Contribution of insulation in cavity walls to propagation of fire

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ABSTRACT

Tests were carried out to examine the contribution of insulating material in cavity walls to propagation of fire. Materials with various flame spread ratings were tested under conditions that are representative of those met with in practice.

It was found that an insulating material used in a vertical position between two layers of non-combustible material with an intervening air space is not likely to contribute to fire propagation if it has a flame-spread rating of 25 or less.

For insulating materials between two layers of incombustible materials without an intervening air space, the results indicate that fire propagation may not occur even if the insulation has a flame-spread rating substantially higher than 75.

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The National Building Code of Canada 1970 requires that thermal and sound insulation in "noncombustible construction" shall have a flame-spread rating of not more than 75 (according to ASTM E84-70[1] or similar test), when the insulation is sandwiched between two layers of noncombustible material without an intervening air space. Where the insulation is not installed in this manner, it is required to have a flame-spread rating of not more than 25.

No investigations have been carried out so far on the behaviour of insulating materials in cavities when they are exposed to fire. Some doubt exists whether the contribution of insulation to the propagation of a fire in a cavity is related to its flame-spread rating, in particular in those cases where the insulation is fully enclosed by a noncombustible material without intervening air space.

To obtain more insight into the behaviour of materials in cavities a study was undertaken in which various insulating materials were examined with regard to their contribution to fire propagation in a cavity. For the purpose of this study a cavity wall was constructed, in which a test specimen could be inserted and exposed to the heat of a furnace.

As a large number of possibilities exists with respect to the choice of type and size of the testing material, the position of the material during the test, the width of the cavity and the testing conditions, investigation of all possibilities is not feasible. Therefore, the most common materials were chosen for further examination under conditions that are representative of those met with in practice. These materials and conditions are briefly as follows.

Type of insulation:

a) expanded polystyrene (thermoplastic) with low and high flame-spread ratings.

b) urethane foam (thermosetting) with low and high flame spread ratings.

Thickness of insulation:	between 1 and 2 in.
Position of insulation:	vertical, since this is the less favourable condition from the point of view of fire propagation.
Width of cavity:	equal to thickness of the insulation or if tested with an air space 1 in. more than the thickness of the insulation.
Heating condition:	exposure to heat from a furnace, whose temperature follows that of the standard fire described in ASTM E119-71[2].

The test specimens, test apparatus and testing procedure are described in more detail in the following paragraphs. The possibility of fire propagation caused by conduction of heat through the wall material has not been considered in this study.

DESCRIPTION OF TEST APPARATUS

The cavity wall for testing the insulation consisted of two reinforced concrete slabs, 7 ft 8 in. high and 3 ft wide (Figure 1). This distance between the slabs was adjustable. It was assumed that, during a fire, openings in the cavity wall would be created and that the insulation would be exposed directly to the fire. To simulate this situation an opening 2 ft by 2 ft was made in the bottom of one of the slabs through which the insulation could be exposed to heating. In the other slab 7 holes of 1 in. diameter were made. Through these holes, which were spaced 1 ft from each other vertically, the propagation of the fire could be observed. During the test these holes were kept closed except when observations were made. In addition, the propagation of the fire in the cavity was recorded by measuring the temperature of the insulation at the location of each hole with the aid of thermocouples.

The cavity wall was attached against the test furnace in such a manner that the opening in the slab coincided with the opening of the test furnace. In this way the bottom of the specimen would be exposed to the heat of the furnace.

The specimen was glued against the concrete slab nearest to the furnace (which corresponds to the inner wall in practice) with the aid of a neoprene-based mastic with a low flame-spread rating of 5.

During the test the edges of the test cavity wall were sealed with a mineral wool, with the exception of a small port, 4 in. in length and width equal to the spacing of the concrete slabs, at the centre of the top. Owing to this opening an upward current was created from the furnace to the top of the wall through the cavity.

