NATIONAL BUREAU OF STANDARDS REPORT

10 405

FIRE ENDURANCE TESTS OF ROOF/CEILING CONSTRUCTIONS FOR SINGLE FAMILY HOUSING

U.S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

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[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.
[2] Part of the Center for Radiation Research.
[3] Located at Boulder, Colorado 80302.

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FIRE ENDURANCE TESTS OF ROOF/CEILING CONSTRUCTIONS FOR SINGLE FAMILY HOUSING

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Department of Housing and Urban Development

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FIRE ENDURANCE TESTS OF ROOF/CEILING CONSTRUCTIONS FOR LOW-COST FAMILY HOUSING

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TABLE OF CONTENTS

ABSTRACT

As a part of Operation Breakthrough, on January 18, 1971, a standard ASTM E119-69 Fire Endurance tests was performed at the National Bureau of Standards on a roof/ceiling assembly. The assembly contained a structural core of paper honeycomb with glass-reinforced plastic skins, and protective layers of gypsum board.

The fire resistance of the roof/ceiling assembly was 37 min: 13 sec. This does not meet the 3/4 hr in Criterion B.4.1.4 Volume III of the "Guide Criteria" for systems when the interdwelling wall does not extend 18 inches above the roof line. The mode of failure was by flame through of the roof/ceiling assembly.

For flame spread, smoke density, and gaseous combustion products from the exposed surfaces of the specimen, refer to NBS Report No. FR3744.

The test results are only applicable to this particular construction with a load of 15.9 psf and a span of 13'6", as described in this report.

1.0 Introduction

For roof/ceiling assemblies, Criterion B.4.1.4, Volume III of the Guide Criteria for Operation Breakthrough states the following:

> Criterion B.4.1.4
>
> Wall Extension Above Roof Line
>
> The wall should extend at least 18 inches above the roof line. When the roof assembly has at least 3/4 hour fire resistance rating the fire wall may extend to the underside of the assembly if a fire stop with a 3/4 hour fire resistance is provided.

A sandwich panel roof/ceiling system for single family attached housing under the Operation Breakthrough program, was submitted for test. The 7 1/4 in. thick panel consisted of a 6 in. thick paper honeycomb core with woven fiber glass and polyester resin faces, a 5/8 inch type X gypsum board on each face and a sand and polyester resin coating on the top (exterior) surface.

The specimen was tested under normal design loading in accordance with the requirements of ASTM Designation E119-69 Standard Methods of Fire Tests of Building Constructions and Materials.

2.0 Roof/Ceiling Test

2.1 Construction of the Test Assembly

The roof/ceiling assembly which was mounted in the 18-0 x 13-6 framed opening of the NBS floor test furnace was composed of two equal-size panels joined along the east-west centerline. Each panel (13'0 x 8'11) was made of a flame retardant treated paper honeycomb core 6" thick, woven glass fiber roving and polyester resin face, and 5/8 inch type X gypsum board top and bottom surfaces. The edges of each panel were finished with a 3 inch thick assembly of laminated plywood closeout pieces. The unexposed surface was finished with a woven glass fiber roving impregnated with resin. The adhesive used for assembling the gypsum board facings to the structural core was a polyester containing one percent asbestos fiber. All joints between the gypsum boards on the exposed surface had been taped and filled with plaster compound U.B.S. STD 47-5-67 (USGF 1880). The joints on the upper and lower gypsum board layers were staggered.

The center joint between the two panels was protected during the test by a 5 inch wide gypsum board strip (/58 inch, type X). The details of the construction are shown in Fig. 1.

2.2 Instrumentation

The instrumentation consisted of thermocouples, deflection indicators, and loading equipment. A total of 15 chromel-alumel (type K) thermocouples were used: eight on the unexposed (top) surface away from the joint, one at the center of the joint, and three thermocouples within each panel. The surface thermocouples were covered with 0.4 in. thick standard asbestos pads. See Fig. 1 for the locations of the thermocouples.

The temperatures of the thermocouples were printed out at one minute intervals on a data logger from which they were punched on cards for processing and plotting by computer. Deflections were measured at three points along the longitudinal center line: at the north quarter point, south quarter point, and at dead center. This was accomplished using wires attached to the unexposed surface which pass over pulleys and were loaded with small weights to keep them taut. Indicating riders were attached to the wires as they passed over a vertical scale just above the small weights. Each rider indicated the amount of movement at the corresponding point on the test specimen during the test. Each pulley was also attached to a linear deflection potentiometer whose output was connected to a recorder.

