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NATIONAL BUREAU OF STANDARDS REPORT

9395

REPORT OF FIRE TESTS ON TWO SCR BRICK WALL COLUMNS

by

J. V. Ryan

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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ABSTRACT

Two brick wall-columns were subjected to fire tests, under applied loads, in cooperation with the Structural Clay Products Research Associateship. The two specimens were nominally identical, except as to age. The first was tested to failure under load, which occurred at 2 hours 54 minutes. The fire exposure in the second test was stopped after 2 hours but the load maintained. The intention was to load the specimen to failure after cooling. However, it collapsed about 1 3/4 hours after the fires were shut off.

1. INTRODUCTION

Since the establishment of the Structural Clay Products Research Associateship at the National Bureau of Standards, part of their research has been on the effects of fire exposure on brick and brick masonry. This is the report of two full scale fire tests of brick wall columns. The first specimen was tested under an applied load computed by recognized design formulas and using strength data obtained with small wallettes. The second was tested under the same load but the fire exposure was stopped at a predetermined time, well short of the failure time observed in the first test. It was planned that the second specimen would be allowed to cool naturally to room temperature, that it would be instrumented, and the load increased until structural failure. The cooling was expected to take most of a day, with another day possibly for instrumentation.

2. SPECIMENS

Both specimens were built, on successive days, by the same experienced brick mason, using materials from the same sources and lots. The specimens were conditioned in the same room but to different ages. The room was not equipped to provide controlled temperature and humidity. Table 1 gives data on the bricks, which are illustrated in Figure 1.

Table 1. Brick Data

Length, inches	11.52
Width, inches	5.48
Height, inches	2.25
Solid, percent	85
Weight, lbs.	9.9
Modulus of rupture, psi	619
Compressive strength, psi	10460

Each brick column was one brick thick by two bricks long by 60 courses high. With mortar joints, the columns were 23 1/2 inches long and 13 feet 2 inches high. The brick were laid in a common running bond pattern, so that every other course consisted of two full bricks, and the other courses of one full brick between two half bricks. The cut ends of the halves were turned in. A specimen is shown, in the furnace, in Figure 2. One long face was well aligned; the other face showed the random variation in brick widths. The mortar was Type S, mixed 1:1/2:4 1/2 by volume (1:0.27:3.93 by weight) of cement:lime:sand. The average compressive strength of three 2-inch cubes was 1720 psi, measured on the day of the first fire test. The average compressive of three 5 1/2 by 11 3/8 by 12 1/2 inch masonry prisms was 5810 psi; the average modulus of elasticity was 3,080,000 psi. The quality of workmanship was excellent.

As the specimens were being fabricated, four thermocouples (22 gage chromel-alumel) and two brass tubes were built into each. The thermocouple junctions were located one each at the bottom, and 2 feet 6 inches, 5 feet, and 7 feet 6 inches above the bottom; each at the center of the cross-section of the specimen. The brass tubes were placed at the midthickness and extended in 6 inches from one of the narrow faces. For specimen 1, the tubes were 6 feet 6 inches and 12 feet 6 inches above the bottom; for specimen 2 they were 4 feet 3 inches and 8 feet 1 inch above the bottom. The brass tubes served as cavities into which relative humidity sensors were placed to measure the relative humidity of the entrapped air. Data were obtained frequently from each of the four cavities. The values of all four were quite similar. Figure 3 shows the values for two, one in each specimen.

In addition to the insertion of the two humidity gage cavities in mortar joints, three mortar samples were made up for each wall column by filling 6 inch long pieces of 1 inch ID tubing. These samples were kept with the wall-column and were weighed frequently. Representative weight loss data are shown in Figure 4. Also, six wallettes were made 11 1/2 by 12 1/2 by 5 1/2 inches. All but the two 11 1/2 by 12 1/2 inch faces were sealed, with bituminous paint, to simulate the drying conditions in the fire test specimens. These walletes were weighed frequently. The data shown in Figure 4A, were similar to those for the mortar cores, whown in Figure 4, further confirming the fact that the specimens had not reached an equilibrium moisture content.

Both specimens were fabricated during the first week in April and were conditioned in a room maintained suitable for work but not controlled to specific temperature or humidity. Specimen 1 was tested at age of 42 days; Specimen 2 at age of 75 days.

3. TEST METHOD

Each specimen was placed in a furnace specifically designed for fire endurance testing of columns, with or without applied load. The specimen's orientation was such that its wide faces were to the North and South. Of the 13 feet 2 inches overall height, the top 2 feet 8 inches was in or above the top closure to the furnace chamber. The bottom 3 inches was surrounded by loose insulation.

Each test was instrumented for measurement of applied load, lateral deflection, vertical expansion and contraction under the combined effects of heat and load, and for temperatures in the specimen and in the furnace. The latter measurements were made with 18 gage chromel-alumel thermocouples run through porcelain spacers and encased in sealed iron tubes.

Each specimen was subjected to an applied load of 56,300 lbs., computed by the SCPI Research Associate, on the basis of 13 feet 2 inches height. This load corresponds to a stress of 435 psi, the allowable stress for f'm of 4470 psi and slenderness ratio of 29. It was learned just before the second test that he was not aware that the top closure of the furnace chamber was firm enough and in good enough contact with the specimen to constitute lateral bracing. The same load was used in the second test in order to be consistent. The lateral bracing effect of the closure is applicable to all columns tested under load in this furnace. The load was applied, through a spherical bearing block, from a hydraulic jack beneath the furnace chamber.

