizing materials with a flaming ignition source that exhibited a CRF of 0.10 W/cm². Six of these materials resulted in full attic involvement (96 ft²). Four developed involvement in terms of affected area of 31 to 44 ft². Seven resulted in affected areas of 4.7 ft² or less.

The 25-Ft Tunnel Test provides a means of ranking or grading the flammability performance of cellulosic materials in comparison of the results developed in the attic tests. However, because the measurements are limited to values of CRF greater than 0.10 W/cm² by the AFRP Test apparatus, correlation cannot be made with the attic tests in terms of flammability performance for materials that developed test results near the threshold values.

Ten of the fifteen cellulosic insulations tested that utilized the cigarette ignition source developed smoldering combustion. The rate of smoldering ranged from 3.25 in. per h for loose fill material having a flame spread of 25 to 6.6 in. per h for untreated cellulose having a flame spread of 70. Those samples that did not support smoldering combustion were Q, S, T, V, and W. These samples all had chemical add-on rated of 25 percent by weight. Sample R also had a chemical add-on rate of 25 percent but supported smoldering combustion at a rate of 3.4 in. per h (Tests 49 and 54). This is consistent with the National Bureau of Standards observation that the effect of borax is to increase the amount of boric acid needed to inhibit smoldering in the cigarette ignition test. Of the

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samples that contained 25 percent chemical add-on (Table 1), sample R had the highest percent of borax and therefore a higher smoldering rate would be expected. This is graphically displayed in ILL. 10.

The relation of the rate of smoldering combustion by cigarette ignition to flame spread is shown in ILL. 11. A similar relationship of smoldering combustion to percent chemical add-on is shown in ILL. 10. As shown on graphs 10 and 11, the smoldering rate of samples H and I are significantly higher as compared to other materials having similar chemical add-on rates. It is noted that materials H and I contain sulphate chemicals which do not restrict the rate of smoldering combustion as well as borax and boric acid chemicals at similar chemical add-on rates.

The blown mineral wool and shredded glass fiber materials (samples P and O, respectively) did not support flaming when exposed to the flaming ignition sources nor smoldering combustion when exposed to the nonflaming ignition source in the attic test.

In those tests that utilized the recessed light fixture in a rated lamped condition (i.e., 60 w bulb), smoldering combustion was not developed. The maximum temperatures that were observed during each test, as measured by a thermocouple positioned on the housing of the fixture, are shown in Table 5. With the same samples exposed to the light fixture in an over-rated condition (i.e., with a 150 w bulb), all materials developed smoldering combustion. These are shown in Table 4 and the maximum temperatures observed are shown in Table 5.

When the fixture housing reached a temperature in the range of 475 to 550°F, temperatures within the insulation began to rise at a faster rate. This sudden change in the rate of temperature rise indicated that the material had begun to support smoldering combustion. As shown in Table 5, the maximum temperature of the fixture with the 60 W bulb was 320°F, with no evidence of smoldering combustion in any of the materials tested. The lowest temperature of the fixture utilizing the 150 W bulb was 480°F and all materials supported smoldering combustion.

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Illustration 12 shows time-temperature histories of the recessed light fixture housing in an overlamped condition for several representative attic tests. The shaded area of the graph represents the range of temperatures in which cellulose materials reportedly begin to support smoldering combustion (475-550°F). The "x" located in each of the temperature profiles represents the time at which a sudden increase in the rate of temperature rise occurred, and is believed to be the point at which the materials began to support smoldering combustion. The following are the times and temperatures at which smoldering is believed to have begun for the four materials involved.

<u>Test No.</u>	<u>Material</u>	<u>Temperature, °F</u>	<u>Time, Min</u>	<u>Percent Add-On</u>
62	W	545	70	25
27	B	535	105	19
34	G	530	75	16
35	I	480	55	16

It is noted that sample I, which contained sulphate chemicals, smoldering combustion occurred sooner and at lower temperature than did Sample G, which contained borate chemicals; and both had 16 percent chemical loading.

The overloaded electrical wire resulted in a maximum temperature, as measured on the wire of 315°F after 8 h of exposure with a current of 48 amperes (Table 6). No discoloration or evidence of smoldering was present. No further tests were conducted using the overheated wire since it was known from the light fixture experiments and other studies^{9,10} that the threshold for smoldering combustion is approximately 500°F.

SUMMARY STATEMENTS AND RECOMMENDATIONS

Sixty-six simulated attic tests were conducted on twenty different cellulose loose fill materials, one shredded glass fiber product, and one mineral wool insulation in this investigation. Information developed is summarized as follows:

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1. The data generated indicated that the 25-Ft Tunnel Test is capable of distinguishing between materials which did or did not propagate flames in the simulated attic tests. Those materials that limited flaming to the immediate area of the ignition source had flame spread values of 35 or less. Those materials that did not confine the flaming to the immediate area of the ignition source had flame spread values of 45 or greater.
2. The present acceptance criterion³ of 0.12 W/cm^2 is near the lowest critical radiant flux (CRF) that the Attic Floor Radiant Panel (AFRP) Test is capable of measuring for the cellulose insulations used. All materials with lower CRF received the same value, e.g., 0.10 W/cm^2 , the minimum value measurable. Because the AFRP Test is incapable of providing values of the CRF less than 0.10 W/cm^2 for the cellulose materials, threshold values of the CRF for full attic involvement fall outside the measurement range of the test. Thus, the AFRP Test did not always distinguish between materials which did or did not propagate flames in the simulated attic tests with a flaming ignition mode. The acceptance criterion of 0.12 W/cm^2 thus eliminates some materials shown to perform acceptably in the simulated attic.
3. Blown mineral wool and shredded glass fiber materials did not support flaming or smoldering combustion in the simulated attic tests.
4. The attic tests that utilized the cigarette ignition source developed a rate of smoldering combustion for all cellulose products having a chemical add-on rate of less than 25 percent by weight. The rate of smoldering ranged from 3.25 in. per h for cellulose material having a flame spread of 25 to 6.60 in. per h for untreated cellulose. Accordingly, the 25 ft Tunnel test method provides an indication of relative smoldering combustion propagation rate for materials having various treatment levels.
5. The results indicated that sulphate chemicals do not restrict the rate of smoldering combustion in cellulosic loose fill formulations as well as borate chemicals at similar chemical add-on rates.

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6. For the materials used, the flaming characteristics of cellulose materials, as measured by the 25-Ft Tunnel Test, were less influenced by the type of chemicals utilized than by the percentage of chemical add-on (ILL. 6). However, smoldering combustion was influenced significantly by both the type of chemical and the amount of add-on (ILLS. 10 and 11).

7. Smoldering combustion was not produced when the various cellulose materials were exposed to the recessed light fixture using its rated lamp capacity (60 W), regardless of the chemical loading, flame spread or CRF values. Smoldering combustion was produced in all cellulose materials when the recessed light fixture was overlamped (150 W).

8. It was demonstrated that the cellulose insulation materials used will begin to support smoldering combustion when exposed to a heat source that will develop temperatures in the range of 475 - 550°F.

9. Test results indicated that smoldering combustion did not occur in the cellulose material when exposed to an overloaded 14 gauge electric wire with a current 48 amperes. Temperatures on the wire did not exceed 320°F for an 8 hr period. These results are based on a limited time exposure. The effect of lesser temperatures over longer periods of time was not investigated.

The results of this investigation suggest continued research, development and testing in several areas as follows:

1. Additional tests should be conducted to develop data that would allow for the analysis of the relationship that may exist between treating chemical add-on percentages and the smoldering combustion of the finished cellulosic insulation at an ambient temperature of 150°F.

2. Additional tests should be conducted to develop data on the maximum ambient temperature needed to bring about the smoldering combustion of the finished cellulosic insulations containing high percentages of chemical add-on (25 percent loading).

3. Additional tests should be conducted to develop data that would allow for the analysis of the relationship that exists between the type of chemical utilized in cellulosic insulations and their acceptable performance in the Attic Floor Radiant Panel apparatus and simulated attic test.