The test furnace was built mainly from insulating fire brick and was heated electrically with the aid of silicon carbide heating elements. The furnace chamber was approximately 30 in. high, 31 in. wide and 16 in. deep. During the test a regulated amount of air could be introduced through steel pipes at the bottom of the furnace. Observations of the exposed surface of the specimen could be made through ports cut in the side walls of the furnace. A more detailed description of the test furnace is given in reference (3).

TEST SPECIMENS

The test specimens have the same dimensions as the test cavity wall, i.e. 7 ft 8 in. high and 3 ft wide. The particulars of the test specimens are as follows:

Test Specimen No. 1

Material: expanded polystyrene
Thickness: $1\frac{1}{2}$ in.; Density: 1 lb/cu ft
Flame-spread rating (ASTM E84-70): 30
No air space in cavity

Test Specimen No. 2

Material: expanded polystyrene
Thickness: 2 in.; Density: 1.88 lb/cu ft
Flame-spread rating (ASTM E84-70): 110
No air space in cavity

Test Specimen No. 3

Material: urethane foam
Thickness: 1 in.; Density: 2.27 lb/cu ft
Flame-spread rating (ASTM E84-70): 23
No air space in cavity

Test Specimen No. 4

Material: urethane foam
Thickness: 1 1/4 in.; Density: 1.67 lb/cu ft
Flame-spread rating (ASTM E84-70): 333
No air space in cavity

Test Specimen No. 5

Material: urethane foam
Thickness: 1 1/4 in.; Density: 1.67 lb/cu ft
Flame-spread rating (ASTM E84-70): 333
1-in. air space in cavity

Test Specimen No. 6

Material: urethane foam
Thickness: 1 in.; Density: 2.04 lb/cu ft
Flame-spread rating (ASTM E84-70): 20
1-in. air space in cavity

Test Specimen No. 7

Material: urethane foam
Thickness: 1 in.; Density: 2.71 lb/cu ft
Flame-spread rating (ASTM E84-70): 40
1-in. air space in cavity

TEST PROCEDURE

The tests were carried out by exposing the bottom part of a test specimen to the heat of a furnace through an opening in the cavity wall. The heat input into the test furnace was controlled in such a way that the average temperature closely followed the standard temperature versus time curve (Figure 2), prescribed by ASTM E119-71[2]. The temperature of the furnace was measured at five locations by thermocouples (3), and the average of the temperatures at these places was regarded as the average furnace temperature.

During the test, temperatures were also measured in the insulation at various heights. The measurements were carried out with the aid of 7 thermocouples, which were inserted in the insulation, the first couple located 1 ft above the bottom of the specimen, and the others above this couple at 1-ft intervals (Figure 3). In those cases where there was an air space in the cavity wall, temperatures were also measured in the air space at the top of the specimen (7 ft above the bottom of the specimen).

Observations were made during the test through the ports in the furnace wall and through the holes in the cavity wall.

TEST RESULTS

The observations made during the various tests are described below. In all tests the furnace temperature followed very closely the standard temperature course prescribed by ASTM E119-71, and therefore they are not given here.

Test No. 1

Specimen: expanded polystyrene
Flame-spread rating: 30
No air space in cavity

Time after the start of the test, (min)	Observations
10	Insulation is melting at a height of 4 ft above the bottom of the specimen.
19	Insulation is melting at 5-ft height.
33	Insulation is melting at 6-ft height.
80	Insulation is melting at 7-ft height.
95	The temperature at the top of the cavity reaches approximately 120°F; test ended.

Further observations: All insulation in the cavity melted during the test and some molten material remained adhered to the concrete slab, but there was no flaming in the cavity above the 4-ft level.

Test No. 2

Specimen: expanded polystyrene
Flame-spread rating: 110
No air space in cavity

Time after the start of the test, (min)	Observations
11	Insultation is melting at a height of 4 ft.
59	Insulation is melting at 7-ft height.
62	The temperature at the top of the cavity reaches 410°F; test ended.

Further observations: All insulation in the cavity melted during the test and some molten material remained adhered to the concrete slab, but there was no flaming in the cavity above the 4-ft level.