Each specimen was subjected to fires controlled to produce, as closely as practicable, the temperatures of the standard time-temperature curve defined in Standard Method for Fire Tests of Building Construction and Materials, ASTM E119, which include: 538 C (1000 F) at 5 min., 704 C (1300 F) at 10 min., 843 C (1550 F) at 30 min., 927 C (1700 F) at 1 hour, 1010 C (1850 F) at 2 hours, and 1052 C (1925 F) at 3 hours. The sole criterion, in the Standard Test Method, for loaded columns is the ability to sustain the applied load.

4. TEST RESULTS

The orientation of each specimen in the furnace was such that its narrow faces were to the East and West, its wide faces to the North and South. Reference, in the observations and results, to the faces will be on that basis. Measurements of transverse deflection were in the North-South directions.

4.1 Specimen 1.

The test was conducted May 17, 1966. The specimen exhibited a length reduction of 0.121 inch as a result of the application of load, just before

the start of the fire exposure. Short vertical cracks appeared within 2 inches of the specimen corners in the first 20 minutes. A few cracks 4 inches and more from corners appeared at about 30 minutes. There was little change until after 1 hour 20 minutes; between then and 2 hours, several vertical cracks appeared on the North and South faces and a few grew to full height of the specimen. All remained 1/16 inch or less. in width. By 2 hours 9 minutes there were cracks at 3 to 4 inches spacing completely across the South face; they were all less than 1/16 inch wide. At 2 hours 47 minutes a few cracks were judged to be 1/8 inch wide. At about 2 hours 51 minutes a slight bow toward the North appeared in the specimen which became pronounced by 2 hours 52 minutes. The specimen collapsed at 2 hours 52 1/2 minutes.

The specimen expanded rapidly early in the test, reaching approximately half its total expansion in the first 20 minutes. The overall length change began decreasing at about 2 hours, and became negative about 4 minutes before collapse. The data are plotted in Figure 5. The design of the transverse deflection measurement system had not anticipated all possible problems; it jammed very early in the test and meaningful data were not obtained.

After the test, the specimen was a somewhat ordered pile of debris. It had folded and laid back on itself, so that about half the remains were neatly aligned. The rest were in a random jumble. The cracks observed during the fire exposure had become complete breaks. The broken bricks are shown in Figure 6.

The time-temperature data are plotted in Figure 7. The severity of the fire exposure was 101.5 percent of standard. A correction of plus 1 minute was applicable due to deviation of the actual furnace temperatures from the Standard Time-Temperature Curve. The results of the test indicated that the fire endurance of the particular specimen tested was 2 hours 54 minutes, as determined by load failure.

4.2 Specimen 2

The test was conducted June 20, 1966. The specimen exhibited a length reduction of 0.195 inch as a result of the application of load one hour before the start of the fire exposure. Short vertical cracks appeared within 2 inches of the specimen's corners in the first 20 minutes. By 50 minutes there were a few cracks 4 inches from the corners and extending vertically through two to seven courses of brick. By 1 hour 32 minutes four cracks (one each 4 inches from each side of the North and South faces) extended essentially the full exposed height of the specimen, but were less than 1/16 inch wide. The furnace fires were turned off at 2 hours, but the load was maintained. The furnace door was kept closed.

The specimen expanded rapidly early in the test, reaching approximately half its total expansion in the first 20 minutes. The maximum overall expansion was reached at 1 hour 54 minutes. A gradual reduction in length took place, under continued loading, as the specimen cooled. Between 2 hours 30 minutes and 2 hours 40 minutes, the rate of shrinkage increased and the specimen collapsed at 2 hours 43 1/2 minutes. The last reading, 1/2 minute before collapse, indicated that the specimen still had nearly half its maximum expansion. The data are plotted in Figure 5. The specimen deflected .02 inch to the North under load application. This increased to approximately .12 inch at 15 minutes but decreased .04 by 35 minutes. Very little change was observed after that time. However, it is doubtful that the readings had much meaning beyond 35 minutes, due to high temperature effects on the measurement system.

After the collapse, a pier about 6 feet high remained. It was badly cracked and retained the original width only for the bottom 3 courses of brick. It was about half the original width for most of its height but only a few inches for the top two courses.

The severity of the fire exposure for the two hours was 101.2 percent. Since the fire test was not carried to failure, the ultimate fire endurance cannot be stated for the specimen. However, the fire endurance of 2 hours was exhibited, and very probably fire endurance of the same order of magnitude as that of specimen 1 would have been exhibited had the fire exposure been continued. The time-temperature data are plotted in Figure 8.

5. SUMMARY

Two brick wall columns were subjected to fire exposure and applied load in accordance with the standard test method. The first test was continued to the applicable end point, load failure, and the particular specimen exhibited fire endurance of 2 hours 54 minutes. The fire test of the second specimen was stopped at 2 hours with the intention of measuring the specimen's modulus of elasticity and ultimate strength after cooling. The load applied throughout the fire exposure was maintained during the cooling. However, the specimen collapsed approximately 1 3/4 hours after the end of the fire exposure.