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4. Additional tests should be conducted to develop data on the effect of the cellulosic insulation when exposed to an overloaded electric wire over an extended period of time.
5. Additional tests should be conducted to develop data that would allow for the analysis of the relationship that may exist between the treating chemical add-on percentages and the smoldering combustion of the finished cellulosic insulation when exposed to a recessed lighting fixture in an overlamped condition (150 W).

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REFERENCES

1. Anon., Standard for Tests for Surface Burning Characteristics of Building Materials, UL 723-77 (ASTM E-84, NFPA 255, and ANSI A2.5).
2. Anon., Standard Method of Test for Critical Radiant Flux of Exposed Attic Floor Insulation Using a Radiant Heat Energy Source, General Services Administration, HH-I-515D Specification for Insulation Thermal (Loose Fill for Pneumatic or Poured Application): Cellulose or Wood Fiber, June 15, 1978.
3. Anon., Amended Interim Standard for Cellulose Insulation, Consumer Product Safety Commission, Federal Register, Vol. 44, No. 47, Friday, July 6, 1979.
4. Anon., Interim Safety Standard for Cellulose Insulation, Consumer Product Safety Commission, Federal Register, Vol. 43, No. 153, Tuesday, August 8, 1978.
5. Liskey, J.F., Briefing Paper on Proposed Amendment to the Interim Standard for Cellulose Insulation, Consumer Product Safety Commission, January 29, 1979.
6. Gross, D., A Preliminary Study of the Fire Safety of Thermal Insulation For Use In Attics Or Enclosed Spaces In Residential Housing, National Bureau of Standards, NBSIR 78-1497, July, 1978.
7. Anon., Technical Note on Flammability of Cellulosic Loose Fill Materials Used For Building Insulation During Laboratory-Scale And Full-Scale Fire Exposures, Underwriters Laboratories Inc., File Subject 86., Project 78ES518, August 8, 1978.
8. Anon., National Electrical Code 1981 Edition, National Fire Protection Association.
9. National Bureau of Standards, Report No. 80-2085, "Fire Performance of Loose Fill Cellulosic Insulation in Residential Occupancies - A Progress Report," August 1980.
10. National Bureau of Standards, Report No. 81-2350, "Smoldering Combustion Hazards of Thermal Insulation Materials, August, 1981.

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TABLE 1

Chemical Formulation of Test Materials

<u>Material Identification</u>	<u>Chemical Formulation</u>	<u>Percent Chemical Load</u>	<u>Blown Density, lb/ft³</u>
A	Hydrated Alum-40% Boric Acid-40% Borax-20%	22	2.2
B	Hydrated Alum-40% Boric Acid-40% Borax-20%	19	1.9
C	Hydrated Alum-40% Boric Acid-40% Borax-20%	13	1.7
D	Hydrated Alum-40% Boric Acid-40% Borax-20%	7	1.7
E	Hydrated Alum-40% Boric Acid-40% Borax-20%	3	1.7
F	Untreated	None	1.6
G	Boric Acid-50% Borax-50%	16	1.9
H	Boric Acid-25% Borax-50% Aluminum Sulfate-25%	18	1.9

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TABLE 1 CONT'D

<u>Material Identification</u>	<u>Chemical Formulation</u>	<u>Percent Chemical Load</u>	<u>Blown Density, lb/ft³</u>
I	Borax-25% Ammonium Sulfate-75%	16	1.7
J	Boric Acid-25% Borax-75%	16	1.8
K	Same as "G"	11	1.6
L	Same as "H"	12	1.7
M	Same as "I"	11	1.7
N	Same as "J"	12	1.7
O	Shredded Glass Fiber	NA	0.7
P	Shredded Mineral Wool	NA	1.9
Q	Borax-33% Boric Acid-67%	25	2.4
R	Borax-67% Boric Acid-33%	25	2.2
S	Borax-33% Boric Acid-33% Aluminum Sulfate-33%	25	2.3
T	Borax-20% Aluminum Sulfate-80%	25	2.1
V	Borax-40% Boric Acid-40% Aluminum Sulfate-20%	25	2.1
W	Polybor-67% Boric Acid-33%	25	2.2

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TABLE 2

Atmospheric Conditions
Attic Experiments

<u>Test No.</u>	<u>Material Identification</u>	<u>Room Temperature, Degrees F</u>	<u>Relative Humidity, Percent</u>	<u>Ignition Source</u>
1	A	75	50	Alc. Spill
2	B	75	52	Alc. Spill
3	C	78	54	Alc. Spill
4	D	63	65	Alc. Spill
5	E	64	41	Alc. Spill
6	F	77	74	Alc. Spill
7	A	85	64	Cigarette
8	B	85	64	Cigarette
9	C	84	64	Cigarette
10	D	84	64	Cigarette
11	E	85	48	Cigarette
12	F	85	48	Cigarette
13	B	87	65	Alc. Spill- Radiant
14	C	85	47	Alc-Spill- Radiant
15	B	77	65	Torch
16	C	77	60	Torch
17	O	78	50	Alc. Spill
18	P	78	50	Alc. Spill
19	J	86	70	Cigarette
20	I	86	70	Cigarette
21	H	73	75	Cigarette
22	B	67	75	Fixture- Rated
23	H	67	75	Fixture- Rated
24	H	70	76	Alc. Spill
25	I	74	60	Alc. Spill
26	J	74	84	Alc. Spill
27	H	74	84	Fixture- Over-rated
28	B	74	84	Fixture- Over-rated
29	G	75	72	Alc. Spill
30	N	75	72	Alc. Spill

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TABLE 2 CONT'D

Test No.	Material Identification	Room Temperature, Degrees F	Relative Humidity, Percent	Ignition Source
31	G	72	58	Fixture-Rated
32	I	72	58	Fixture-Rated
33	L	73	68	Alc. Spill
34	G	73	68	Fixture-Over-rated
35	I	73	68	Fixture-Over-rated
36	K	68	62	Alc. Spill
37	M	68	62	Alc. Spill
38	G	77	68	Cigarette
39	J	77	68	Fixture-Rated
40	J	76	60	Fixture-Over-rated
41	J	72	62	Overheated Wire
42	S	79	55	Alc. Spill
43	T	79	55	Alc. Spill
44	T	78	57	Cigarette
45	S	85	57	Cigarette
46	W	85	57	Alc. Spill
47	R	76	88	Alc. Spill
48	W	76	88	Cigarette
49	R	84	67	Cigarette
50	V	84	67	Alc. Spill
51	Q	84	67	Alc. Spill
52	V	79	84	Cigarette
53	Q	79	84	Cigarette
54	R	74	87	Cigarette
55	V	80	58	Fixture-Rated
56	S	80	58	Fixture-Rated
57	Q	80	58	Fixture-Rated
58	T	80	58	Fixture-Rated
59	V	74	82	Fixture-Rated

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TABLE 2 CONT'D

<u>Test No.</u>	<u>Material Identi- fication</u>	<u>Room Temperature, Degrees F</u>	<u>Relative Humidity, Percent</u>	<u>Ignition Source</u>
60	S	74	82	Fixture- Rated
61	Q	74	82	Fixture- Rated
62	T	74	82	Fixture- Rated
63	W	74	52	Fixture- Rated
64	W	74	52	Fixture- Rated
65	R	74	52	Fixture- Over-rated
66	R	74	52	Fixture- Rated

TABLE 3

Material Identification	Installed Blown Density, lb/ft ³	<u>Laboratory Test Results</u>			Attic Floor Radiant		
		Percent Chemical Loading	25-Ft Funnel Test Flame Spread		Panel Test CRF, W/cm ²		
			Test 1	Test 2	Test 1	Test 2	Test 3
A	2.2	22	22.6	25.9	0.14	0.13	0.13
B	2.0	19	35.6	38.5	0.10	0.10	0.10
C	1.7	13	48.7	39.1	0.10	0.10	0.10
D	1.7	7	51.4	47.3	0.10	0.10	0.10
E	1.7	3	61.1	58.4	NC++	NC++	NC++
F	1.6	-	71.7	63.8	NC++	NC++	NC++
G	1.9	16	24.8	25.3	0.16	0.15	0.15
H	1.9	18	33.9	37.7	0.11	0.10	0.10
I	1.7	16	32.3	31.9	0.10	0.10	0.10
J	1.8	16	39.1	35.6	0.11	0.10	0.10
K	1.6	11	45.4	48.8	0.10	0.10	0.10
L	1.7	12	45.2	42.0	0.10	0.10	NC++
M	1.7	11	38.7	39.0	0.10	0.10	NC++
N	1.7	12	52.3	NC+	0.10	0.10	NC++
O	0.7	NA	9.6	9.8	1.2	1.2	1.2
P	1.9	NA	3.0	3.0	1.2	1.2	1.2
Q	2.4	25	22.7	NC+	0.17	0.16	0.17
R	2.2	25	19.3	NC+	0.15	0.14	0.16
S	2.3	25	19.4	NC+	0.11	0.14	0.14
T	2.1	25	22.8	NC+	0.10	0.10	0.10
V	2.1	25	19.2	NC+	0.10	0.13	0.11
W	2.2	25	21.9	NC+	0.17	0.18	0.18

NC+ = Not conducted.

