Fire tests of eight wide-flange steel columns protected with gypsum-sanded plaster

Stanzak, W. W.

For the publisher's version, please access the DOI link below./ Pour consulter la version de l'éditeur, utilisez le lien DOI ci-dessous.

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40001365
Fire Study (National Research Council of Canada. Division of Building Research), 1968-01-01

NATIONAL RESEARCH COUNCIL OF CANADA

DIVISION OF BUILDING RESEARCH

FIRE TESTS OF EIGHT WIDE-FLANGE STEEL COLUMNS PROTECTED WITH GYPSUM-SANDED PLASTER

by

W. W. Stanzak

Fire Study No. 20
of the
Division of Building Research

Ottawa

January 1968

FIRE TESTS OF EIGHT WIDE-FLANGE STEEL COLUMNS PROTECTED WITH GYPSUM-SANDED PLASTER

by

W. W. Stanzak*

This report describes a series of eight fire tests conducted on steel-column sections protected with gypsum-sanded plaster. The tests form part of a more extensive investigation of sand/aggregate/plaster protection under way in the Fire Research Section at the Division of Building Research.

One purpose of the tests was to provide fire performance information for columns protected with gypsum-sanded plaster throughout the range of thickness that might normally be encountered in practice. A second objective was to obtain data on the influence of cross-sectional size and shape on fire endurance time. The first six tests were confined to plaster thicknesses of less than 1 in. as it was thought that spalling might make greater thickness impractical. The complete absence of any spalling during the fire tests, however, led to two additional tests, with protective covers up to 1 1/2-in. thick.

The tests were carried out in the DBR Floor Furnace and the specimens were not loaded. A detailed description of the fire test facilities at the National Research Council is available (1).

DESCRIPTION OF TEST SPECIMEN

The dimensions and weight of the column sections are given in Table I. Construction details of a typical test specimen are shown in Figure 1; a column prepared for plastering in Figure 2; two completed test specimens prior to installation in the furnace, in Figure 3; and a view of the test specimen installed in the furnace prior to the fire test, in Figure 4.

The item numbers below correspond to the part numbers in Figure 1.

1. Wide-flange steel column section: 8 ft-4 in. long, Steel Specification ASTM A36-61T (see Table I for details).

---

* Steel Industries Fellow. Division of Building Research (first holder of an industrial fellowship established by the steel industry of Canada at the National Research Council).

2. Furring channels: 3/4 in. by 3/8 in. by 18 gauge (0.048 in.), supplied in 12-ft lengths, cold-formed channel sections weighing 230 lb per 1000 lin ft and painted with red lead oxide paint. Vertical and horizontal furring was tied with three loops of 18 gauge soft galvanized tie wire.

3. Expanded-wing corner beads: 2 1/2 in. by 2 1/2 in., were attached to each corner to provide the desired plaster thickness. For columns 7 and 8 metal lath spacers were used to locate the corner beads to give the required depth of plaster. Figure 5 shows column 7 after the application of the furring, metal lath, and corner beads. Note metal lath spacers under corner bead.

4. Diamond mesh metal lath, in sheets 8 ft long by 27 in. wide, weighing 2.5 lb per sq yd, was applied either vertically or horizontally, depending on which was most convenient for the dimensions of the column. The metal lath was tied to the furring with a single loop of 18-gauge (0.048 in.) galvanized wire, spaced approximately 6 in. apart. The joints in the lath were lapped approximately 1 in. over supports. Where the joints were not over supports, the laps were approximately 4 in. and securely tied.

5. Scratch coat, 1 part gypsum: 2 parts sand (by weight)
   Average density: 105 lb/ft^3
   Average compressive strength of four cylinders: 419 psi.

6. Brown coat, 1 part gypsum: 3 parts sand (by weight)
   Average density: 105 lb/ft^3
   Average compressive strength of four cylinders: 473 psi.

7. End caps: two per specimen, cut from 3/4-in. thick plate having dimensions X by Y, as shown in Table I and Figure 1. End caps were welded to the sections with a 3/8-in. fillet weld all around.

8. Tie wire (not shown): No. 18 Imperial wire gauge (0.048 in.) soft, annealed, galvanized steel.

WORKMANSHIP

Furring, lathing and plastering were carried out in accordance with the provisions of CSA Standard A82.30 - 1965 (2). The plaster was applied in two coats, with no finish coat.