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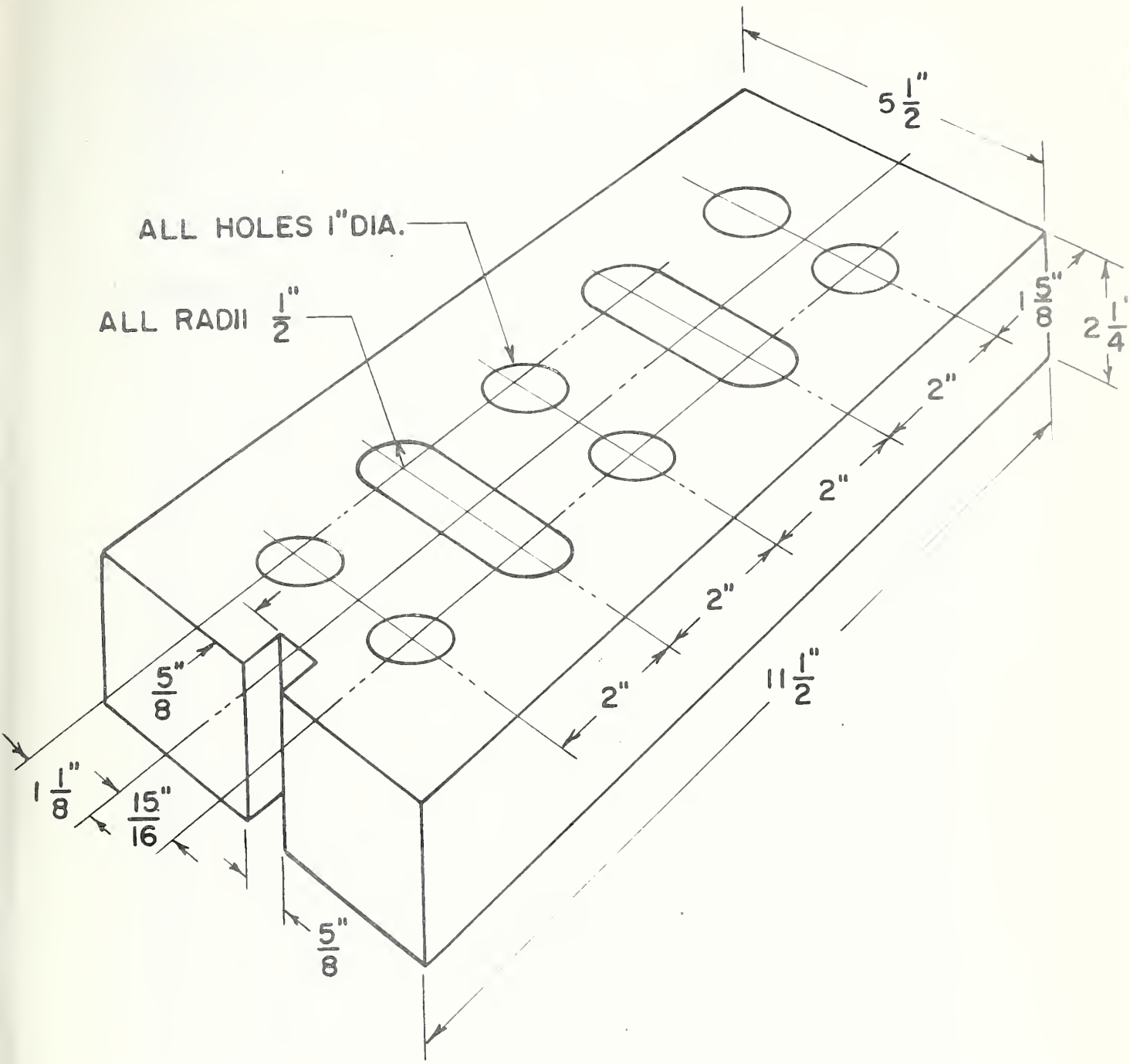