NC++ = Not conducted based on preceding test results.

NA = Not applicable

TABLE 4

Results of Simulated Attic Tests
(Initial Ambient Temperature of 150°F)

Test No	Material ID	Blown Density, lb/ft ³	Average Flame Spread	Average Critical Radiant Flux, W/cm ²	Method of Heating	Ignition Source	No. Of Joist Cavities Filled	Maximum Extent Of Flame Propagation Inches and Time, min:s	Affected Area Flaming Mode, ft ²	Sustained Smoldering	Rate Of Smoldering, in./h
1	A	2.2	25	0.13	C	1	6	3 @ 2:00	1.0	No	-
2	B	2.0	35	0.10	C	1	6	12 @ 0:20	1.25	No	-
3	C	1.7	45	0.10	C	1	6	144 @ 6:25	96.0	Yes	ND++
4	D	1.7	50	0.10	C	1	6	144 @ 3:15	96.0	Yes	ND
5	E	1.7	60	NC	C	1	6	144 @ 2:50	96.0	Yes	ND
6	F	1.6	70	NC	C	1	6	144 @ 2:32	83.1	Yes	ND
7	A	2.2	25	0.13	C	2	3	-	-	Yes	3.25
8	B	2.0	35	0.10	C	2	3	-	-	Yes	3.40
9	C	1.7	45	0.10	C	2	3	-	-	Yes	5.00
10	D	1.7	50	0.10	C	2	3	-	-	Yes	4.90
11	E	1.7	60	NC	C	2	3	-	-	Yes	6.10
12	F	1.6	70	NC	C	2	3	-	-	Yes	6.60
13	B	2.0	35	0.10	R	1	6	3 @ 0:30	1.0	No	-
14	C	1.7	45	0.10	R	1	6	66 @ 2:30	44.0	No	-
15	B	2.0	35	0.10	C	3	6	7 @ 0:50	1.0	Yes	ND
16	C	1.7	45	0.10	C	3	6	96 @ 4:00	40.6	Yes	ND
17	O	0.7	10	1.2	C	1	3	2 @ 1:00	1.0	No	-
18	P	1.9	5	1.2	C	1	3	-	-	No	-
19	J	1.8	35	0.10	C	2	3	-	-	Yes	4.00
20	I	1.7	30	0.10	C	2	3	-	-	Yes	5.55

TABLE 4 CONT'D

Test No	Material ID	Blown Density, lb/ft ³	Average Flame Spread	Average Critical Radiant Flux, W/cm ²	Method of Heating+	Ignition Source++	No. Of Joist Cavities Filled	Maximum Extent Of Flame Propagation In, and Time,min:s	Affected Area Flaming Mode, ft ²	Sustained Smoldering	Rate Of Smoldering, in./h
21	H	1.9	35	0.10	C	2	6	-	-	Yes	4.75
22	B	2.0	35	0.10	C	4	3	-	-	No	-
23	H	1.9	35	0.10	C	4	3	-	-	No	-
24	H	1.9	35	0.10	C	1	6	3 @ 1:00	1.0	Yes	ND
25	I	1.7	30	0.10	C	1	6	30 @ 1:15	4.7	Yes	ND
26	J	1.8	35	0.10	C	1	6	2.5 @ 0:30	1.0	No	-
27	H	1.9	35	0.10	C	5	3	-	-	Yes	7.09
28	B	2.0	35	0.10	C	5	3	-	-	Yes	3.40
29	G	1.9	25	0.15	C	1	6	3 @ 0:30	1.0	No	-
30	N	1.7	50	0.10	C	1	6	66 @ 3:15	31.3	Yes	ND
31	G	1.9	25	0.15	C	4	3	-	-	No	-
32	I	1.7	30	0.10	C	4	3	-	-	No	-
33	L	1.7	45	0.10	C	1	6	90 @ 6:00	32.3	Yes	ND
34	G	1.9	25	0.15	C	5	3	-	-	Yes	4.20
35	I	1.7	30	0.10	C	5	3	-	-	Yes	5.32
36	K	1.6	45	0.10	C	1	6	144 @ 6:00	74.6	Yes	ND
37	M	1.7	40	0.10	C	1	6	144 @ 3:45	76.0	Yes	ND
38	G	1.9	25	0.15	C	2	3	-	-	Yes	3.80
39	J	1.8	35	0.10	C	4	3	-	-	No	-
40	J	1.8	35	0.10	C	5	3	-	-	Yes	4.30
41	J	1.3	35	0.10	C	6	3	-	-	Yes	4.30
42	S	2.3	20	0.13	C	1	3	2.5 @ 0:30	1.0	No	-
43	T	2.1	25	0.10	C	1	3	2.75 @ 0:30	1.0	No	-
44	T	2.1	25	0.10	C	2	3	-	-	No	-
45	S	2.3	20	0.13	C	2	3	-	-	No	-
46	W	2.2	20	0.18	C	1	3	3.0 @ 0:45	1.0	No	-

TABLE 4 CONT'D

Test No.	Mate- rial ID	Blown Density lb/ft ³	Average Flame Spread	Average Critical Radiant Flux, W/cm ²	Method of Heating+	Ignition Source++	No. of Joist Cavities Filled	Maximum Extent Of Flame Propagation Inches and Time, Min:s	Affected Area Flaming Mode, ft ²	Sus- tained Smol- dering	Rate of Smol- dering, in./h
47	R	2.2	20	0.15	C	1	3	3.5 @ 0:15	1.0	No	-
48	W	2.2	20	0.18	C	2	3	-	-	No	-
49	R	2.2	20	0.15	C	2	3	-	-	Yes	3.43
50	V	2.1	20	0.11	C	1	3	4.25 @ 1:00	1.0	No	-
51	Q	2.4	25	0.17	C	1	3	5.25 @ 0:15	1.0	No	-
52	V	2.1	20	0.11	C	2	3	-	-	No	-
53	Q	2.4	25	0.17	C	2	3	-	-	No	-
54	R	2.2	20	0.15	C	2	3	-	-	Yes	3.43
55	V	2.1	20	0.11	C	4	3	-	-	No	-
56	S	2.3	20	0.13	C	4	3	-	-	No	-
57	Q	2.4	25	0.17	C	4	3	-	-	No	-
58	T	2.1	25	0.10	C	4	3	-	-	No	-
59	V	2.1	20	0.11	C	5	3	-	-	Yes	3.76
60	S	2.3	20	0.13	X	5	3	-	-	Yes	3.70
61	Q	2.4	25	0.17	C	5	3	-	-	Yes	2.53
62	T	2.1	25	0.10	C	5	3	-	-	Yes	2.48
63	W	2.2	20	0.18	C	5	3	-	-	Yes	3.70
64	W	2.2	20	0.18	C	4	3	-	-	No	-
65	R	2.2	20	0.15	C	5	3	-	-	Yes	1.92
66	R	2.2	20	0.15	C	4	3	-	-	No	-