Test No. 3

Specimen: urethane foam
Flame-spread rating: 23
No air space in cavity

Time after the start of the test, (min)	Observations
60	No indications of temperature rise at a height of 3 ft above the bottom of the specimen ($\frac{1}{2}$ ft above that part of the specimen that is directly exposed to the heat of the furnace).
90	The temperature has risen to 110°F at 3-ft height. The rise of temperature at this height, however, is very slow. Therefore the test is stopped and another test with a urethane foam of much higher flame-spread rating is prepared (see test No. 4).

Test No. 4

Specimen: urethane foam
Flame-spread rating: 333
No air space in cavity

Time after the start of the test, (min)	Observations
170	The fire has propagated to a height of 3 ft above the bottom ($\frac{1}{2}$ ft above that part of the specimen that is directly exposed to the heat of the furnace).
350	There are no indications of further propagation of the fire and energy supply to the furnace is shut off.

Further observations: after cooling down the furnace the cavity wall was opened. It appeared that the fire had propagated to about 15 in. above that part of the specimen that has been directly exposed to the heat of the furnace (Figures 4 and 5).

Test No. 5

Specimen: urethane foam
Flame-spread rating: 333
1-in. air space in cavity

Time after the start of the test, (min)	Observations
20	The temperature in the air space at the top reaches 500°F and remains approximately constant. To prevent unnecessary pollution of the air in the laboratory by smoke, the port at the top of the cavity was kept closed initially.

Test No. 5 (Continued)

Time after the start of the test, (min)	Observations
70	The port at the top of the cavity is opened intermittently. Each opening of the port is quickly followed by development of dense smoke and a substantial rise of temperature in the air space, indicating that the foam is burning.
75	Test is ended.

Test No. 6

Specimen: urethane foam
Flame-spread rating: 20
1-in. air space in cavity

Time after the start of the test, (min)	Observations
11	The port at the top of the cavity which has been kept closed initially is opened. No signs of burning of the insulation in the cavity are seen.
60	There are no signs of propagation of fire. The temperature in the air space at the top has remained constant at approximately 300°F for about one half hour. Test is ended.

Test No. 7

Specimen: urethane foam
Flame-spread rating: 40
1-in. air space in cavity

Time after the start of the test, (min)	Observations
1	The port at the top of the cavity, which has been kept closed initially, is opened. There are no signs of burning of the insulation in the cavity.
24	Sudden increase of the smoke from the port at the top of the cavity wall.
60	The fire has propagated to a height of 4 ft above the bottom of the specimen ($1\frac{1}{2}$ ft above the furnace opening. The test is ended.

CONCLUSIONS

The test results indicate that an insulating material used in a vertical position between two layers of noncombustible material with an intervening air space is not likely to contribute to fire propagation if it has a flame-spread rating of 25 or less. Urethane foam with a flame-spread rating of 20, tested under these conditions, displayed practically no propagation of fire. Urethane foam with a flame-spread rating of 40 showed slow propagation of fire ($1\frac{1}{2}$ ft in the first hour and probably much slower after this).

As the vertical position is the least favourable from the point of view of fire propagation, it may be assumed that a flame-spread rating of 25 or less is a safe requirement for materials installed in horizontal position between two layers of noncombustible materials with an intervening air space.

For insulating materials between two layers of noncombustible materials without an intervening air space the results indicate that fire propagation may not occur even if the insulation has a flame-spread rating substantially higher than 75. During the tests of expanded polystyrene (flame-spread rating: 110) and urethane foam (flame-spread rating: 333) only an insignificant propagation of fire was observed. This calls into question the relevancy of the flame-spread classification as a measure of fire hazard for this insulation arrangement.

REFERENCES

1. Standard Methods of Fire Tests for Surface Burning Characteristics of Building Materials. ASTM Designation E84-70, 1971 Book of ASTM Standards, Part 14, pp. 395 - 403.

2. Standard Methods of Fire Tests of Building Construction and Materials. ASTM Designation E119-71, 1971 Book of ASTM Standards, Part 14, pp. 431 - 448.

3. Blanchard, J.A.C. and Harmathy, T.Z. Small-Scale Fire Test Facilities of the National Research Council. National Research Council, Division of Building Research. Fire Study No. 14, Ottawa, 1964.