FIG. 1 – BRICK USED IN SPECIMENS

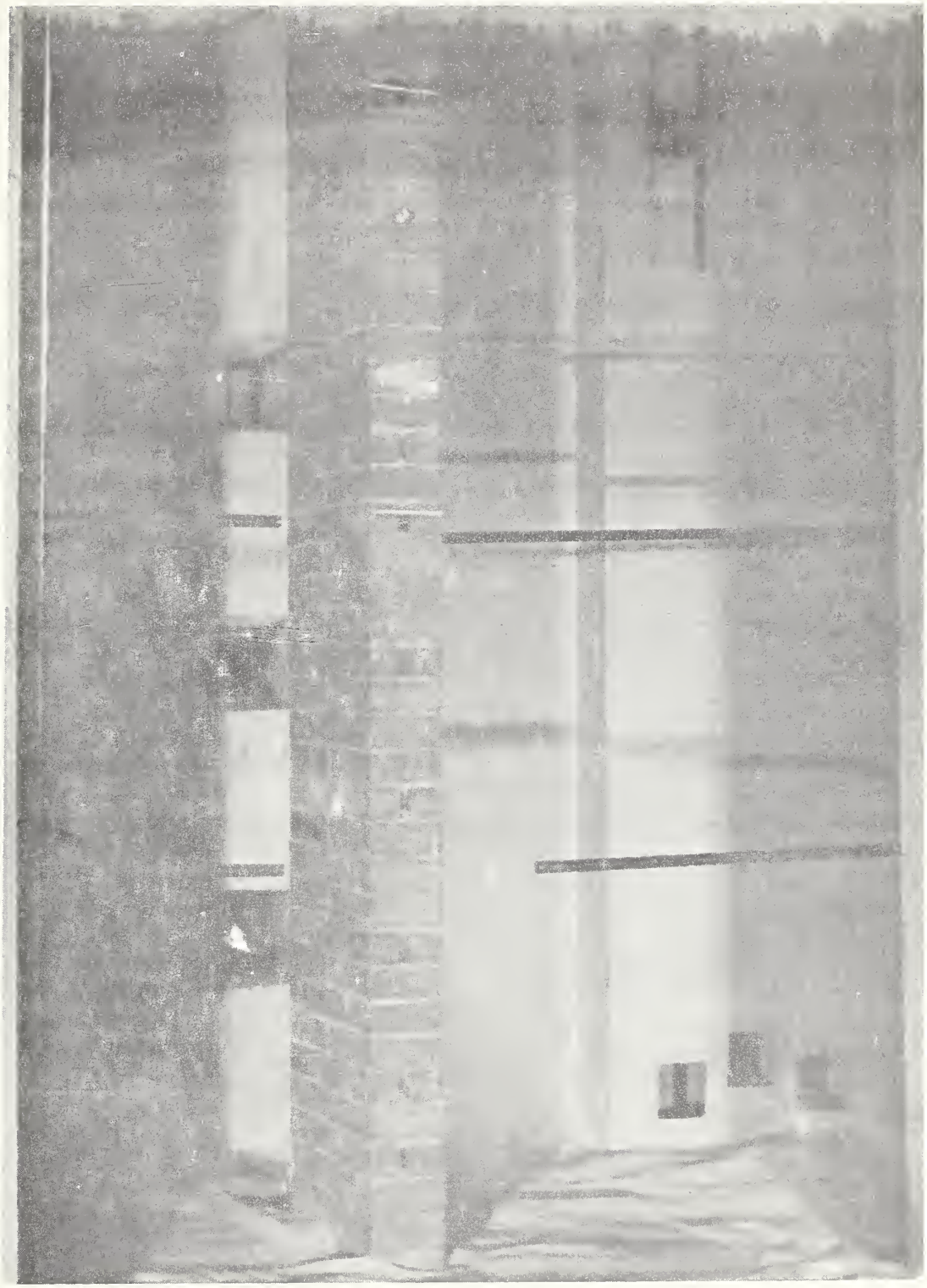


Fig. 2. Wall Column Specimen in Furnace Prior to Test