2.3 Test Procedures

A load of 15.9 psf was calculated to produce the same bending moment, and bending stresses on the 13'-6" span in the test furnace as 20 psf produced on the 12'-0 span that is actually used in the module. This load was applied 24 hours before the test started. The load was applied at 36 points, and approximated a uniform load.

The average temperature inside the furnace was measured by twelve protected ASTM thermocouples and followed the standard ASTM E119-69 temperature-time curve by automatic control of the gas flow to the burners. The average furnace temperatures are shown in Fig. 2.

The fire endurance of a construction according to the criteria of failure designated by the ASTM E119-69:

a. The construction shall have sustained the applied load during the fire endurance test without passage of flame or gases hot enough to ignite cotton waste, for a period equal to that for which classification desired.

b. Transmission of heat through the construction during the fire endurance test shall

not raise the average temperature on the unexposed surface more than 250°F (139°C) or 325°F (181°C) at one point, above the initial temperature.

A test shall be regarded as successful if the above conditions are met.

2.4 Test Results

A complete log of test observations is given in the Appendix I. Flame penetration occurred south of the center through a joint in the upper layer of gypsum boards. This was observed at 37 minutes:50 seconds. A local load failure occurred 10 seconds later at the point of flame through. Fig. 3 is a picture taken at the instant of flame through. The location of flame through and the associated char region after the test is shown in Fig. 4.

The rate of deflection was very slow until 30 minutes after the start of the test and then showed a more rapid increase. Fig. 5 shows the deflection vs. time at the north and south quarter points.

A local load failure was initiated by a local crushing of the upper (roof) surface under a loading point near the center of the test specimen.

At the time of failure by local flame through (37 min: 50 sec), the average temperature of the unexposed surface was 58°C (136F) and the maximum temperature rose 83°C (182F) as shown in Fig. 6. According to the standard correction formula in ASTM E119-69, based on the comparison of the areas under the actual time-temperature curve and the standard curve, the corrected time of flame through was 37 min:13 sec.

Fig. 7 shows the temperatures of the six internal thermocouples. Figs. 8, 9, and 10 are photographs taken from the underside of the specimen after the completion of the test. Fig. 8 shows a closeup of the ruptured woven glass roving, and gypsum board at the edge of the flame through and ruptured hole. The top view is also shown in Fig. 4.

Fig. 9 shows the deterioration of the underside of the specimen. Most of the honeycomb has either fallen into the furnace or has been consumed. In Fig. 10, the circled area shows continued flaming of the honeycomb core two hours after the end of the test, even though the specimen had been sprayed with water, using a fog nozzle immediately after the end of the test, and flames had appeared to be extinguished.

The core and adhesive contributed much fuel to the furnace during the test (see potential heat estimates in NBS Report FR 3744).

2.5 Discussion

Though the assembly was able to carry the applied load during the test, an analysis indicated that the load was probably carried by the wood closeout pieces at the edges of the panel. Due to the loading arrangement used, the rigid filler piece transmitted the load primarily to the closeout pieces, which were only slightly scorched during the test. This does not represent the load conditions that would normally be imposed on the supporting walls of a module. In actual construction the closeout pieces would be spaced about 30 feet apart, and most of the roof/ceiling load would be applied between the edge pieces. Under more representative loading conditions, it is questionable if the assembly could sustain the load for as long as 1 hour 16 minutes.

The core and adhesive contributed fuel to the furnace during the test (see potential heat estimates in NBS Report FR 3744).

3.0 Conclusion

A test was conducted to study the fire endurance characteristrics of a floor/ceiling consisted of a paper honeycomb sandwich with woven fiber glass and gypsum board faces.

The fire endurance of the floor assembly, 37 min:13 sec., did not meet the 3/4 hr. requirement of Criterion B.4.1.4 Volume III of the Guide Criteria of Operation Breakthrough.

The test results are only applicable to this particular construction with a load of 15.9 psf and a span of 13'6", as described in this report.

Further information of this report can be found in Laboratory Notebook No. 168, Test No. 482, in the Fire Research Section, National Bureau of Standards.