+ - C = Convective.
R = Radiant

++ - 1 = Alcohol spill.
2 = Cigarette.
3 = Torch
4 = Fixture-rated
5 = Fixture-over-rated

6 = Overheated wire
NC - Not conducted
ND - Not determined

File USNC97

TABLE 5

Maximum Temperature of Recessed Fixture

<u>Test No.</u>	<u>Material</u>	<u>Test Method</u>	<u>Maximum Temperature on Fixture, °F (Prior To Smoldering)</u>
22	B	Rated 60 W	153 +
23	H	Rated 60 W	200
27	H	OVERRATED 150 W	550
28	B	OVERRATED 150 W	535
31	G	Rated 60 W	290
32	I	Rated 60 W	293
34	G	OVERRATED 150 W	530
35	I	OVERRATED 150 W	480
39	J	Rated 60 W	305
40	J	OVERRATED 150 W	610
55	V	Rated 60 W	290
56	S	Rated 60 W	290
57	Q	Rated 60 W	315
58	T	Rated 60 W	315
59	V	OVERRATED 150 W	550
60	S	OVERRATED 150 W	540
61	Q	OVERRATED 150 W	550
62	T	OVERRATED 150 W	550
63	W	OVERRATED 150 W	545
64	W	Rated 60 W	320
65	R	OVERRATED 150 W	545
66	R	Rated 60 W	300

+ - After test, one thermocouple was found to be bent away from source.

File USNC97

TABLE 6

Overloaded Electric Wire TemperaturesTest No. 41

Material J (16 Percent Add-On)

<u>Time,</u> <u>-h:m</u>	<u>Amperage</u>	<u>°C</u>	<u>°F</u>
0:00	48	52	126
0:30	48	124	255
1:00	48	138	280
1:30	47.5	144	291
2:00	47.5	147	297
2:30	47.5	148	298
3:00	47.5	149	300
3:30	47.5	150	302
4:00	47.5	150	302
4:30	47.5	150	302
5:00	48	152	306
5:30	48	153	307
6:00	48	154	309
6:30	48	155	311
7:00	48	155	311
7:45	48	157	314
8:00	48	157	315

SIMULATED ATTIC

ILL. 1

SIMULATED ATTIC

RIGHT SIDE

ILL. 2

SIMULATED ATTIC

LEFT SIDE

ILL. 3

RADIANT PRE-HEATING ASSEMBLY

ILL. 4

ATTIC THERMOCOUPLE LOCATIONS

CRITICAL RADIANT FLUX vs. PERCENT CHEMICAL ADD-ON

ILL. 7

FLAME SPREAD vs. CRITICAL RADIANT FLUX

ILL. 8

FLAME SPREAD vs. AFFECTED AREA SIMULATED ATTIC TESTS

ALCOHOL SPILL
CONVECTIVE HEATING

ILL. 9

RATE OF SMOLDERING COMBUSTION vs. CHEMICAL ADD-ON

FLAME SPREAD vs. RATE OF SMOLDERING COMBUSTION

ILL. 11

RECESSED LIGHT FIXTURE

TEMPERATURES - OVERLAMPED CONDITION

File USNC97

APPENDIX A
TRANSCRIBED VOICE RECORDS

The following transcribed voice records provides information of time and events occurring during the course of each full-scale simulated attic experiment.

File USNC97

Test No. 1

Material Identification - A

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition of alcohol.
1:50	Flames extending 1-1/2 in. in all directions, char to 5 in. diameter.
2:30	Flames decreasing.
4:00	No change.
5:00	Flames decreased to 1-1/2 in. diameter.
7:00	No change.
11:00	Minor flickers only remain.
14:20	All flame and glow self-extinguished.

Test No. 2

Material Identification - B

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition of alcohol.
0:20	Flames spread to 18 in. diameter.
1:30	Flames receded to 3 in. diameter in alcohol spill area only.
3:00	No change.
5:15	Flames decreased to 1-1/2 in. diameter.
7:20	No change.
8:40	All flaming and glow self-extinguished.

File USNC97

Test No. 3

Material Identification - C

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition.
0:10	Flames spread to 18 in. diameter.
0:25	Flames spread to 2 ft mark (cavity 4).
0:35	Flames jumped to cavity 5.
0:54	Flames spread to 3-1/2 ft mark.
1:11	Flames jumped to cavity 3.
1:25	Flames spread in two cavities to 5 ft.
1:47	Flames now in cavities 3, 4, 5 and 6.
2:30	Flames spread in cavities 3 and 4 to 7 ft, cavities 5 and 6 to 6-1/2 ft.
3:30	Flames spread in cavities 3 and 4 to 8 ft.
4:10	Flames spread in cavities 5 and 6 to 8 ft.
4:40	Flames spread in cavities 3 and 4 to 10 ft.
5:20	Flames spread in cavity 2 at 8 ft.
6:25	Flames spread in cavity 4 (spill cavity) to end.
7:10	Flaming to end in cavities 5 and 6.
7:25	Flaming out in cavities 4, 5 and 6.
7:45	Flames spread to 10-1/2 ft in cavity 3.
9:41	Flames spread in cavity 2 to end.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
10:16	All flaming out.
15:00	Slight glow in spill area.
19:45	No sign of glow, appears out.
25:00	Material continues to smoke in spill area. Smoldering apparent.
42:00	Char area to 14 in. mark.
*	Material continued to smolder. The test was terminated 6 h after ignition. Refer to smoldering rate column of appropriate tables.

Test No. 4

Material Identification - D

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition.
0:10	Flaming in cavity 4 to 2 ft.
0:15	Flames jumped to cavities 3 and 5.
0:30	Flames spread to 4 ft in cavities 3, 4, 5 and 6.
0:55	Flames jumped to cavity 1, spread in all other cavities to 6 ft.
1:20	Flames spread to 8 ft in all but cavity 1.
1:50	Flames spread to 10 ft in all cavities.
3:15	Flames spread to end in all cavities.
4:12	All flaming out except in spill area.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
6:00	No change.
11:25	All flaming out. Slight glow in spill area.
17:00	Smoke continues in spill area. Smoldering apparent.
*	Material continued to smolder. Test terminated 1:45:00 after ignition.

Test No. 5

Material Identification - E

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition.
0:10	Flames spread to 2 ft mark - cavity 4.
0:20	Flames jumped to cavities 3 and 5.
0:25	Flames in all but cavity 1.
0:30	Flames spread in all affected cavities to 4 ft.
0:35	Flames spread in all cavities to 5-1/2 ft.
1:00	Flames spread in all cavities to 7 ft.
2:00	Flames spread to 11 ft.
2:50	Flames to end in cavities 1, 2, 3 and 6.
3:10	Roof rafters at end of cavity 4 on fire.
3:20	Flames to end in cavities 4 and 5.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
4:30	Flaming out with exception of spill area.
6:00	No change.
9:45	All flaming out.
15:30	Smoke continues from spill area. Smoldering apparent
*	Material continued to smolder. Test terminated 1:30:00 after ignition. Refer to smoldering rate table.

Test No. 6
 Material Identification - F
 Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition.
0:16	Flames spread to 2-1/2 ft in cavity 4.
0:44	Flames spread to 5 ft, all cavities involved.
1:04	Flames spread to 7-1/2 ft in all cavities but No. 6.
1:34	Flames spread to 9 ft mark.
1:46	Flames to 10 ft in all cavities but No. 6.
1:52	Flames spread to 10-1/2 ft.
1:58	Flames to 11 ft in cavities.
2:32	Flames spread to 12 ft in cavities 1, 2 and 3.
4:05	Flames spreading in cavity 1 from approx 6 ft mark backwards towards the 0 ft mark.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
6:25	All flaming out except in spill area.
9:53	Flaming out. Smoke continues.
20:00	No change.
48:00	Smoke continues and increasing.
63:00	Test terminated. Smoldering in cavity 1 at 12 ft mark.