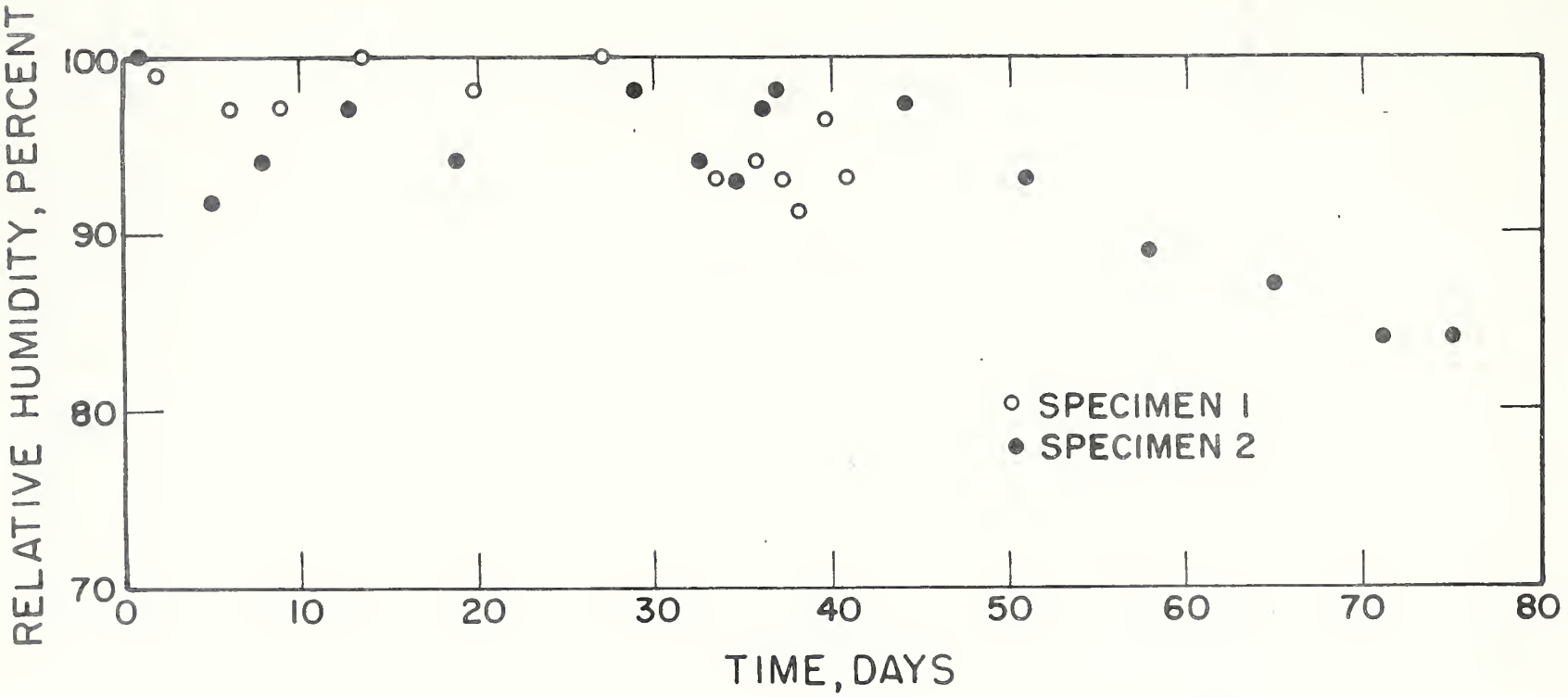


FIG. 3 - REPRESENTATIVE RELATIVE HUMIDITY DATA

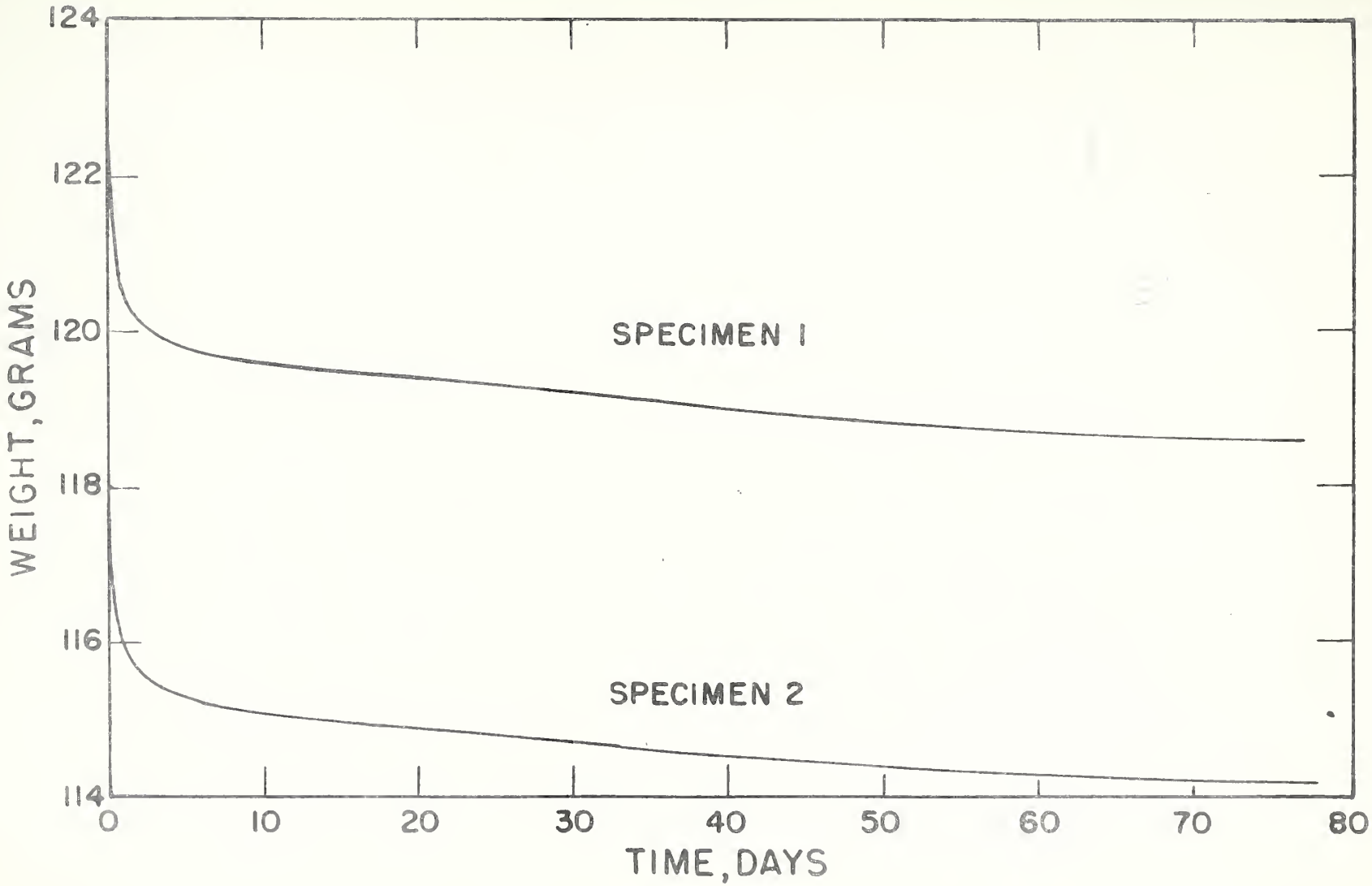


