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FIRE PERFORMANCE OF WALLS WITH PLASTER OVER EXTRUDED POLYSTYRENE

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The increased use of fire-retardant, extruded-type, cellular polystyrene as a building material has prompted the Fire Research Section of the Division of Building Research, National Research Council of Canada, to conduct a limited study of its fireperformance when it is used as a plaster base. One property of this material that is of great interest when considering its use as a plaster base is its decomposition characteristics at elevated temperatures; it rapidly decomposes and seems to "disappear". Thus the critical question is whether the foam can support the plaster until the latter has performed its fire enduring function. In order to study this problem a limited number of tests, including laboratory tests were carried out.

TESTS

Small Scale

A wall specimen (30 by 30 in.) was constructed of 8-in. hollow concrete blocks. Fire-retardant, extruded-type, cellular polystyrene 1 in. thick was secured to the concrete blocks with portland cement mortar approximately 1/4 in. thick (1 part portland cement, 3 parts clean sand and 15 per cent hydrated lime by cement volume). Two coats of plaster were applied to the plastic foam, the first or scratch coat, 1/2 in. thick, the second or finish coat, approximately 1/16 in. thick. The scratch coat was composed of 1 part gypsum plaster and 2 1/2 parts sand; the finish coat was lime putty. The specimen was then placed in a small electric furnace (1) and heated in accordance with the ASTM E-119 standard time-temperature curve (2).

The finish coat of plaster cracked at 10 min, and after 17 min smoke issued around the top edge of the specimen. After 32 1/2 min the seal on the side of the specimen was removed and it was observed that almost all of the plastic foam had disappeared. The plaster stayed in place throughout the test.

In spite of the fact that the plaster did not come down during this test it could not be concluded that it would stay in place during a full-scale test. Consequently, it was decided to perform fire tests on larger specimens.

Full Scale

Two specimens (I and II) were constructed in a large reinforced concrete frame (Figure 1), which had been used previously for special tests so that the opening in the frame was partly bricked in at the sides and bottom. A single wythe of bricks 4 in. thick was built in the opening flush with one side of the old construction. During the erection of the brickwork a single row of bricks, 8 in. deep, was placed vertically at the centre of the construction, extending about 2 in. from the surface of the wall to form a divider between the two specimens, which were approximately 6 by 12 ft high. A mortar consisting of 1 part portland cement, 3 parts sand and 15 per cent hydrated lime by cement volume was then applied to the flush surface of the specimens to a thickness of approximately 1/4 in. This mortar served as an adhesive for the 1-in. thick fire-retardant, extruded-type, cellular polystyrene which was applied next. On specimen I, plaster was applied directly to the plastic foam; on specimen II, 1-in. mesh chicken wire was fastened with 1-1/4-in. staples to the plastic foam before the plaster was applied. This technique was considered to be in keeping with the practice outlined in Reference (3). The mixes for the plaster coats were as follows:

Scratch Coat: 1 part gypsum plaster, 2 1/2 parts sand, applied 1/4-in. layer.

Brown Coat: 1 part gypsum plaster, 3 1/2 parts sand, applied 3/8-in. layer.

Finish Coat: 1 part lime putty, 1 part sand, applied 1/16-in. layer.

Two observation ports were provided in each specimen on the unexposed side (see Figure 1). Thermocouples were installed between the plaster and the plastic foam and in the mortar between the plastic foam and the brick as the specimens were constructed. Thermocouples were also installed on the unexposed surface of the specimens, which were then allowed to stand for a period of 148 days, at which time they were placed in the large wall furnace and heated in accordance with ASTM E-119 time-temperature curve.

Specimen I: The finish coat of plaster separated and fell within the first minute of test. At 6 min it was observed through the viewing ports that the plastic foam was very soft. At 7 min the whole of the plaster fell and the foam caught fire. The mortar used on the brick as adhesive for the foam was still in place at the end of the test.