APPENDIX I

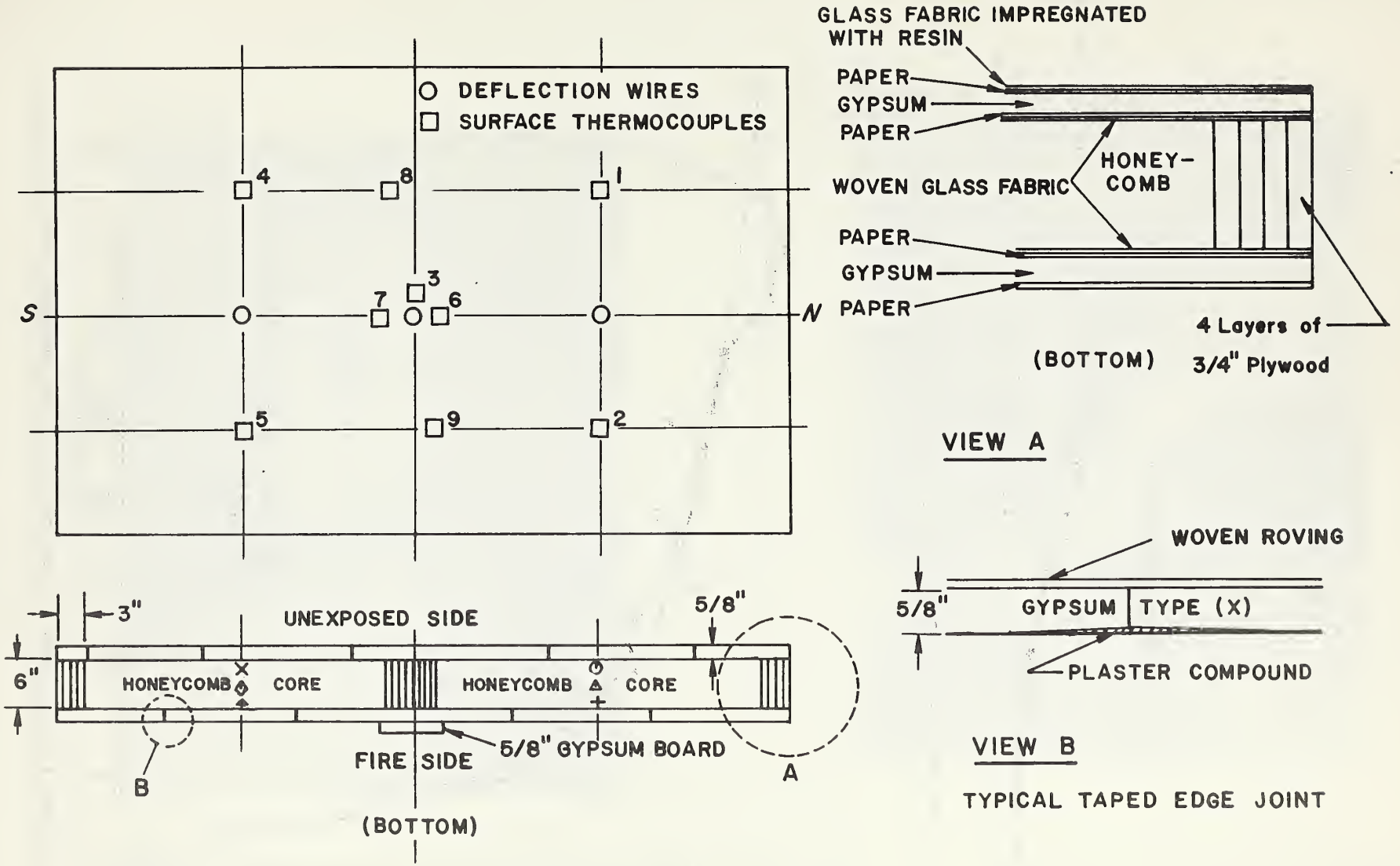
Log of Tests

1. Roof/Ceiling Test

Visual Observations

Min:sec	Observations
0:00	Start test
2:00	Blue flaming over the exposed surface
3:00	Flame disappeared
4:00	Blue flame again spreading over the exposed surface
4:20	Flame disappeared. Much smoke coming through the unexposed surface
24:00	Flaming at a gypsum joint near south quarter point on exposed surface (honeycomb core burning)
28:00	Large flaming at the middle of the south panel on exposed surface (opening up of the gypsum joints)
30:00	Bottom layer of gypsum board on south panel has started to fall into the furnace
30:50	Furnace filling with smoke and flame. Deflection of 1 in. at the south quarter point was observed on the recorder