Test No. 7
 Material Identification - A
 Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	An ignited cigarette has been placed lit end up into the material.
3:00	Cigarette continues to smoke; light char surrounding the cigarette.
6:00	Discoloration around the source approx 1/2 in. radius.
13:00	No change; still smoking.
21:00	Smoking increased.
26:00	Char approx 1-1/2 in. radius.
33:00	Diameter of char 4 in.
38:00	Diameter of char 4-1/2 in.
47:00	Diameter of char 6 in.
53:00	Diameter of char 7 in.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
62:00	Diameter of char 8 in.
180:00	The char reached the 20 in. mark within the cavity. The diameter of char could not continue because as the material charred, it sank into the cavity, therefore, bringing it within a given cavity only.
200:00	The char reached the 24 in. mark. The test was terminated.
214:00	Refer to the smoldering rate table for the smoldering rate.

Test No. 8
 Material Identification - B
 Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	The lighted cigarette was placed into the material with the burning end up.
3:00	The cigarette continued to smoke with light char occurring around the cigarette.
6:00	Discoloration around source approx 1/2 in. radius.
13:00	No change; still smoking.
21:00	The sample appears to be out; no flaming or smoke is visible.
26:00	No change.
38:00	The diameter of char is approx 3 in.
47:00	The diameter of char is 4 in.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
53:00	The diameter of char is 5 in.
62:00	The diameter of char is 6 in.
74:00	The diameter of char is 7 in.
84:00	The diameter of char is 10 in.
95:00	The diameter of char is 6 in.
110:00	The diameter of char is 14 in.
131:00	The diameter of char is 16 in.
180:00	The char has reached the 20 in. mark.
200:00	The char has reached the 22 in. mark.
214:00	The test was terminated. Refer to the smoldering rate table for the individual values.

Test No. 9
Material Identification - C
Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Glowing cigarette inserted with glowing end up into material.
2:00	1/4 in. radius char around cigarette.
6:00	1/2 in. radius char around cigarette. Medium smoke beginning in chamber.
10:00	1 in. radius char; smoke increasing to heavy.
15:00	1-1/2 in. radius char around cigarette.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
20:00	2 in. radius of char.
30:00	6 in. diameter of char.
40:00	8 in. diameter of char.
55:00	12 in. diameter of char.
65:00	14 in. diameter of char.
95:00	Char has reached the 21 in. mark.
110:00	Char has reached the 22 in. mark.
135:00	Char the full width of the cavity; has extended to the 2 ft mark.
190:00	The test was terminated; char had extended to the 2 ft, 3 in. mark. Refer to the smoldering rate table for individual smoldering rates.

Test No. 10
Material Identification - D
Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Glowing cigarette inserted into insulation material.
2:00	1/4 in. radius char around cigarette.
6:00	1/2 in. radius char around cigarette. Medium smoke in chamber.
10:00	No change.
15:00	1 in. radius char around cigarette.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
20:00	3 in. diameter char.
30:00	5 in. diameter char.
40:00	8 in. diameter char.
55:00	12 in. diameter char.
65:00	No change.
95:00	16 in. diameter of char. Heavy smoke being emitted from the smoldering area.
110:00	Char has reached the 21 in. mark.
135:00	Char the full width of the cavity and extending to the 2 ft mark.
190:00	The test was terminated; char had extended the full width of the cavity to the 2 ft, 9 in. mark. Refer to the smoldering rate table for individual values.

Test No. 11
Material Identification - E
Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Glowing cigarette installed into insulation material.
4:00	1/2 in. radius char around cigarette.
14:00	3 in. diameter char.
30:00	6 in. diameter char. Heavy smoke visible.
45:00	12 in. diameter char. Heavy smoke continues.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
60:00	14 in. diameter char with heavy smoking.
70:00	Visibility in the attic is limited to three cavities.
75:00	Char is the full width of the cavity and spreads to the 19 in. mark.
105:00	Char has spread to the 21 in. mark.
120:00	Char has spread to the 2 ft mark.
160:00	Char has spread to the 2 ft, 2 in. mark.
200:00	Char has spread to 30 in.
*	The test was terminated at 7 h, 15 min after ignition. Smoldering continued all during this time. The test, when terminated, had spread to the 4 ft, 7 in. mark. Refer to the smoldering rate table for individual values.

Test No. 12
Material Identification - F
Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Glowing cigarette inserted into insulation material.
4:00	1/2 in. radius of char; light smoke beginning.
14:00	1 in. radius of char; heavy smoking beginning.
30:00	4 in. diameter; heavy smoke continues.
45:00	10 in. diameter of char around cigarette.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
60:00	12 in. diameter of char around cigarette.
70:00	Visibility in attic limited to 3 cavities.
75:00	Char is extended to the full width of the cavity and has spread to 19 in. mark.
105:00	Char has spread to the 22 in. mark.
120:00	Char has reached the 2 ft mark.
160:00	Char to the 22 in. mark.
200:00	Char has reached the 2-1/2 ft mark.
715:00	Test terminated. Smoldering continued up until this point. Spread of char reached a maximum of 4 ft, 7 in. Material would have continued to smolder if it were allowed. Refer to the smoldering rate table for individual values.

Test No. 13

Material Identification - B

Ignition Source - Alcohol Spill With Radiant Heating Preheat

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition of alcohol.
0:30	6 in. diameter of char.
1:30	No change.
3:30	Flame height reduced from 6 in. to 2 in. 6 in. diameter of char.
6:00	6 in. diameter of char, 1/2 in. flame height.
7:30	Flaming out, minor glow continues.
10:00	No smoke, no glow, test terminated.

File USNC97

Test No. 14

Material Identification - C

Ignition Source - Alcohol Spill With Radiant Heating Preheat

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition.
0:30	Flaming in cavity No. 4, out to 3 ft mark, flaming has also jumped to cavities 5 and 3.
1:10	Flaming to 4 ft mark in cavity 4, 3-1/2 ft in cavities 3, 5 and 6.
2:00	Flaming to 5 ft in cavities 3, 4, 5 and 6.
2:30	Flaming in all cavities to 5-1/2 ft.
3:30	Flaming subsiding in all cavities.
4:45	All flaming out except in spill area.
8:30	Light flickering at alcohol spill only.
11:45	All flaming is out, no apparent smoldering. Test terminated.

Test No. 15

Material Identification - B

Ignition Source - Propane Torch

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition of torch.
0:13	Ignition of sample material as the burner is lowered at approx the 60 deg angle to within 1 in. of the surface.
0:50	6 in. diameter of char.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
1:42	Light smoke from ignition area. Flames have spread to approx 19 in.
3:00	No change. All flaming of sample appears out; only the test flame continues.
5:00	No change.
10:00	Flame removed and test terminated. Sample continues to smolder at point of flame contact.

Test No. 16

Material Identification - C

Ignition Source - Propane Torch

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition of material on contact in cavity form.
0:15	Spread in cavity form to 2-1/2 ft, flames have jumped to cavities 3 and 5.
0:40	Flames jumped to cavities 2 and 6, spread to 5 ft.
2:00	Spread to 6 ft in cavities 4 and 6, spread to 5 ft in cavities 2 and 3.
4:00	Spread of flame to 8 ft in cavity 6, all other flaming appears out.
6:00	Flaming appears out.
10:00	Test terminated; light smoke in ignition area indicates presence of smoldering.

File USNC97

Test No. 17

Material Identification - O

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition of alcohol.
1:00	Discoloration of the sample material in the direct spill area.
2:00	Light flaming in the glass below the surface; slight smoking observed.
3:00	No change.
4:00	Flaming within the material appears to be out.
5:00	No activity can be seen.
10:00	Test terminated.

Test No. 18

Material Identification - P

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition of alcohol.
1:00	No change other than the flaming that remains in the ignition area.
2:00	Flames approx 4 to 6 in. high. No change or char noticed in material.
3:00	No change.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
4:00	Slight smoke from the material; no apparent flaming.
5:00	All activity appears finished.
10:00	Test terminated.