Specimen II: Most of the finish coat of plaster separated and fell within the first minute of test. At 6 min it was observed through the viewing ports in the brick that the plastic foam was very soft. At 10 min the plaster cracked. At 15 min no foam was visible from the ports. At 25 min flames appeared at the crack on the exposed side, and flames between the plaster and the brick could be seen from the ports. At 1 hr 20 min flaming was almost stopped, and the plaster bulged considerably. At 2 hr 24 min the test was terminated. At 2 hr 26 min, just before opening the furnace, the lower half of the plaster fell. The remainder of the plaster fell about 3 min later. It could be seen from the exposed side that some of the staples used to fasten the wire mesh were still attached to the wall.

Temperature measurements for both specimens are shown in Figure 2, which shows that the allowable temperature rise on the unexposed surface of specimen I was reached at 1 hr 44 min and that of specimen II at 2 hr 17 min. The fact that the plaster stayed in place on specimen II is the main factor to which the 33-min difference in fire endurance can be attributed.

The plaster on specimen II stayed in place for two reasons. The chicken wire provided reinforcing for the plaster membrane and the staples were long enough to penetrate the mortar behind the foam, thus providing support for the plaster.

Laboratory Tests

In addition to studies of the fire tests others were made of certain basic properties of the material using both thermogravimetric and dilatometric apparatus.

The thermogravimetric apparatus is an instrument that accurately measures the variation of the weight of a sample of material as the temperature of the sample is steadily increased. Variation of the weight of the sample may be due to decomposition or change in the material from the solid to the gaseous state (see Figure 3).

The dilatometric apparatus is an instrument that measures the variation of the length of a sample resulting from a change in its temperature (see Figure 4).

The foam is thermoplastic and its mechanical properties are considerably affected when its temperature reaches 175°F, the temperature at which the cellular structure of the foam collapses. This may be seen in Figure 3, which indicates a veryrapid deformation of the sample tested, starting at 175°F. It is clear that as soon as this temperature is reached the foam can no longer support the plaster, and that the temperature continues to climb the foam becomes softer until it reaches 450°F when it starts to decompose and burn (Figure 4).

CONCLUSIONS

1. Where cellular polystyrene is used as a base for unreinforced plaster, the plaster and polystyrene should not be considered to add significantly to the fire resistance of the wall.

2. If the plaster is reinforced with a steel mesh or chicken wire, which is itself secured to the outer structure (such as by stapling it securely to wood nailers at the top of the wall or by embedding the staples in the fresh mortar on the unexposed side of the cellular styrene) then the plaster should add significantly to the fire resistance of the wall.

REFERENCES

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2. Standard Methods of Fire Tests of Building Construction and Materials, ASTM Designation E119-61.

3. Platts, R. E. Plastering on Polystyrene Foam, National Research Council, Division of Building Research, Housing Note No. 9, March 1963.