For the specimens used in test Nos. 1 through 6 the workmanship was average. Large variations in thickness of plaster on the column surfaces were detected, due to careless application by laboratory standards of furring lath and beading.

Specimens 7 and 8, which were completed at a later time, were of good commercial grade workmanship.

TEST METHOD

The fire endurance tests were carried out in accordance with CSA STANDARD B54.3-1964 (3), Alternate Test of Protection For Steel Columns. The furnace temperature was measured by nine thermocouples installed in a metal frame constructed from 13/16-in. OD Inconel tubes having 0.035-in. wall thickness. The location of the furnace thermocouples is shown in Figure 6.

The hot junction of the thermocouples was 12 in. away from the surface of the specimen. Both the individual temperatures at nine points of the furnace and the average of the nine temperatures were recorded. The fuel input to the furnace was controlled to make the average temperature follow as closely as possible the prescribed temperature versus time curve.

The temperature of the steel section was measured by fifteen thermocouples (Nos. 1 to 15, Figure 7) located in groups of three at five levels. Two thermocouples were on the inside of the plaster located as shown in Figure 7.

RESULTS

The average furnace temperature during the fire tests was always within allowable limits. Figure 8 is a graph showing the temperature rise of the columns. Figures 9 to 15 show the furnace temperature, the temperature of the two thermocouples (Nos. 17 and 18) on the inside of the plaster, the maximum individual thermocouple temperature, and the average temperature at the hottest level for each column. (Note re: Column No. 7.)

Two successive fire tests were conducted on column 7. During the first a malfunction of the furnace automatic temperature control caused the column to be seriously overexposed and the test was discontinued. The specimen was allowed to cool and was re-tested in order to make possible an estimate of the temperature rise curve for this column. The estimate was made by combining the results of the re-test from the point where the furnace malfunction occurred during the fire test with those obtained on the first test up to that point. The resulting estimate is conservative because the fire exposure of the first test raised the thermal conductivity of the plaster.

The results of the column tests are summarized in Table I.

From the observations taken during the fire tests, the results show a similarity in that all specimens had hairline cracks near and parallel to the corner beading. All columns were examined carefully after the tests to determine the condition of the plaster, furring and steel core. The plaster was friable, particularly the brown or second coat. The scratch or first coat was relatively strong. The corner beads had oxidized considerably where they were exposed to the fire and the metal lath had lost its protective coating. The steel column section itself was not visibly affected by the fire exposure.

Column 5 was virtually identical to column 4, except that on No. 5 both coats of plaster were one part hardwall plaster to two parts sand. Upon examination after the test it was found that the plaster on column 5 was considerably stronger and less friable than the plaster on column 4, but that it had cracked more at the corners.

COMMENTS

Modern North American fire testing practice has favoured the use of 8- by 8- and 10- by 10-in. sections as standards. Members smaller than these seldom form the principal supporting members of a steel structure. The fire endurance times yielded by the four tests on these sections may therefore be considered for use directly for rating purposes. The results of the fire tests indicate column protection requirements as shown in Table II.

It was previously stated that a number of the sections were chosen to demonstrate the influence of column size and shape on fire performance. These were the 14-in. by 10-in. by 61-lb and the 12-in. by 12-in. by 190-lb sections. A measure of the compactness of a section is given by dividing the product of its nominal dimensions by the weight per foot. As may be seen, the first section is much less compact than the other; in fact, it is less compact than even the standard 8-in. by 8-in. by 48-lb section. The 12-in. by 12-in. by 190-lb section was chosen because it is one of the most compact rolled shapes available. The authors are not aware of any previous tests on such a heavy and compact section.

Due to the complex mechanism of heat transfer encountered with a membrane-protected column, no simple relation between column geometry and fire endurance can be established. It is interesting to note that the fire resistance classification for column 3 was higher than that for the standard test sections. The relatively non-compact sections 4 and 5, however, still yielded a fire resistance rating of one hour. One may conclude from this that although the compactness of the column section can have a significant effect on fire behaviour with unprotected or very lightly protected columns, it is of only secondary importance with membrane protections having low thermal conductivity and a high heat capacity. That is, the effect of cross-sectional compactness or the heat capacity of the steel section decreases as the thermal resistance and heat capacity of the cover increase. The air gap in a membrane-protected member may be regarded as adding to the thermal resistance of the protective cover. (Increasing the thickness of an air gap does not significantly affect the thermal resistance or the fire endurance time of a structure.)