FIG. 4–REPRESENTATIVE WEIGHT LOSS DATA, MORTAR CORES

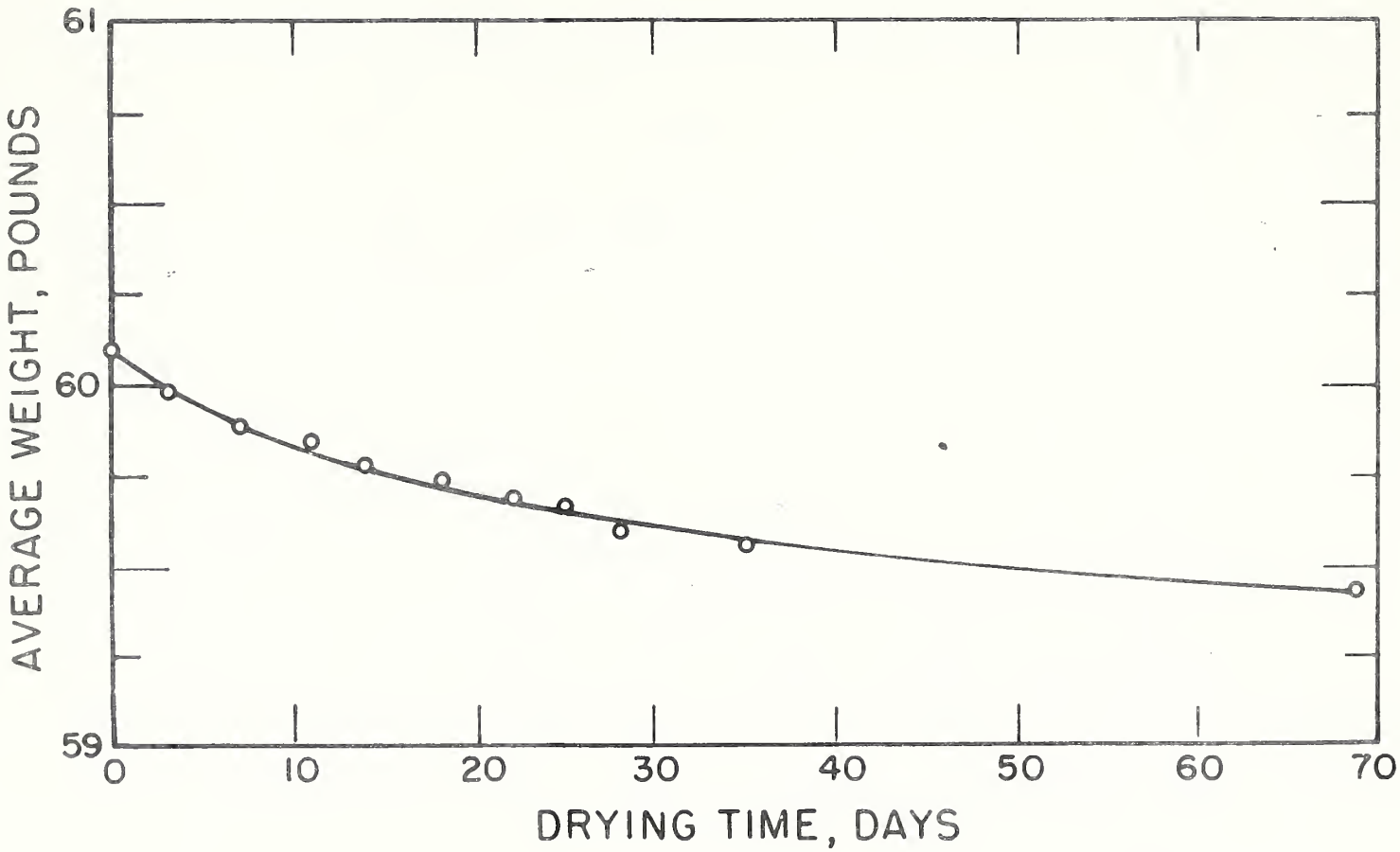


FIG. 4A - DRYING OF SMALL WALLETTES

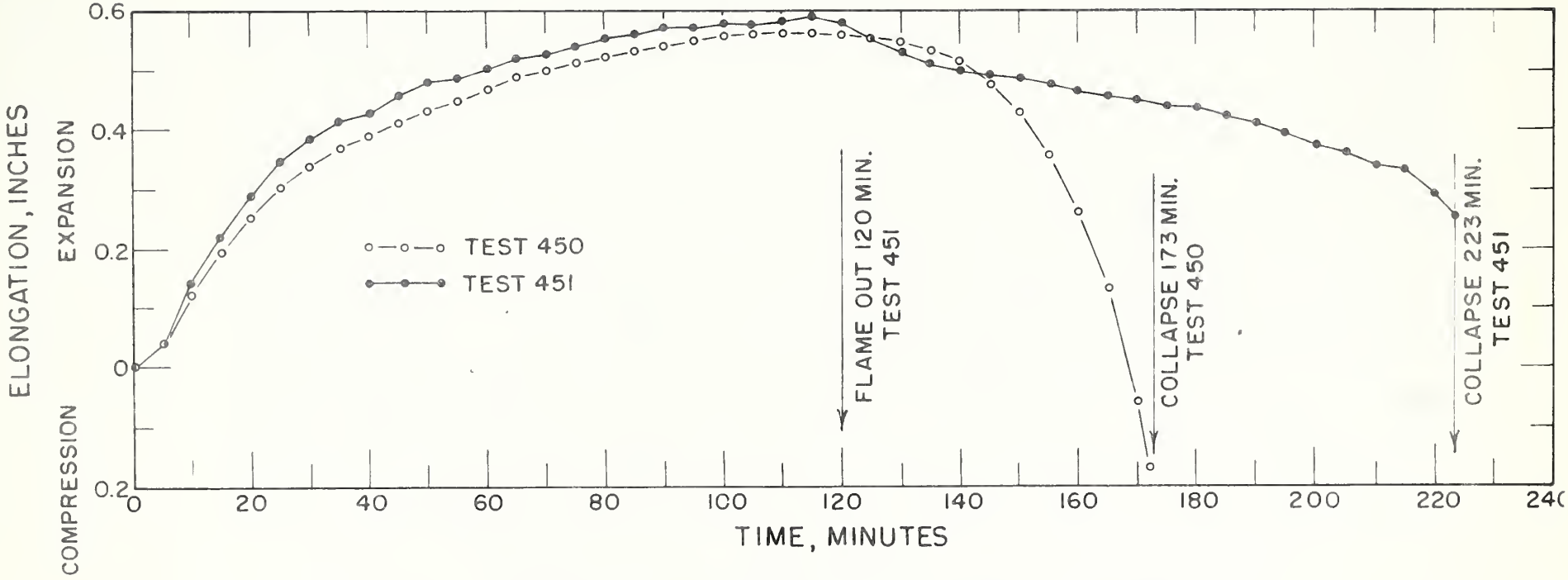