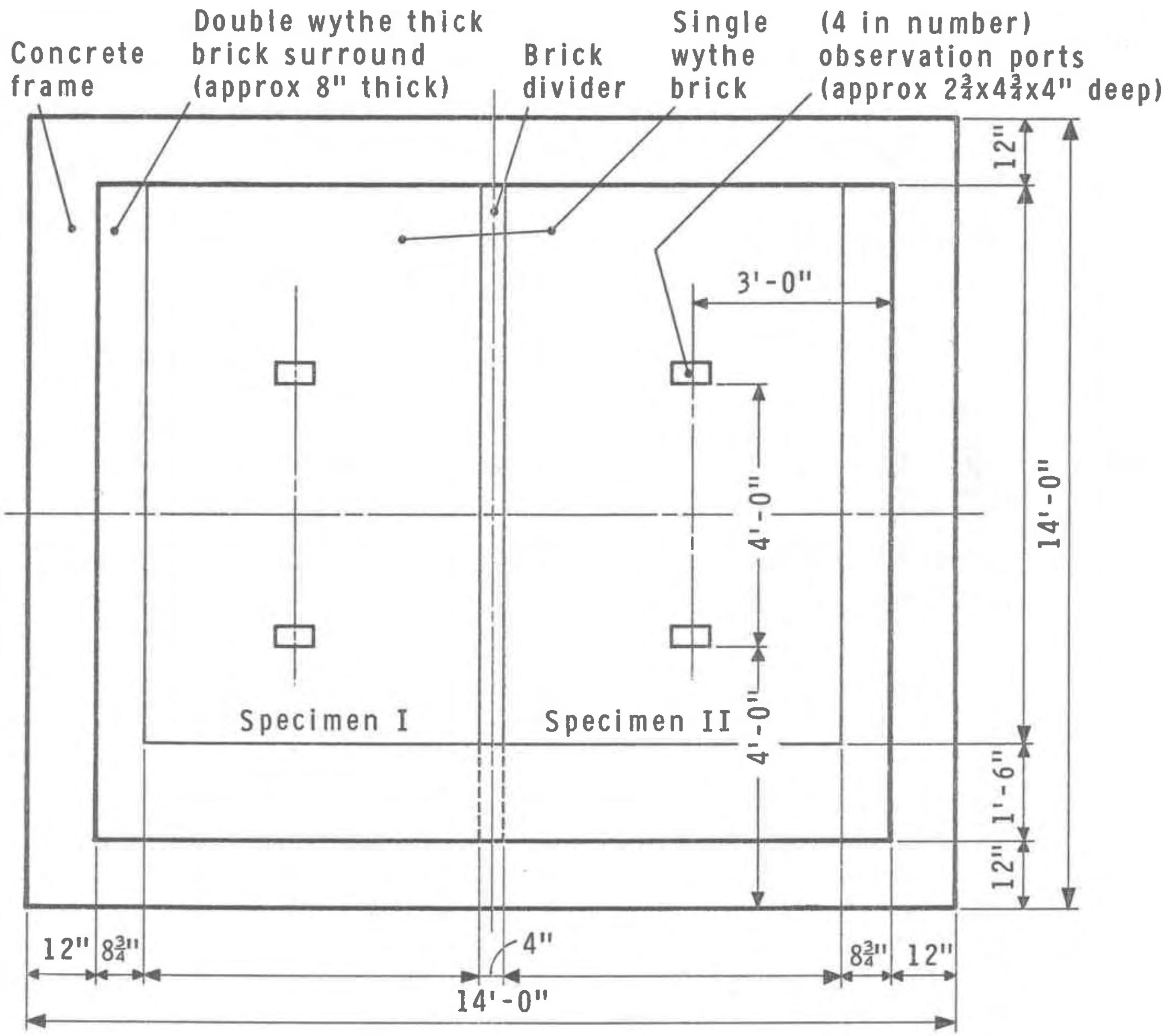

FIGURE 1 UNEXPOSED SIDE OF SPECIMEN

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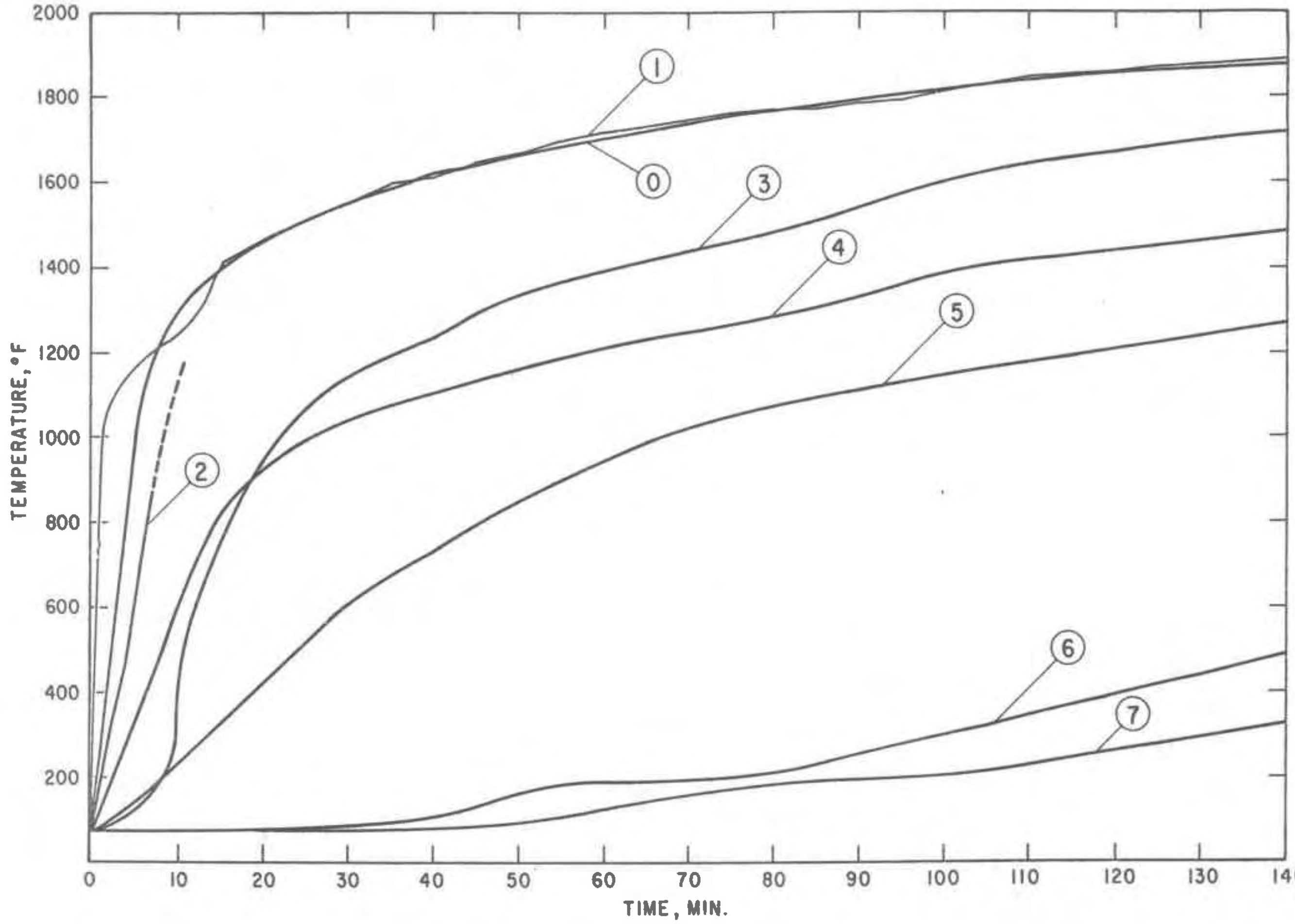

(0) Prescribed furnace temperature
(1) Average furnace temperature
(2) Average temperature between the plastic foam and the plaster of Specimen I
(3) Average temperature in the adhesive mortar of Specimen I
(4) Average temperature between the plastic foam and the plaster of Specimen II
(5) Average temperature in the adhesive mortar of Specimen II
(6) Average unexposed surface temperature of Specimen I
(7) Average unexposed surface temperature of Specimen II