The compactness of steel sections used in ordinary buildings does not vary greatly, and for the sake of simplicity the effect of compactness may be neglected when assigning fire ratings. This is particularly true when no portion of the protection comes in direct contact with the steel of the column section, and the protective material has low thermal conductivity and high heat capacity. It should also be kept in mind that the variables involved in the plastering operation do not lend themselves to precise specification.

Sand aggregate plasters have a somewhat higher thermal conductivity than plasters with lightweight aggregates. This series of tests demonstrated that gypsum-sanded plaster is suitable as a membrane protection for column sections in that it does not deteriorate significantly during fire exposure. When applied as a membrane protection in appropriate thicknesses gypsum-sanded plaster provides satisfactory protection against fire for periods of up to 2 hours.

Economic considerations, however, make it unsuitable for longer periods.

CONCLUSIONS

1. Gypsum-sanded plaster applied to metal lath remains in place during fire exposure and in appropriate thicknesses provides satisfactory protection to steel columns for periods of up to 2 hours.

2. Large (heavy) columns have better fire endurance qualities than small shapes similarly protected. For gypsum-sand plaster membrane protection, however, it is not practical to take account of the column size in assigning ratings.

3. No simple reliable relation can be found between fire resistance time and column size for this type of protection.

4. Protective materials such as gypsum-sanded plaster are considerably more effective applied as a membrane than applied directly in contact with the steel section.

ACKNOWLEDGEMENT

The author would like to thank Mr. O. E. Porteous of the Fire Research Section for his assistance. These tests were carried out as part of a cooperative program of research in the Fire Research Laboratories of DBR/NRC under the Steel Industries Fellowship arrangement with the Canadian Steel Industry.

REFERENCES

1. Shorter, G. W. and T. Z. Harmathy, Fire Endurance Test Facilities at the National Research Council. National Research Council, Division of Building Research. Fire Study No. 1, Ottawa, July 1960 (NRC 5732).

2. Specification for Gypsum Plastering, Interior Furring, and Interior Lathing. CSA Standard A82.30 - 1965, Canadian Standards Association, Ottawa.

3. Methods of Fire Tests of Walls, Partitions, Floors, Roofs, Ceilings, Columns, Beams and Girders. CSA Standard B54.3 - 1964, Canadian Standards Association, Ottawa.