Min:sec	Observations
35:00	A gypsum joint near the south of the center on the unexposed surface started to open and the gypsum board under a nearby loading point was being crushed
37:50*	Flame through occurring at the same point where the gypsum board was failing under a loading point (See Fig. 3)
38:00	Pieces of the upper layer of gypsum board at this loading point were falling into the furnace, (a local load failure) at the point of flame through
39:00	Gas off, end of test
37:13*	Corrected time to flame through in accordance with the formula given in paragraph 5(c) of ASTM E119-69



Figurel. Details of construction and locations of thermocouples for roof-ceiling specimen

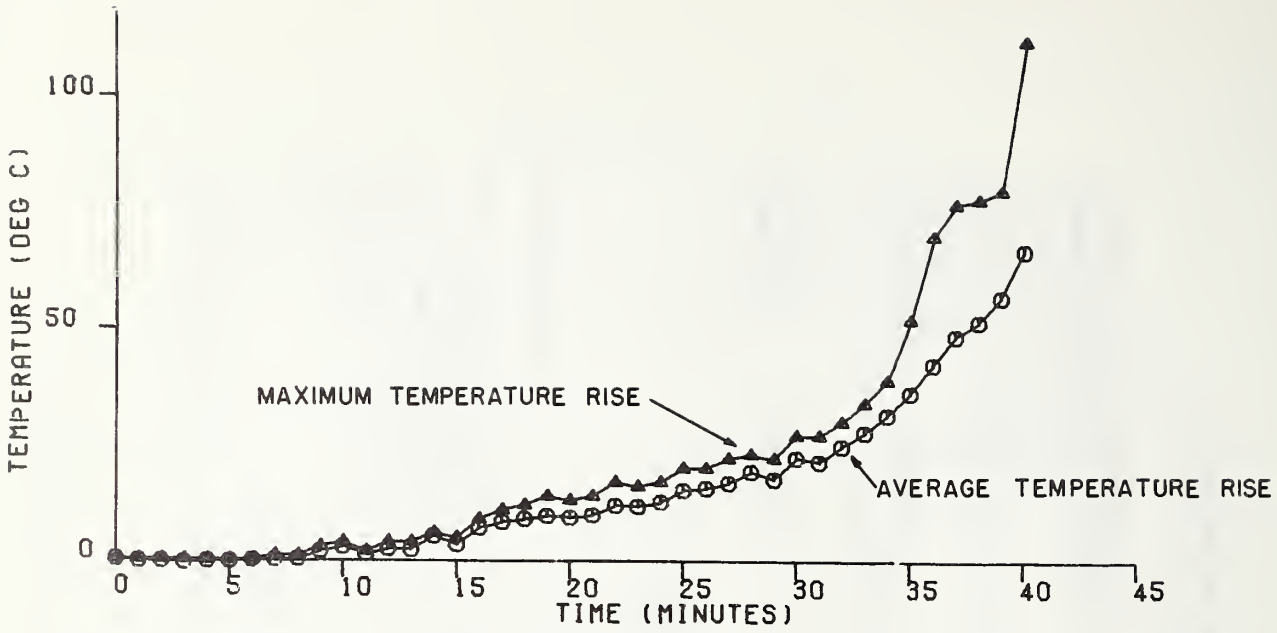


Fig. 6 MAXIMUM AND AVERAGE SURFACE TEMPERATURE RISE FOR TEST 482

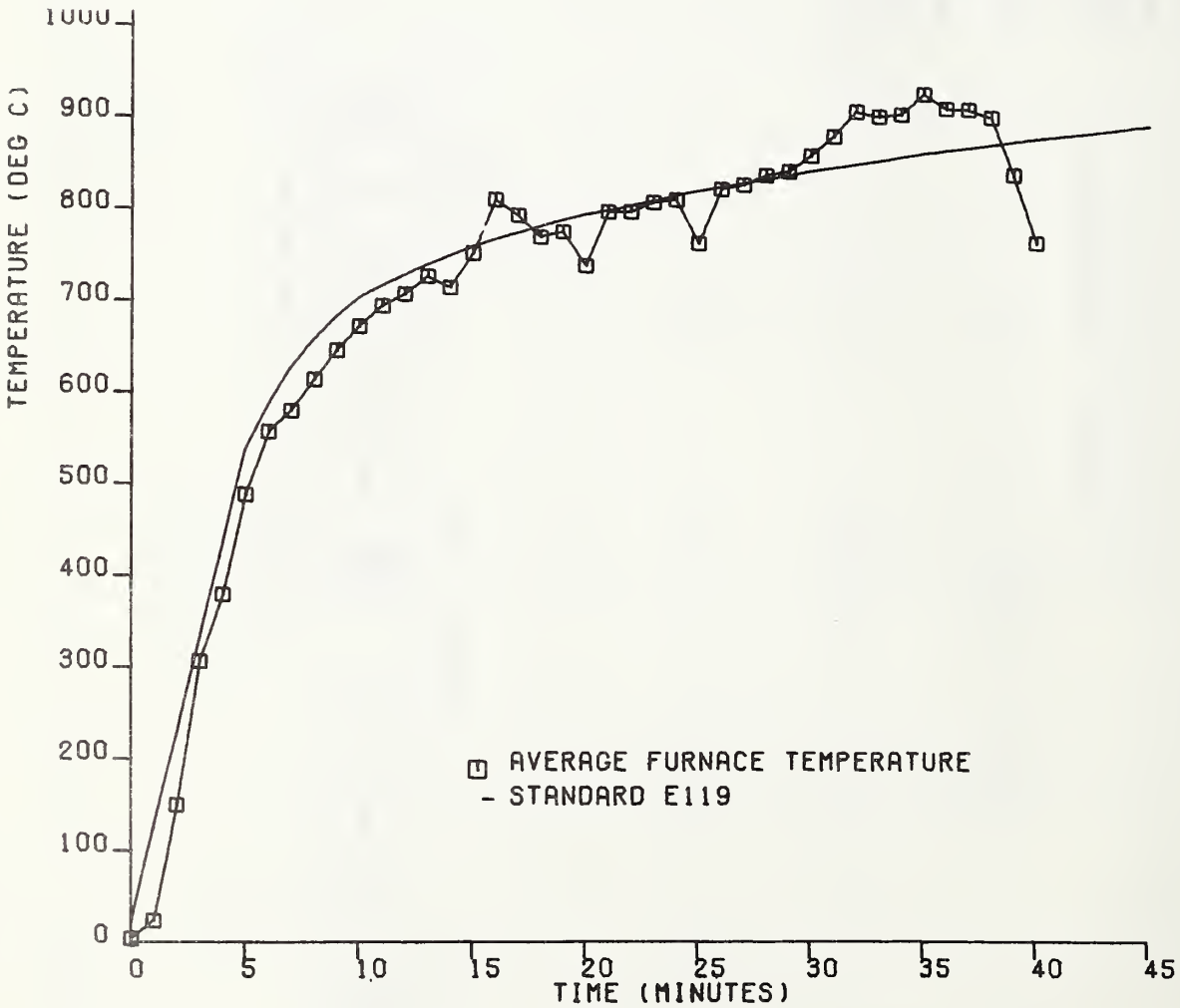