Test No. 19

Material Identification - J

Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignited cigarette placed in material glowing end up.
2:30	Light smoke observed from ignition source area.
5:00	No change.
10:00	Smoke slightly increased, 1 in. diameter char around material.
15:00	Smoke continues; smoldering apparent.
25:00	Diameter of char approx 3 in.
30:00	No change.
35:00	Diameter of char approx 4 in.
45:00	Diameter of char 6 in.
60:00	Diameter of char 8 in.
75:00	Diameter of char 10 in.
90:00	Diameter of char 12 in.
*	The material continued to smolder for approx 7 h. For the smoldering rate, refer to the appropriate tables.

File USNC97

Test No. 20
Material Identification - I
Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignited cigarette placed in material glowing end up.
2:30	Light smoke detected from ignition area.
5:00	No change.
10:00	Smoking slightly increased, 1 in. diameter char around cigarette.
15:00	Smoke continues, smoldering apparent.
25:00	Smoking continues, diameter of char around cigarette 3 in.
30:00	No change.
35:00	Diameter of char approx 3 in.
45:00	Diameter of char around cigarette 5 in.
60:00	Diameter of char 7 in.
75:00	Diameter of char 9 in.
90:00	Diameter of char approx 14 in.
*	Smoldering continued for approx 7 h at which time the test was terminated. Refer to the smoldering table for the appropriate rate.

File USNC97

Test No. 21

Material Identification - H

Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignited cigarette placed in material glowing end up.
5:00	No apparent activity.
10:00	1/2 in. radius of char from around cigarette.
20:00	3 in. diameter char; smoke increasing.
45:00	6 in. diameter of char around cigarette. Smoke continues to increase.
60:00	10 in. diameter char.
75:00	12 in. diameter of char.
*	Material continued to smolder approx 7 h at which time the test was terminated. For the calculated smoldering rate, see the appropriate tables.

Test No. 22

Material Identification - B

Ignition Source - Light Fixture Rated Bulb

At 9:30 in the morning, after 2 h of preheat, the recessed light fixture was switched on. Temperatures were monitored during the test with no smoke, no discoloration of the material and no smoldering apparent when the test was terminated at 9:00 P.M.

File USNC97

Test No. 23

Material Identification - H

Ignition Source - Light Fixture Rated Bulb

At 9:30 in the morning, after 2 h of preheat, the recessed light fixture was switched on. Temperatures were monitored during the test with no smoke, no discoloration of the material and no smoldering apparent when the test was terminated at 9:00 P.M.

Test No. 24

Material Identification - H

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition.
0:30	4 in. diameter char.
1:00	5 in. diameter of char.
3:00	No change.
4:00	Flame diminishing.
6:00	Light flaming approx 1 in. high; no further spread.
8:30	Light smoke increasing.
10:00	Light flaming and smoke continues; smoke increasing.
15:00	Flaming out, smoke continues, smoldering apparent.

File USNC97

Test No. 25

Material Identification - I

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition.
0:30	Flames spread to 2 ft mark, full cavity width, flames have jumped to cavity 5.
1:15	Flame spread remains at 2 ft. Smoke only observed in cavity 5.
2:15	Flame front out. Flaming only observed in the ignition area.
5:00	Light flaming in the source area only. Light smoke continues.
9:00	No change.
10:00	Flaming out. Smoke increasing, smoldering evident.

Test No. 26

Material Identification - J

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition.
0:30	4 in. diameter char, flame height extending 6 in.
2:30	No change.
6:30	Light flaming and smoke continues.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
8:00	Decreased flaming.
10:00	Flaming out, light smoke continues.
15:00	No smoke observed. Test terminated. No apparent smoldering.

Test No. 27

Material Identification - H

Ignition Source - Light Fixture Over Lamped

The attic was preheated for 2 h prior to switching on the recessed light fixture. Preheat was continued for an additional 2 h. Smoldering took place within 2 h after the light fixture was turned on and continued during the remaining 5 or 6 h of the test. See the appropriate tables for the smoldering rate.

Test No. 28

Material Identification - B

Ignition Source - Light Fixture Over Lamped

The attic chamber was preheated for 2 h prior to actuation of the recessed light fixture. The preheat continued for two additional hours. Within the continuing preheat period, smoldering was evident and continued during the remaining 6 h of the test. For the appropriate smoldering rates, see the smoldering rate table.

Test No. 29

Material Identification - G

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition.
0:30	Flame spread to 6 in. diameter, flames 4 to 6 in. high.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
2:00	Flame front back to ignition source.
4:30	Light flaming only observed in the ignition source area. Light smoke also observed.
7:00	Light surface flaming in the material. Very light smoke.
9:00	Flaming out. Light smoke continues.
13:00	No smoking or flame is evident. Test terminated.

Test No. 30

Material Identification - N

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition.
0:05	Flame spread to 12 in. radius.
0:10	Flames jumped into cavities 3 and 5.
0:45	Flames spread to the 3 ft mark.
1:00	Flames jumped into cavities 6 and 2.
1:30	Spread to 4 ft mark.
2:30	Flames have spread into cavity 1.
3:15	Flames spread to the 5 ft mark in cavity 5, 3 ft mark in cavity 2.
4:30	Flaming out in cavity 5. Flaming continues in cavity 2.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
5:13	Flaming out in cavity 2. Only flaming at ignition source. Light flaming in ignition area at 7 min. Light smoke from the source.
12:00	Smoke increasing in the ignition area.
17:00	Test terminated. Smoldering evident.

Test No. 31
 Material Identification - G
 Ignition Source - Light Fixture Rated Bulb

The attic chamber was preheated for 2 h prior to actuation of the recessed light fixture. The preheat continued for an additional 2 h, after which it was turned off. The lamp remained on. The lamp remained on through the entire test. The results of the test indicated no smoking, no charring or discoloration of the insulation around the lamp and no smoldering.

Test No. 32
 Material Identification - I
 Ignition Source - Light Fixture Rated Bulb

The attic chamber was preheated for 2 h prior to actuation of the recessed light fixture. Preheating continued for an additional 2 h, at which time it was terminated and the light remained on during the entire test. The results of the test indicated no smoke, no charring or discoloration of the material adjacent to the light fixture and no smoldering after a period of approx 6 h of exposure.

File USNC97

Test No. 33

Material Identification - L

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition.
0:30	Flames spread to 8 in. of ignition source, full width of the cavity, flames jumping to cavities 3 and 5.
1:00	16 in. spread in all directions.
2:00	Flames spread to cavity 1, spread to the 4 ft mark in cavity 4, slightly less in cavities 3 and 5.
3:00	Flames jumped to cavity 2.
3:30	Flames spread now to the 5 ft mark.
4:00	Flaming continues in all cavities.
5:00	Flaming to 6-1/2 ft in cavities 2, 3 and 4. Flaming to 7 ft in cavity 4 at 6 min.
8:00	All flaming out except in cavity 1, moving backward toward the perpendicular plane of the ignition source.
9:00	Ignition source flaming out.
10:00	All flaming out. Smoke continues.
13:00	Smoldering evident. Test terminated.

File USNC97

Test No. 34

Material Identification - G

Ignition Source - Light Fixture Over Lamped

The attic chamber was preheated for 2 h prior to actuation of the recessed light fixture. The preheat continued for an additional 2 h at which time the preheat was terminated. The lamp remained on throughout the entire test from that point on. Smoldering occurred within the first 2 h after the lamp was ignited and continued throughout the remainder of the test which was approx 6 h. For the smoldering rate, see the appropriate tables.

Test No. 35

Material Identification - I

Ignition Source - Light Fixture Over Lamped

The attic chamber was preheated for 2 h prior to the actuation of the recessed light fixture. The preheat continued for an additional 2 h at which time it was terminated. The light continued on from ignition until the end of the test. Within the first 2 h after ignition of the lamp, smoldering occurred and continued throughout the remaining 6 h of the test. For the smoldering rate, see the appropriate tables.