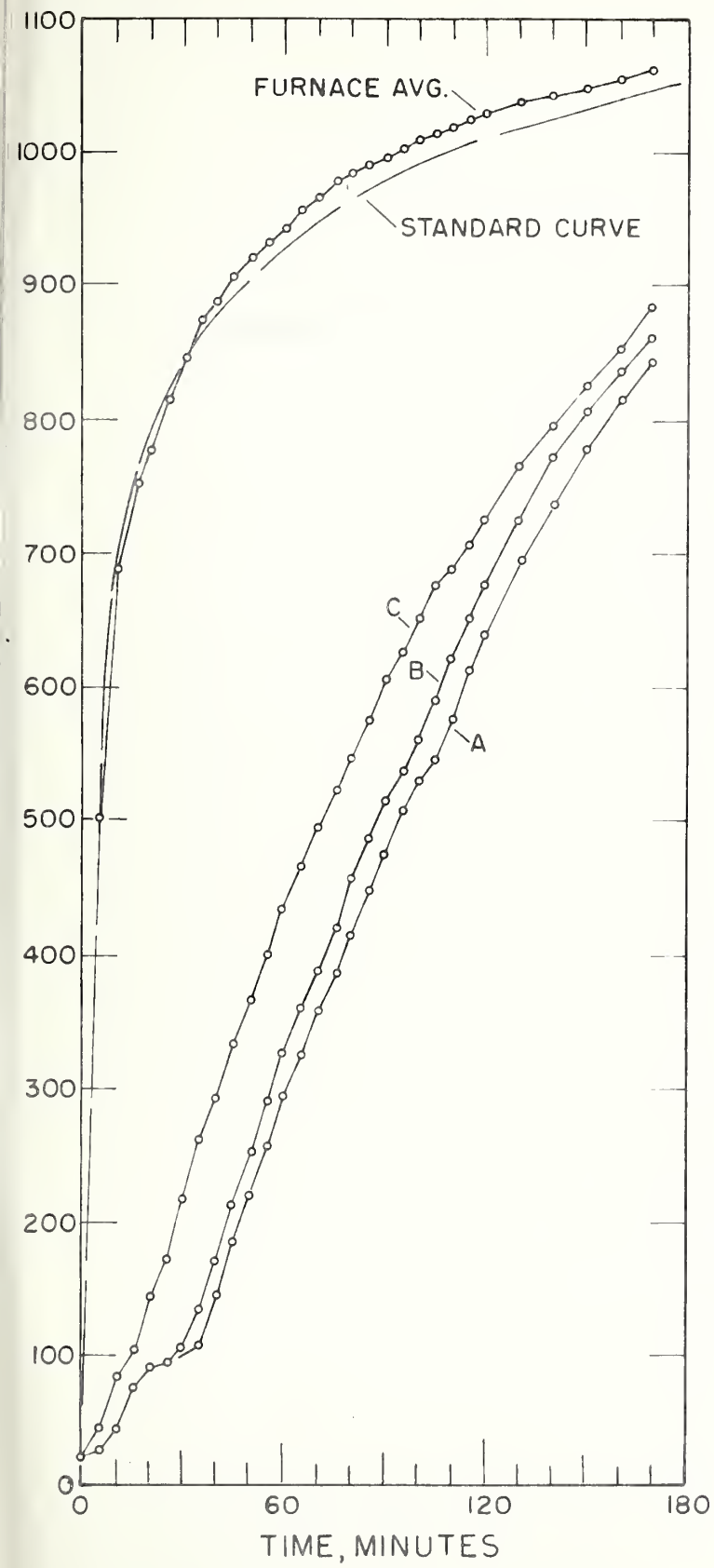


FIG. 5—ELONGATION OF S.C.P.I. BRICK COLUMNS



Fig. 6. Column Fragments for Specimen 1.