Fig. 2 AVERAGE FURNACE TEMPERATURE FOR TEST 482 COMPARED WITH STANDARD E119

Figure 3 The instant of flame through near center

Figure 4 The location of flame through and associated char region

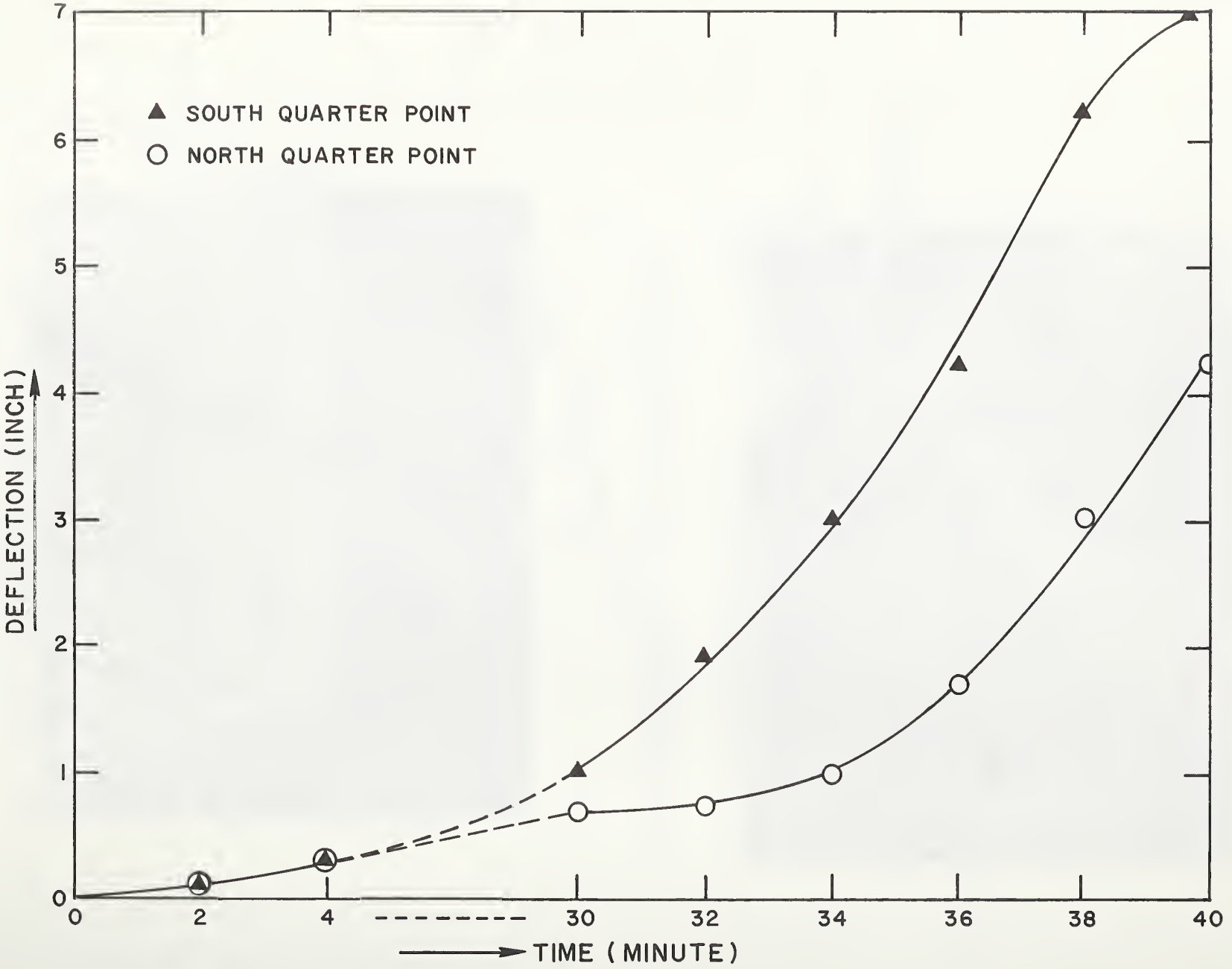


Figure 5 Deflections at north and south quarter point vs time.

FIG.7 TEMPERATURES OF SIX THERMOCOUPLES WITHIN ROOF-CEILING ASSEMBLY

(See Fig 1 for the corresponding locations of thermocouples)