TABLE I

SUMMARY OF RESULTS

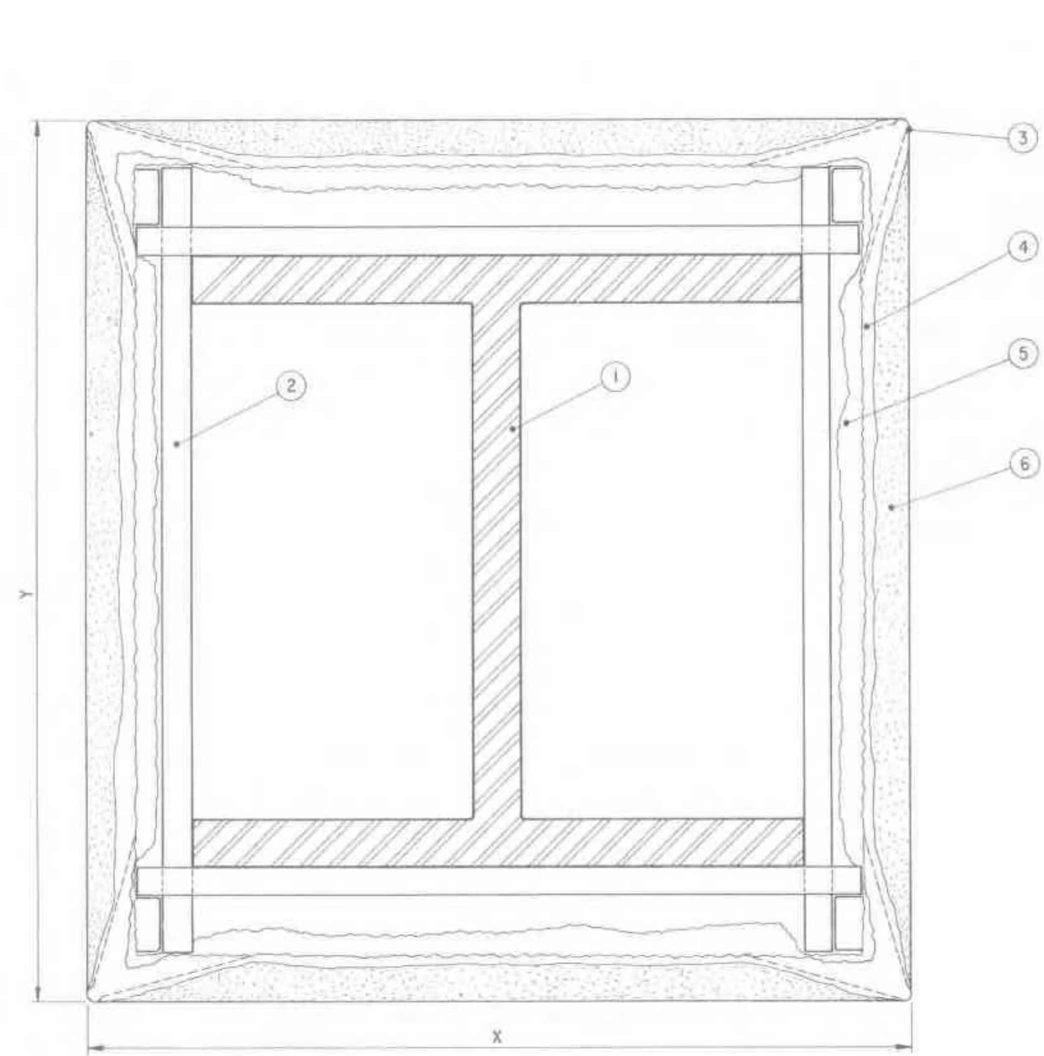
TEST NO.	SECTION	X(in.)	Y(in.)	OUTSIDE DIMENSIONS (in.)	NOMINAL PLASTER (in.)	AVERAGE* MEASURED PLASTER (in.)	FAILURE (min)	LEVEL NO.	FIRE RESISTANCE CLASSIFICATION (hr)
1	8" x 8" x 48 lb	11	11-1/2	11-1/2 x 12-1/2	5/8	0.62	65	5	1
2	12" x 12" x 190 lb	15 1/2	16	16 x 18	1/2	0.42	85	5	1
3	12" x 12" x 190 lb	15 1/2	16	16-3/8 x 18-1/8	5/8	0.59	118	1	1-1/2
4	14" x 10" x 61 lb	14	18-1/2	18 x 13-1/2	5/8	0.61	77	3	1
5	14" x 10" x 61 lb	14	18-1/2	18 x 13-1/2	5/8	0.57	67	1	1
6	10" x 10" x 112 lb	14	14-1/2	16 x 14-1/2	1	0.88	122	5	2
7	8" x 8" x 48 lb	11	11-1/2	12 x 12-1/2	1-1/4	1.14	94	-	1-1/2
8	10" x 10" x 112 lb	14	14-1/2	16 x 17	1-1/2	1.43	136	2	2

* Plaster thickness measured from face of metal lath at 96 points on each column, i.e. at 24 points on each face.