ACKNOWLEDGEMENT

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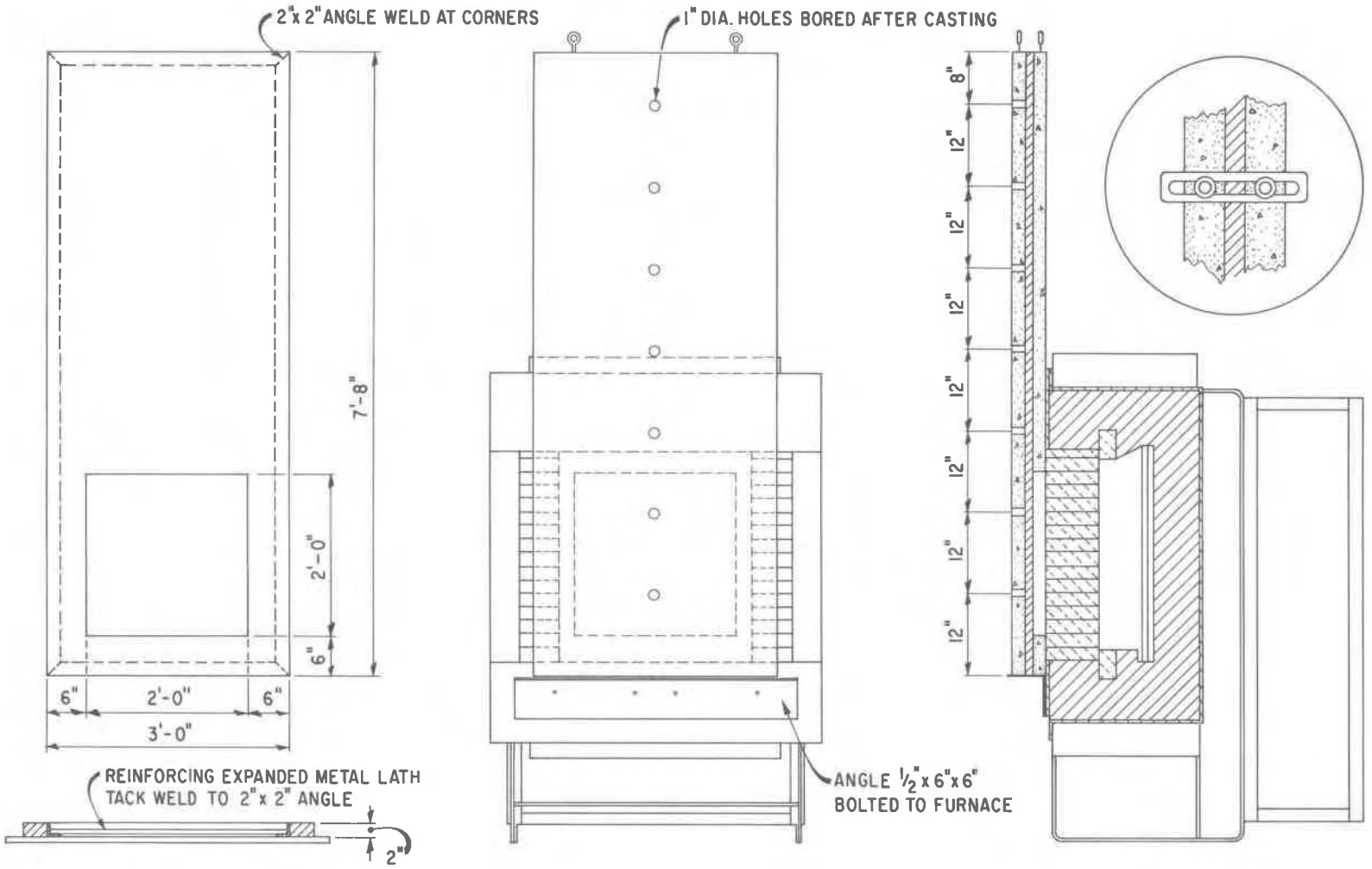