Test No. 36

Material Identification - K

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition.
1:00	Flaming has spread into cavities 5, 6, 3 and 2 and has spread to 3 ft.
1:20	The flames have spread to 4 ft in cavities 3, 4 and 5.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
1:30	Flaming has spread into cavity 1.
2:00	Flames spread to 6-1/2 ft in all affected cavities.
2:30	Flames spread to 8 ft in cavities 2 through 6.
3:30	Flames spread to 9 and 10 ft mark in cavities 2, 3, 4, 5 and 6.
4:15	Flames spread to 11 ft in cavities 4 and 6 to the 10 ft mark in cavity 2.
5:00	Flame front is out in cavities 1, 2 and 3. Flames continue in the remaining three cavities.
6:00	Flames have reached the 12 ft mark in cavities 4, 5 and 6.
7:15	Flaming out in cavities 4 and 6.
7:40	Flaming out in cavity 5. Light flaming at the ignition source.
10:00	No change.
20:00	Light flaming continues at the ignition source. Smoldering is evident.
25:00	Flaming is increasing in the 6 in. diameter circle around the source.
38:00	Smoldering continues in cavities 3, 4 and 5. Light spontaneous flaming is observed in cavity 4 for approx a 10 in. char circle.
40:00	All flaming out. Test terminated. Smoldering is evident.

File USNC97

Test No. 37

Material Identification - M

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition.
0:30	Flames spread to cavities 3 and 5. Flame spread to the 3 ft mark.
1:15	Flames have jumped to cavities 6 and 2. Flame spread to the 6 ft mark in cavity 4.
2:00	Flames have jumped to cavity 1.
2:15	Flames to the 8 ft mark and moving rapidly.
3:00	Flames to the 11-1/2 ft mark in cavities 4 and 5.
3:45	Flames to the 12 ft mark in cavities 4 and 5.
4:00	Flaming out in cavities 6 and 1.
4:45	Flaming out in cavities 2, 4 and 5. Only cavity 3 continues to flame to the 11 ft mark.
5:30	Flaming has extended to the 12 ft mark in cavity 3 and has jumped over to cavity 2.
6:00	The roof rafter ignited and started to flame. It was necessary to extinguish this before continuing the test.
10:00	All flaming was out. Smoldering was apparent. The test was terminated at 15 min.

File USNC97

Test No. 38
Material Identification - G
Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignited cigarette placed with glowing end up.
3:00	Light smoke evident. A browning of the material directly adjacent to the source.
9:00	No change.
20:00	Smoke increasing in the area of the char surrounding the cigarette.
27:00	No change.
35:00	Smoldering evident, smoke increasing.
45:00	3 in. diameter char around cigarette. Smoke increasing.
60:00	4 in. diameter char around source. Smoke continues to increase.
449:00	After the test began, the test was terminated. During that time, smoldering was evident and continued. For the appropriate smoldering rate, see the smoldering tables.

Test No. 39
Material Identification - I
Ignition Source - Insulated Light Fixture Rated Bulb

The attic chamber was preheated for 2 h prior to actuation of the recessed light fixture. Preheating continued for an additional 2 h, at which time it was terminated and the light remained on during the entire test. The results of the test indicated no smoke, no charring or discoloration of the material adjacent to the light fixture and no smoldering.

File USNC97

Test No. 40

Material Identification - J

Ignition Source - Light Fixture Over Lamped

The attic chamber was preheated 2 h prior to actuation of the recessed light fixture. The preheat continued for an additional 2 h and was then terminated. The lamp continued to burn throughout the remainder of the test. Within 2 h after the ignition of the lamp, smoldering was evident. The smoldering was allowed to continue for approx 6 h before the test was terminated. For the appropriate smoldering rate, see the smoldering tables.

Test No. 41

Material Identification - J

Ignition Source - Overheated Wire

The attic chamber was preheated for 2 h prior to activating the overheated wire apparatus. The preheat was continued for two additional hours. Temperatures adjacent to the source were monitored during the test with no smoke, no discoloration or smoldering of the material apparent when the test was terminated. See Table 7 for temperature profile.

Test No. 42

Material Identification - S

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition of alcohol.
0:15	Flames extending to 4 in. diameter.
0:30	Flames extending to 5 in. diameter; 3 in. flame height.
1:00	Flames decreasing.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
2:00	Light flickers in spill area only.
7:45	No change.
12:30	All flame and glow self-extinguished.

Test No. 43

Material Identification - T

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition of alcohol.
0:15	Flames extending to 4 in. diameter; 4 in. flame height.
3:30	Flames decreasing.
8:00	Flickering flames in spill area.
10:00	Test terminated.

Test No. 44

Material Identification - T

Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Glowing cigarette inserted into insulation material.
90:00	1 in. diameter light discoloration around cigarette.
180:00	No smoldering. Test terminated.

File USNC97

Test No. 45

Material Identification - S

Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Glowing cigarette inserted into insulation material.
90:00	1 in. diameter light discoloration around cigarette.
180:00	No smoldering. Test terminated.

Test No. 46

Material Identification - W

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition of alcohol.
0:15	Flames extending to 4 in. diameter, green-yellow flame approx 3 in. flame height.
0:45	Flames extending to 5 in. diameter.
2:00	Flames decreasing, 2 in. flame height.
4:00	Light flickers in spill area only.
12:42	All flame and glow self-extinguished.

File USNC97

Test No. 47

Material Identification - R

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition of alcohol.
0:15	Flames extending to 4 in. diameter, 3 in. flame height.
1:00	No change.
1:45	Flames decreasing, 2 in. height greenish flame.
3:30	Flames in spill area only.
8:30	Light blue flickers in spill area.
14:15	All flame and glow self-extinguished.

Test No. 48

Material Identification - W

Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Glowing cigarette inserted into insulation material.
10:00	1/2 in. diameter discoloration and light smoke around cigarette.
17:00	1 in. diameter discoloration. Smoldering indicated.
110:00	No smoke, no smoldering, test terminated.

File USNC97

Test No. 49

Material Identification - R

Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Glowing cigarette inserted into insulation material.
11:00	3/4 in. diameter of discoloration and increasing smoke around cigarette.
18:00	1-1/2 in. diameter discoloration. Smoldering evident.
73:00	6 in. diameter char.
85:00	8 in. diameter char.
193:00	Char the full width of cavity, extending to 18 in. length and heavy smoke being emitted.
328:00	Char has reached 32 in. mark.
583:00	The test was terminated; char had extended the full width of the cavity to the 47 in. mark. Refer to the smoldering rate table for individual values.

Test No. 50

Material Identification - V

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition of alcohol.
0:15	Flames extending to 6 in. diameter and 4 in. flame height.
1:00	Flames extending to 8 in. width, 6 in. length with 3 in. high green flame.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
2:00	No change.
3:00	Flames decreasing, 1-1/2 in. flame height.
5:00	Light flickers in spill area only.
11:02	All flame and glow self-extinguished.

Test No. 51

Material Identification - Q

Ignition Source - Alcohol Spill

<u>Time, Min</u>	<u>Observations</u>
0:00	Ignition of alcohol.
0:15	Flames extending to 10 in. width, 8 in. length and 4 in. flame height.
1:00	Flames decreased to spill area, 3 in. flame height.
3:00	No change.
8:00	Light flickers in spill area only.
10:02	All flame and glow self-extinguished.

Test No. 52

Material Identification - V

Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Glowing cigarette inserted into insulation material.
8:00	1/2 in. diameter of discoloration and light smoke around cigarette.

File USNC97

<u>Time, Min</u>	<u>Observations</u>
68:00	1 in. diameter char, 1-1/2 in. diameter discoloration, no smoke, no glow. Test terminated.

Test No. 53
 Material Identification - Q
 Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Glowing cigarette inserted into insulation material.
19:00	1/2 in. diameter char, 1 in. diameter discoloration and light smoke around cigarette.
79:00	1 in. diameter char, 1-1/2 in. diameter discoloration, no smoke, no smoldering. Test terminated.

Test No. 54
 Material Identification - R
 Ignition Source - Cigarette

<u>Time, Min</u>	<u>Observations</u>
0:00	Glowing cigarette inserted into insulation material.
67:00	5 in. diameter char and medium smoke around cigarette, smoldering evident.
265:00	Char the full width of cavity and extending to 25 in. mark. Original cigarette burn test verified. Test terminated.