TABLE II

FIRE RESISTANCE OF STEEL COLUMNS PROTECTED WITH GYPSUM-SANDED PLASTER

PLASTER THICKNESS (IN.)	FIRE ENDURANCE RATING (HR)
1/2	3/4
5/8	1
1-1/8	1-1/2
1-1/2	2



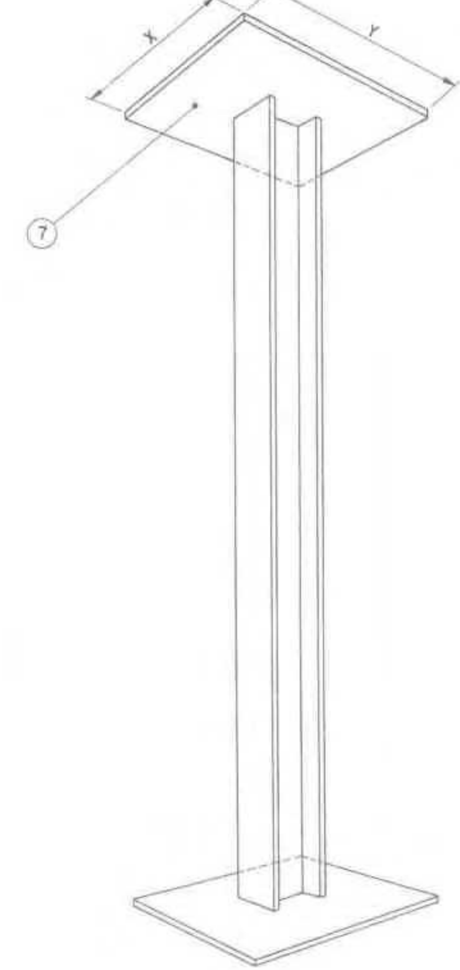


FIGURE I CONSTRUCTION DETAILS OF TYPICAL SPECIMEN

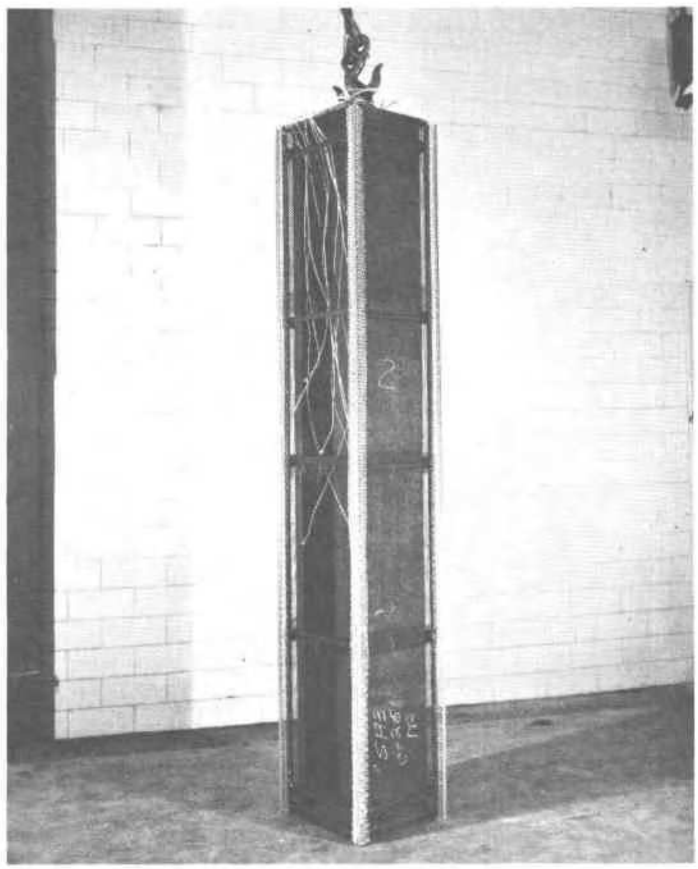


Figure 2 Column Prepared for Plastering.

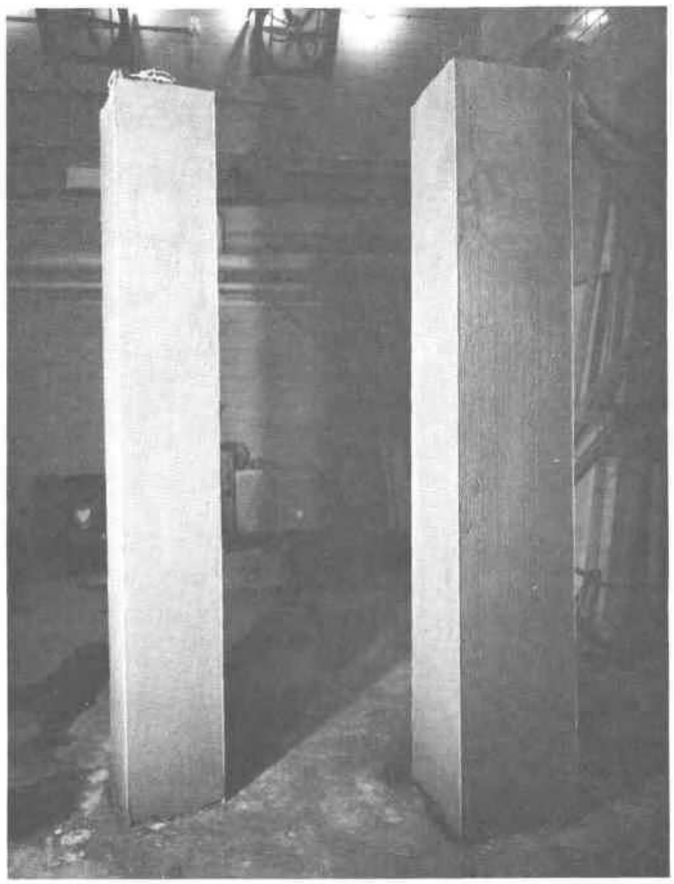


Figure 3 Columns 7 and 8 Completed.