FIGURE 2 TEMPERATURE VS TIME PLOT

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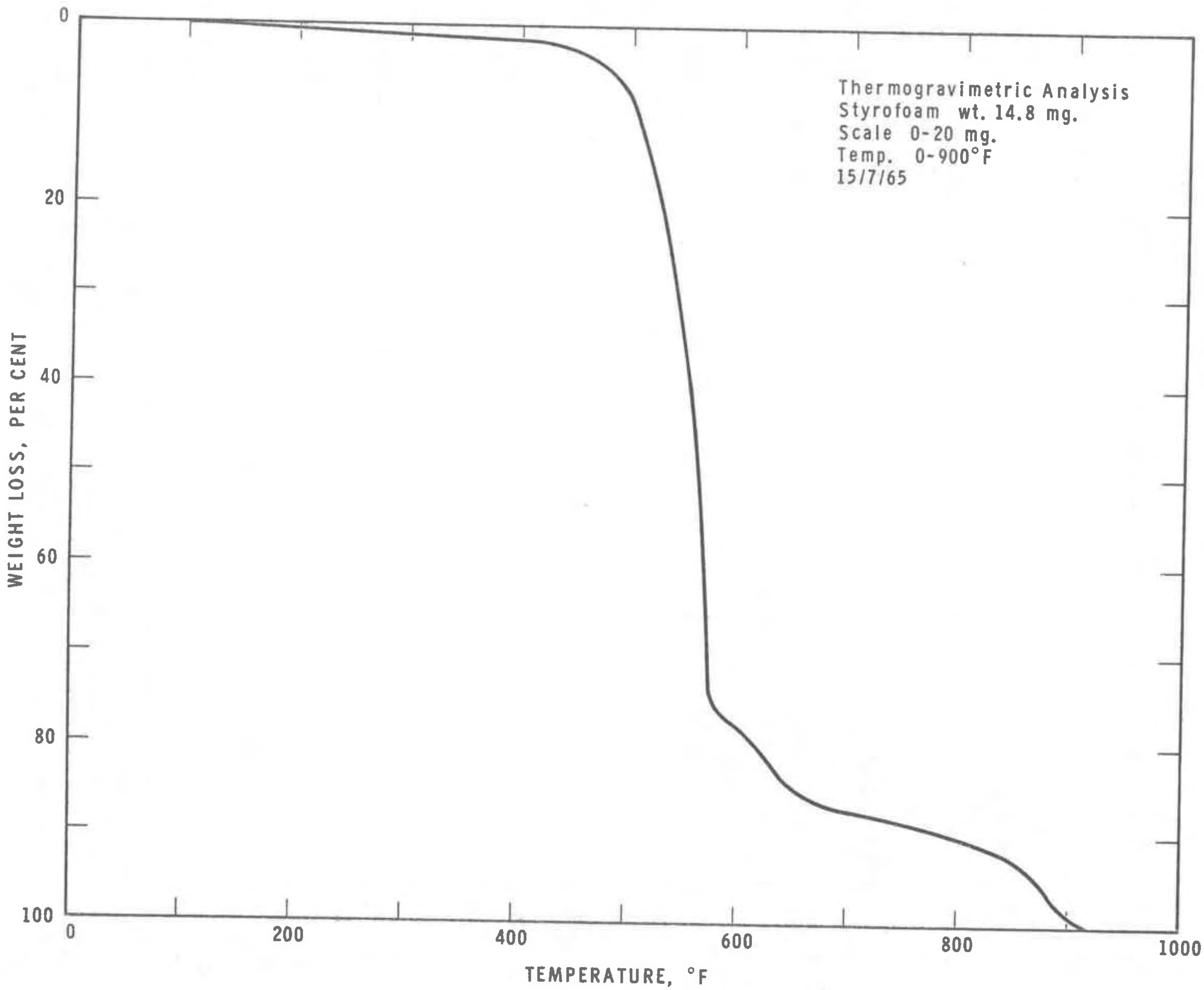