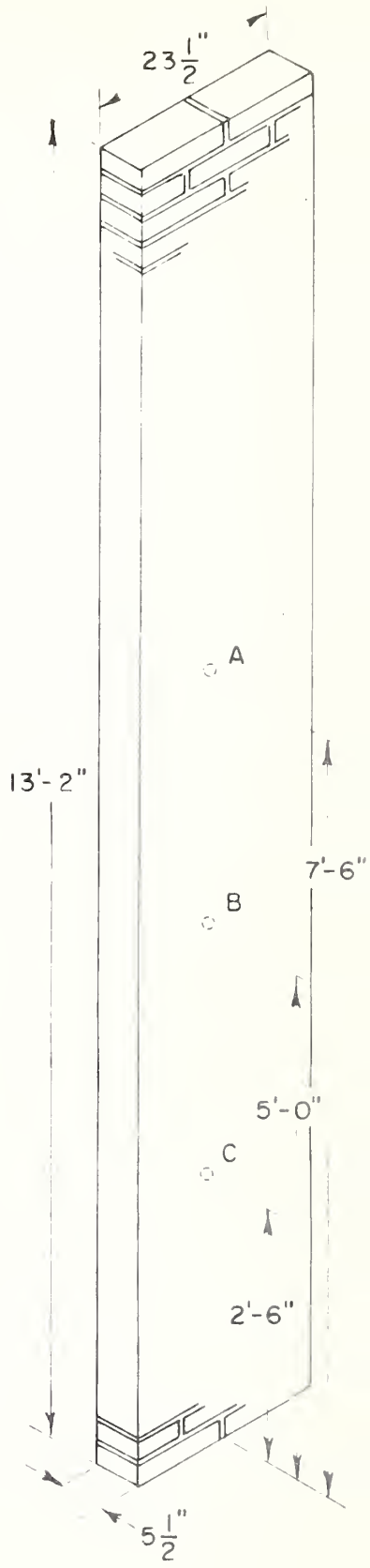


FIG. 7 – TIME-TEMPERATURE DATA FOR TEST 450

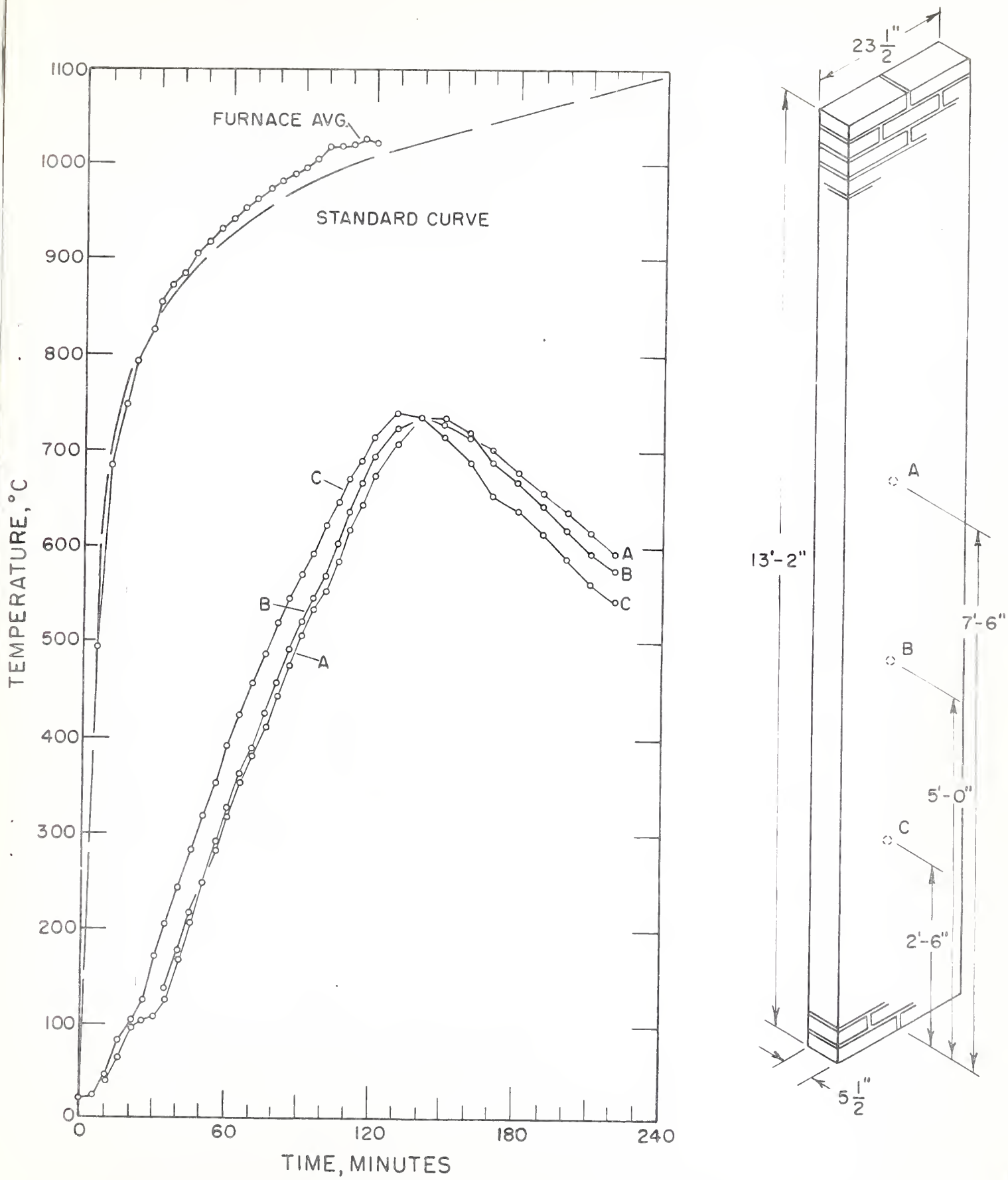


FIG. 8 – TIME-TEMPERATURE DATA FOR TEST 451


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