FIGURE 1 CAVITY WALL AND TEST FURNACE

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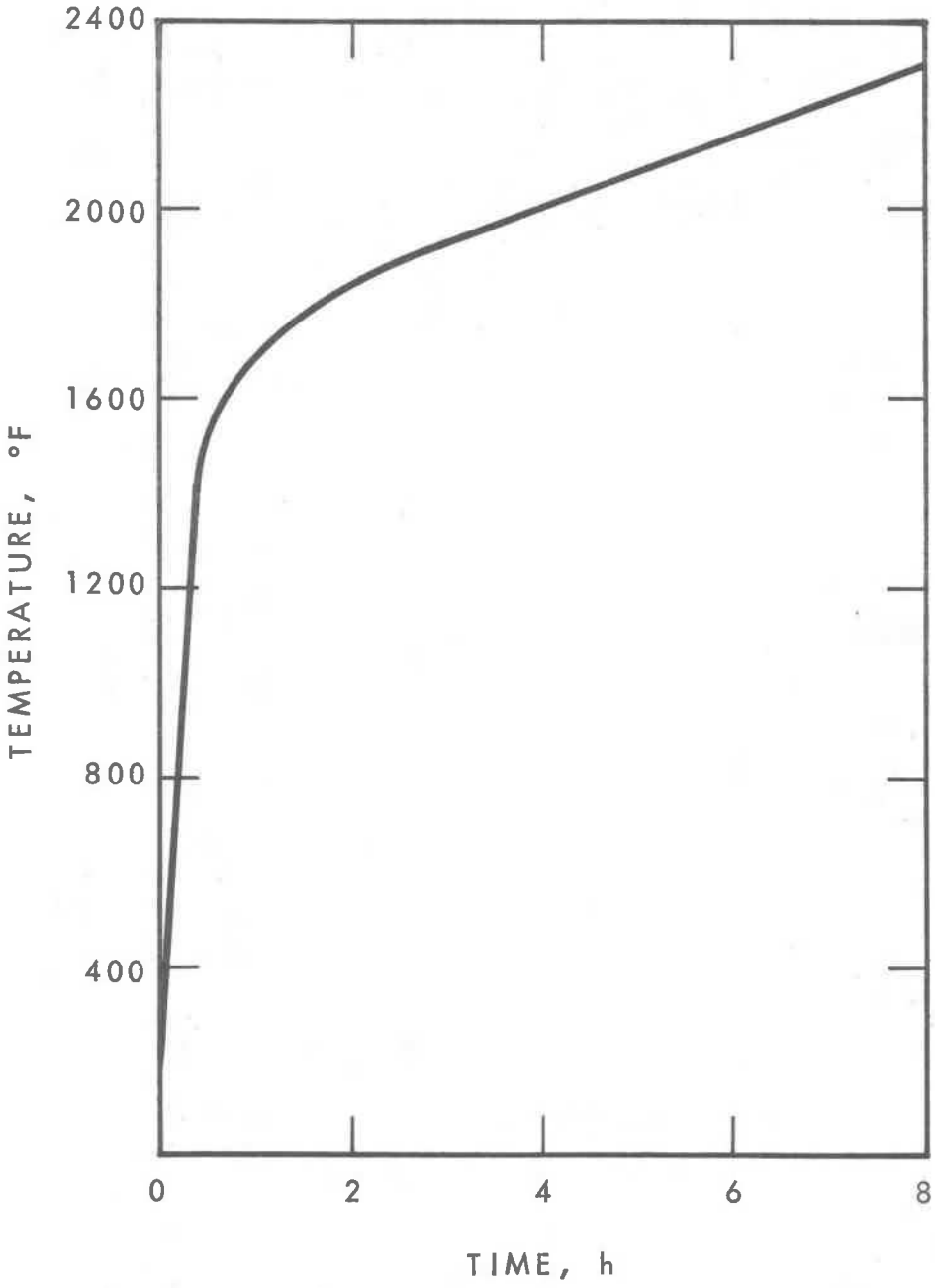