FIGURE 3

THERMOGRAVIMETRIC CURVE OF EXTRUDED-TYPE CELLULAR POLYSTYRENE

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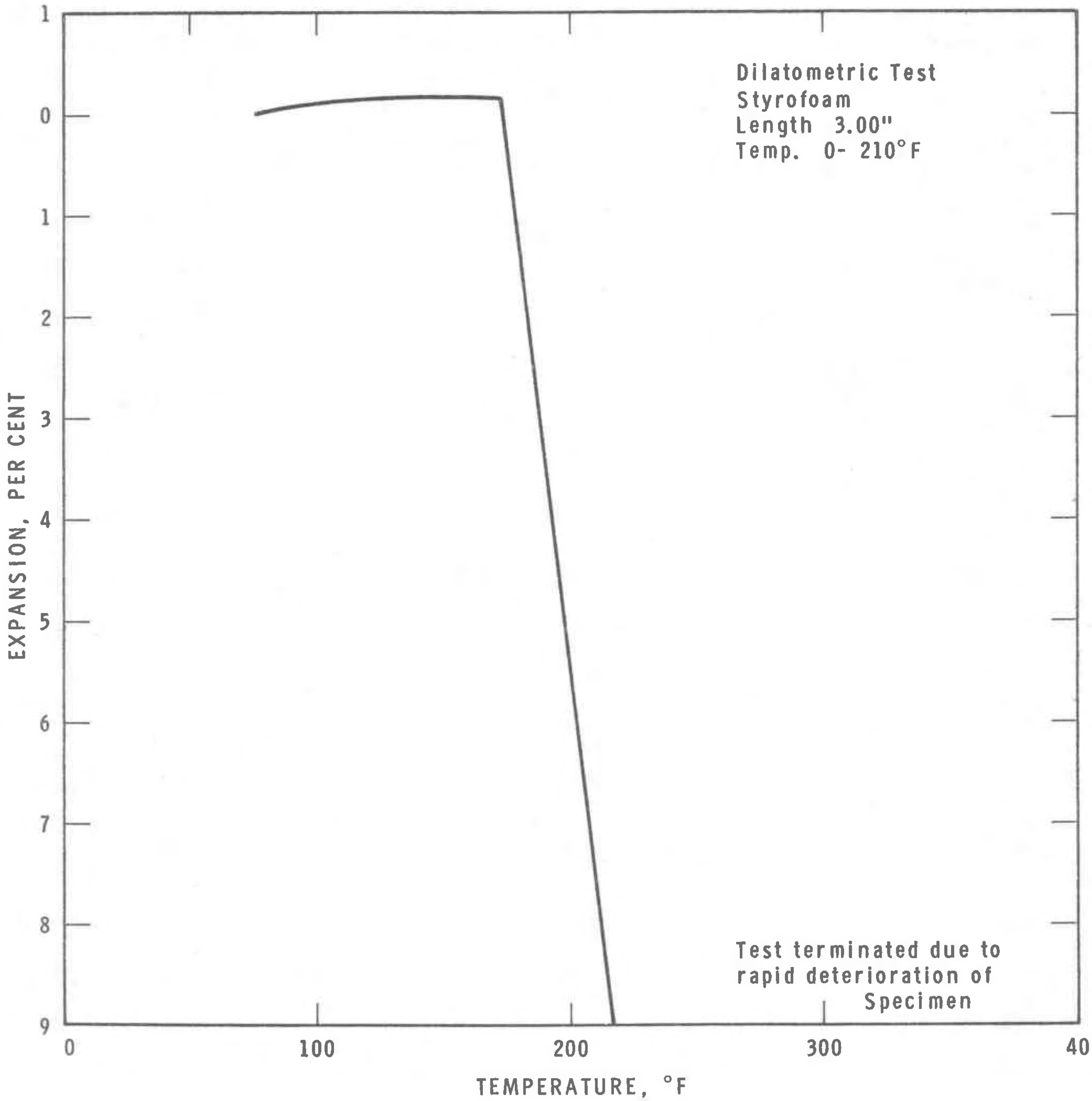

FIGURE 4

DILATOMETRIC CURVE OF THE EXTRUDED-TYPE CELLULAR POLYSTYRENE

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