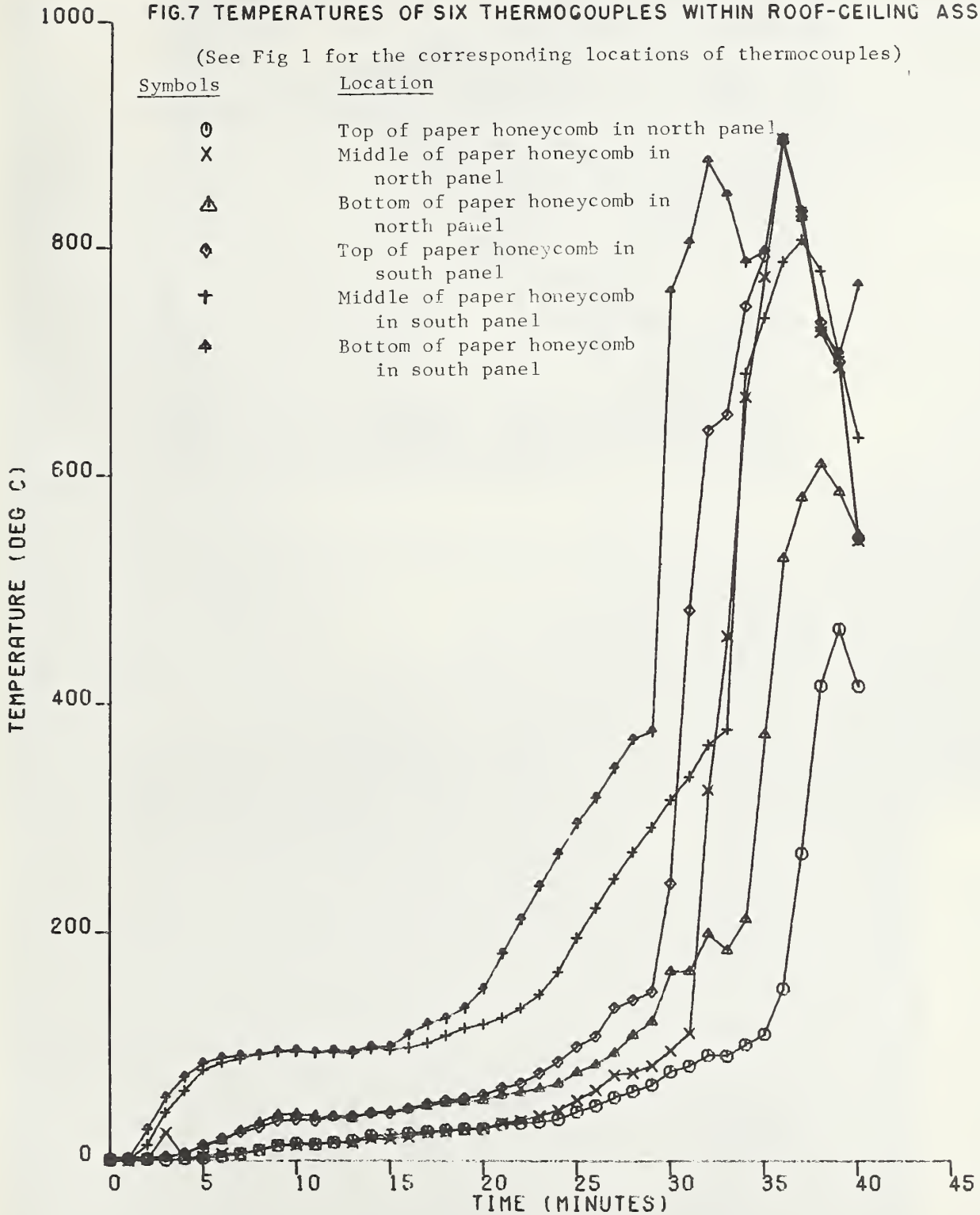


Figure 8 The close up of the edge of the hole.
(Woven glass roving with resin, paper, gypsum board)

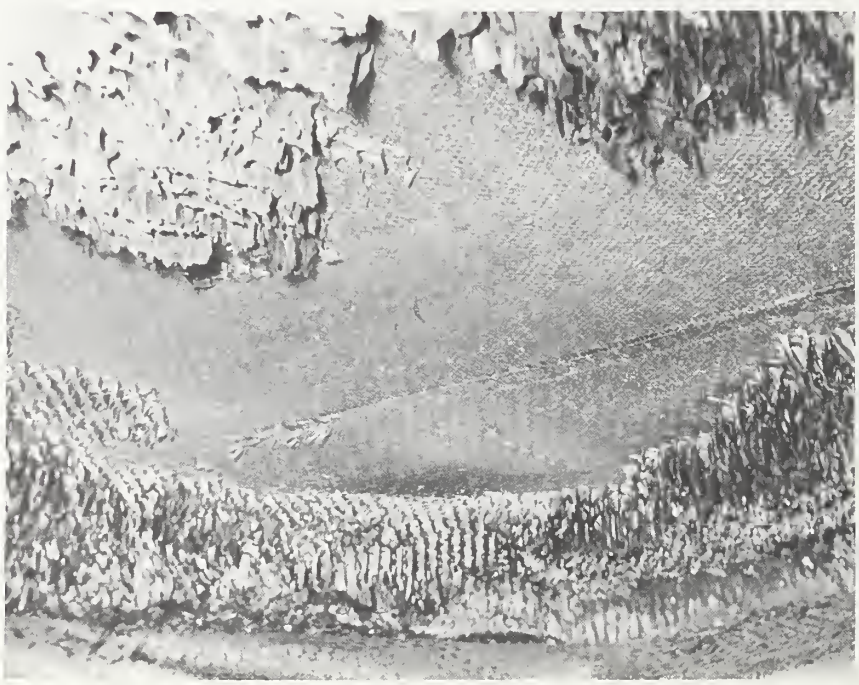


Figure 9 The deterioration of the underside of the specimen.