FIGURE 2

STANDARD TEMPERATURE-TIME CURVE ACCORDING TO ASTM E119-71

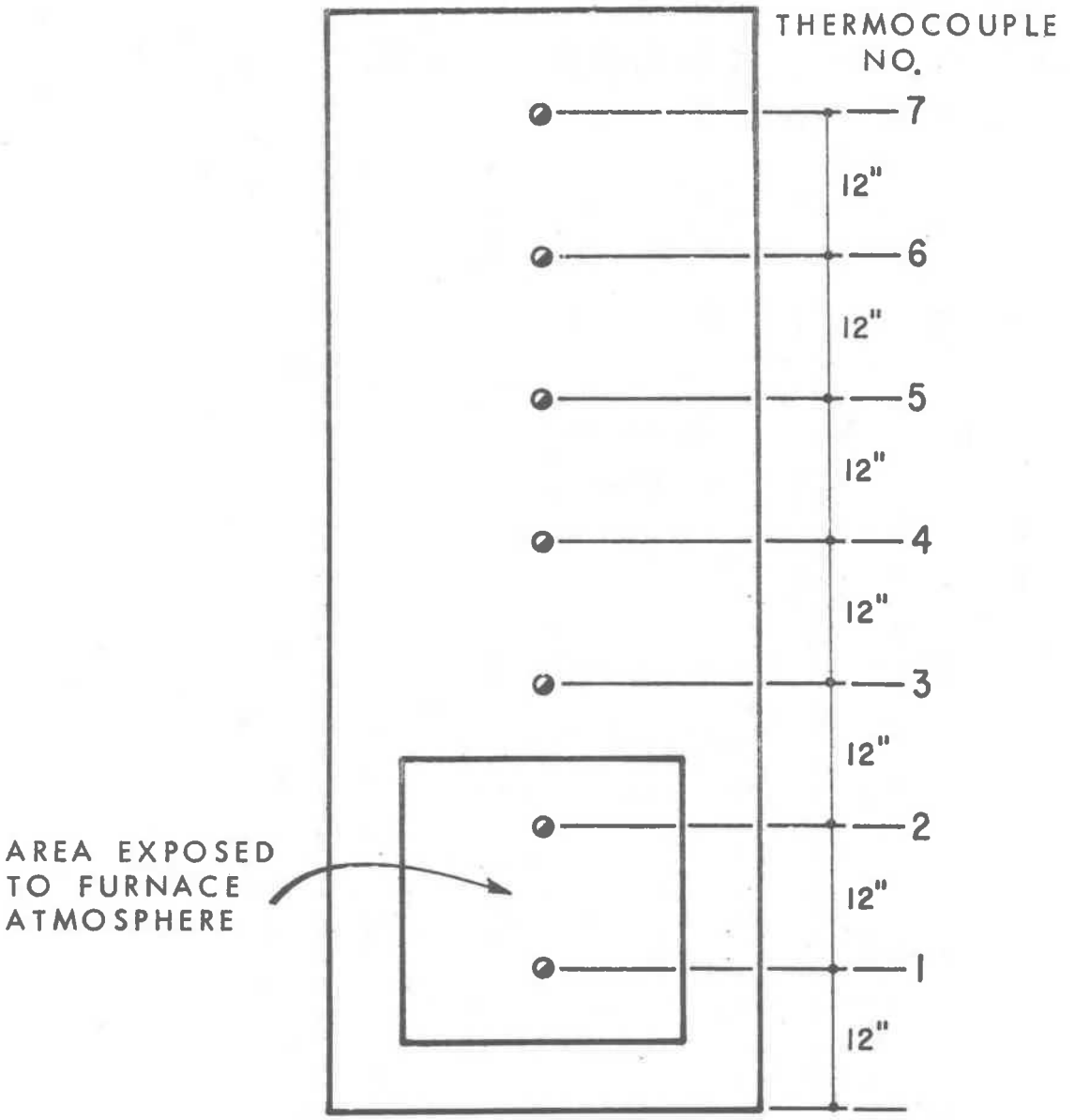

FIGURE 3

LOCATION OF THERMOCOUPLES IN INSULATION

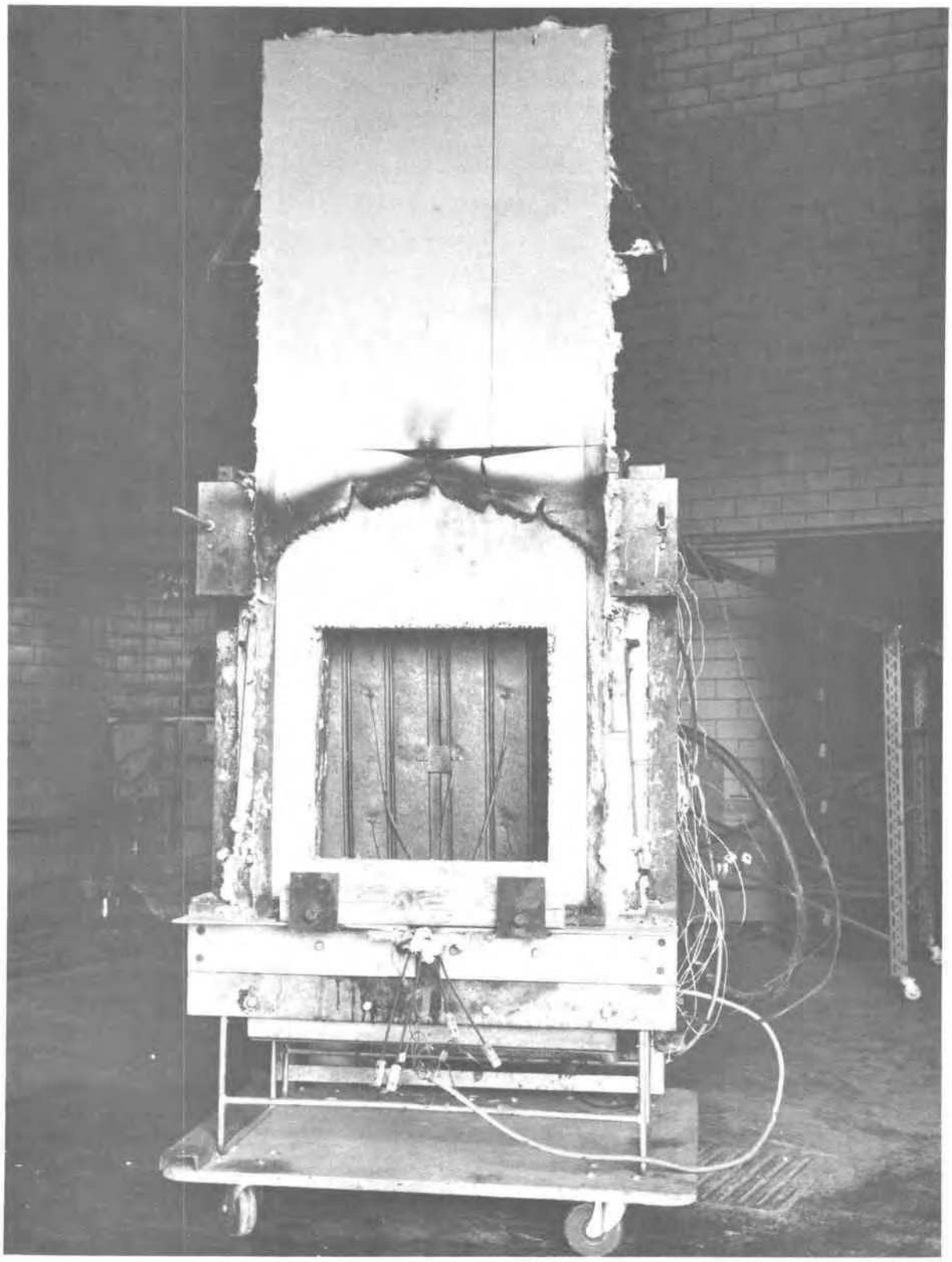

Fig. 4. Test Specimen No. 4 (urethane foam) after exposure to approximately 6 hours of standard heating at the bottom. (flame spread rating: 333; no air space in the cavity)