File USNC97

Test No. 55

Material Identification - V

Ignition Source - Light Fixture Rated Bulb

At 2:00 P.M. after 2 h of preheat, the light fixture was switched on. Temperatures were monitored during the test with no smoke, no discoloration of the material and no smoldering apparent when the test was terminated at 9:00 P.M. The fixture body temperature was 290 °F.

Test No. 56

Material Identification - S

Ignition Source - Light Fixture Rated Bulb

At 2:00 P.M. after 2 h of preheat, the light fixture was switched on. Temperatures were monitored during the test with no smoke, no discoloration of the material and no smoldering apparent when the test was terminated at 9:00 P.M. The fixture body temperature was 290 °F.

Test No. 57

Material Identification - Q

Ignition Source - Light Fixture Rated Bulb

At 2:00 P.M. after 2 h of preheat, the light fixture was switched on. Temperatures were monitored during the test with no smoke, no discoloration of the material and no smoldering apparent when the test was terminated at 9:00 P.M. The fixture body temperature was 315 °F.

Test No. 58

Material Identification - T

Ignition Source - Light Fixture Rated Bulb

At 2:00 P.M. after 2 h of preheat, the light fixture was switched on. Temperatures were monitored during the test with no smoke, no discoloration of the material and no smoldering apparent when the test was terminated at 9:00 P.M. The fixture body temperature was 315 °F.

File USNC97

Test No. 59

Material Identification - V

Ignition Source - Light Fixture Over Lamped

The attic chamber was preheated for 2 h prior to actuation of the recessed light fixture. The preheat continued for two additional hours. Within the continuing preheat period, smoldering was evident and continued during the remainder of the test. For the appropriate smoldering rates, see the smoldering rate table. The fixture body temperature prior to smoldering was approx 550 °F.

Test No. 60

Material Identification - S

Ignition Source - Light Fixture Over Lamped

The attic chamber was preheated for 2 h prior to actuation of the recessed light fixture. The preheat continued for two additional hours. Within the continuing preheat period, smoldering was evident and continued during the remainder of the test. For the appropriate smoldering rates, see the smoldering rate table. The fixture body temperature prior to smoldering was approx 550 °F.

Test No. 61

Material Identification - Q

Ignition Source - Light Fixture Over Lamped

The attic chamber was preheated for 2 h prior to actuation of the recessed light fixture. The preheat continued for two additional hours. Within the continuing preheat period, smoldering was evident and continued during the remainder of the test. For the appropriate smoldering rates, see the smoldering rate table. The fixture body temperature prior to smoldering was approx 550 °F.

File USNC97

Test No. 62

Material Identification - T

Ignition Source - Light Fixture Over Lamped

The attic chamber was preheated for 2 h prior to actuation of the recessed light fixture. The preheat continued for two additional hours. Within the continuing preheat period, smoldering was evident and continued during the remainder of the test. For the appropriate smoldering rates, see the smoldering rate table. The fixture body temperature prior to smoldering was approx 550 °F.

Test No. 63

Material Identification - W

Ignition Source - Light Fixture Over Lamped

The attic chamber was preheated for 2 h prior to actuation of the recessed light fixture. The preheat continued for two additional hours. Within the continuing preheat period, smoldering was evident and continued during the remainder of the test. For the appropriate smoldering rates, see the smoldering rate table. The fixture body temperature prior to smoldering was approx 550 °F.

Test No. 64

Material Identification - W

Ignition Source - Light Fixture Rated Bulb

At 12:00 P.M. after 2 h of preheat, the light fixture was switched on. Temperatures were monitored during the test with no smoke, no discoloration of the material and no smoldering apparent when the test was terminated at 5:30 P.M. The maximum fixture body temperature was 320 F.

File USNC97

Test No. 65

Material Identification - R

Ignition Source - Light Fixture Over Lamped

The attic chamber was preheated for 2 h prior to actuation of the recessed light fixture. The preheat continued for two additional hours. Within the continuing preheat period, smoldering was evident and continued during the remainder of the test. For the appropriate smoldering rates, see the smoldering rate table. The fixture body temperature prior to smoldering was approx 550 °F.

Test No. 66

Material Identification - R

Ignition Source - Light Fixture Rated Bulb

At 12:00 P.M. after 2 h of preheat, the light fixture was switched on. Temperatures were monitored during the test with no smoke, no discoloration of the material and no smoldering apparent when the test was terminated at 5:40 P.M. The maximum fixture body temperature was 300 F.

File USNC97

APPENDIX B
PHOTOGRAPHIC DOCUMENTATION

The following photographic documentation provides information of selected fire tests under exposure to the 25 ft Tunnel Test, Attic Floor Radiant Panel Test, and Full-Scale Simulated Attic Tests.

NOTE: The reproduction of the photographs are poorer because color photographs were submitted by the subcontractor.

25 FT. TUNNEL TEST APPARATUS

TYPICAL CELLULOSIC SAMPLE READY FOR TEST

SAMPLE B POST TEST

SAMPLE C POST TEST

ATTIC FLOOR RADIANT PANEL TEST SAMPLE B

ATTIC FLOOR RADIANT PANEL SAMPLES-POST TEST

ATTIC ENCLOSURE

ATTIC ENCLOSURE -CONVECTIVE HEATING MODE

TYPICAL ALCOHOL SPILL

SAMPLE W-ALCOHOL SPILL

SAMPLE B BY PROPANE TORCH

SAMPLE B BY PROPANE TORCH-POST TEST

SAMPLE C BY PROPANE TORCH

SAMPLE C BY PROPANE TORCH-POST TEST

TEST NO. 3-SAMPLE C

TEST NO. 36-SAMPLE K

TEST NO. 37-SAMPLE M

TYPICAL CELLULOSIC SAMPLE-CIGARETTE IGNITION

SAMPLE A-CIGARETTE IGNITION

SAMPLE V-CIGARETTE IGNITION

RECESSED LIGHT FIXTURE

RECESSED LIGHT FIXTURE-OVERLAMPED CONDITION-SAMPLE S

ORNL/Sub/79-7863/1

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61. R. S. Lukasz, Underwriters Laboratories, Inc., Northbrook, IL
62. H. R. Marien, Headquarters, Air Force Engineering & Services
Center, HQ AFESC/DEMM, Tyndall AFB, Florida 32403
63. J. P. Millhone, DOE/CE, Washington, DC
64. K. Mentzer, MIMA, 382 Springfield Avenue, Summit, NJ
65. W. R. Newton, TVA, Chattanooga, TN
66. T. J. Ohlemiller, National Bureau of Standards,
Gaithersburg, MD

67. R. Orlandi, W. R. Grace & Company, Cambridge, MA
68. C. M. Pelanne, 4900 Pinyon Drive, Littleton, CO
69. L. Peterson, Technical Services Div., Thermoguard
Insulation Co., Seattle, WA
70. F. J. Powell, National Bureau of Standards, Gaithersburg, MD
71. F. Rickenbach, Urethane Foam Contractors Association,
Dayton, OH
72. E. Schaffer, Forest Products Laboratory, Madison, WI
73. W. W. Seaton, ASHRAE, Atlanta, GA
74. M. Sherman, Jim Walter Research Corp., St. Petersburg, FL
75. C. J. Shirliffe, NRC, Ottawa, Canada
76. J. A. Smith, DOE/CE, Washington, DC
77. H. S. Smith, Cellin Manufacturing Inc., Lorton, VA
78. N. Smith, 48 L. Newton Street, St. Albans, VT 05478
79. G. A. Tsongas, Portland State University, Portland, OR
80. R. P. Tye, Dynatech R/D, Cambridge, MA
81. C. R. Vander Linden, Manville Corporation, Denver, CO
82. J. D. Verschoor, 179 Gail Lane, Bailey, CO
83. J. R. Warner, ACEC Research and Management Foundation,
Washington, DC
84. Office, Assistant Manager, Energy Research & Development,
DOE-ORO, Oak Ridge, TN
- 85-111. Technical Information Center, U.S. Department of Energy,
POB 62, Oak Ridge, TN

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