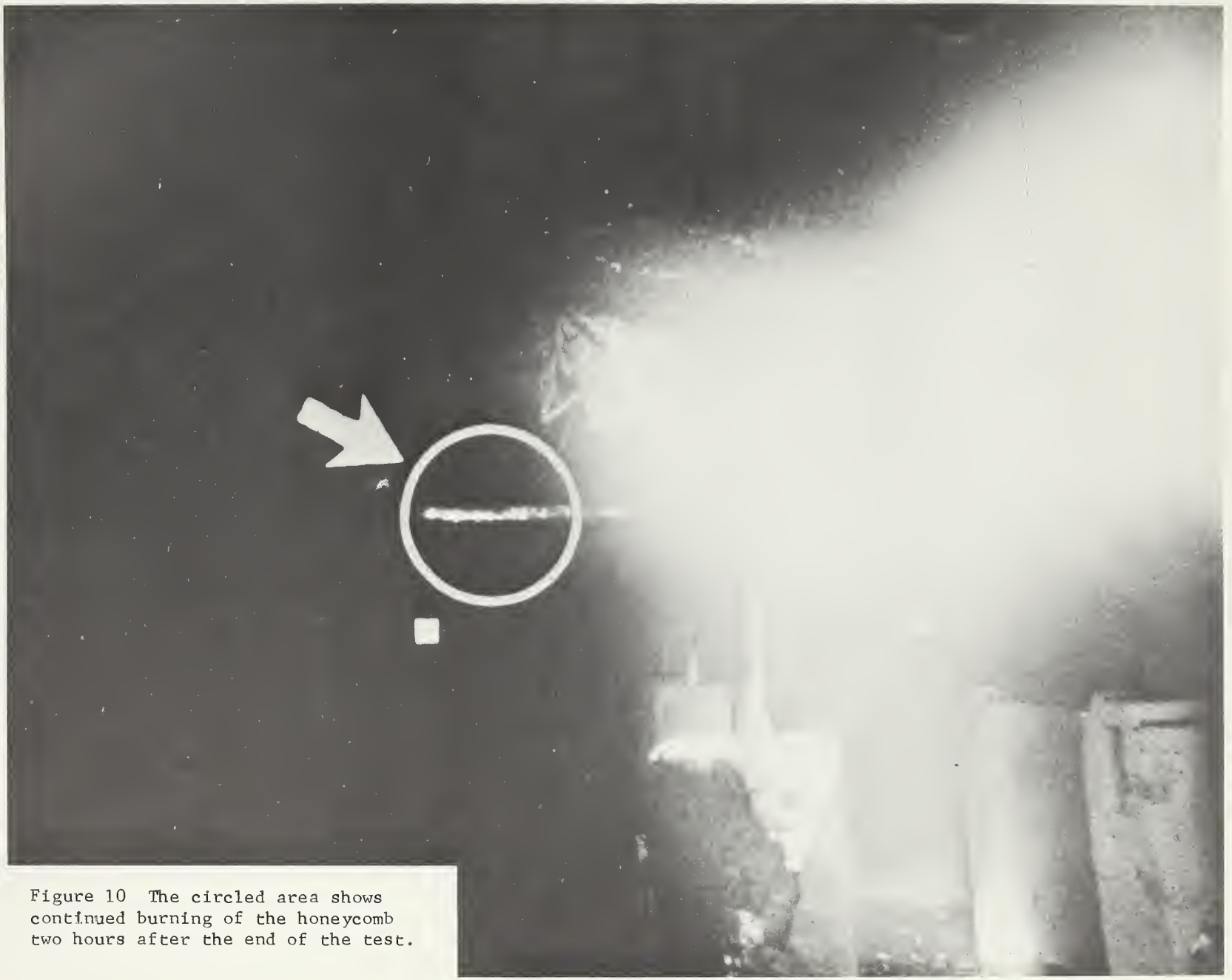
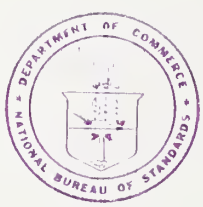


Figure 10 The circled area shows continued burning of the honeycomb two hours after the end of the test.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