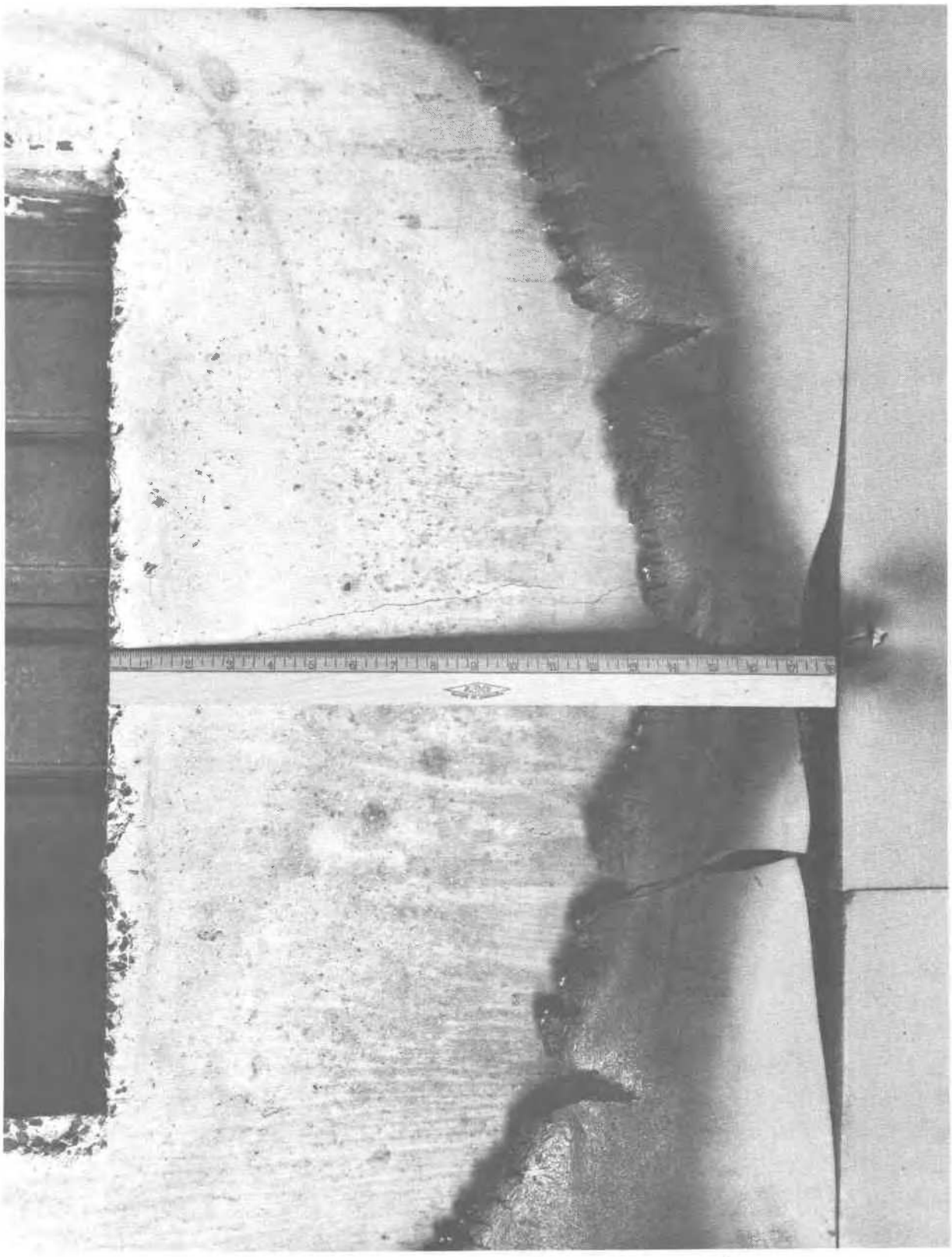

Fig. 5. Details of burned part of test specimen No. 4.