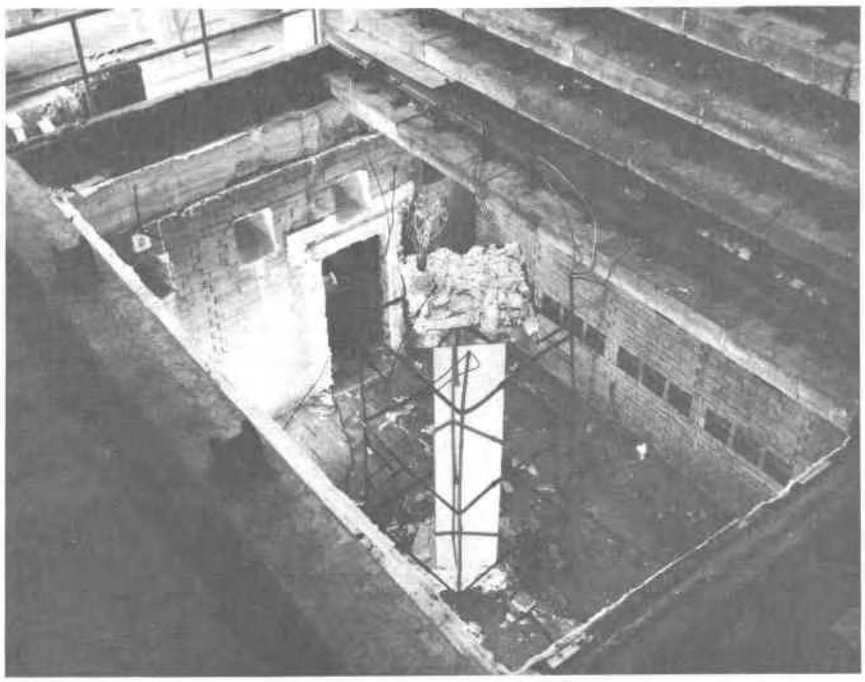


Figure 4 Column Installed In Furnace.

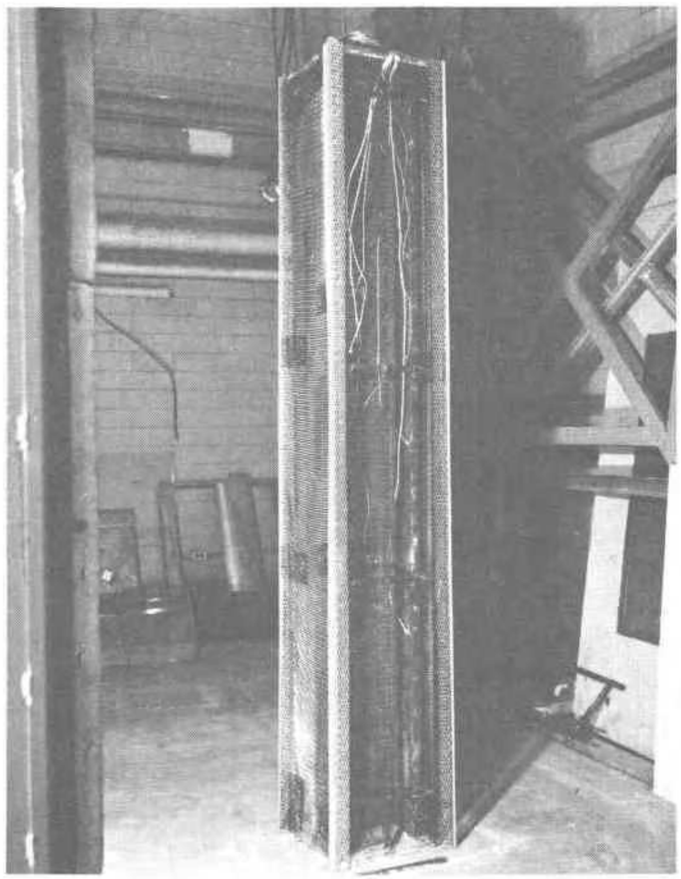


Figure 5 Column #7 Furred and Lathed.

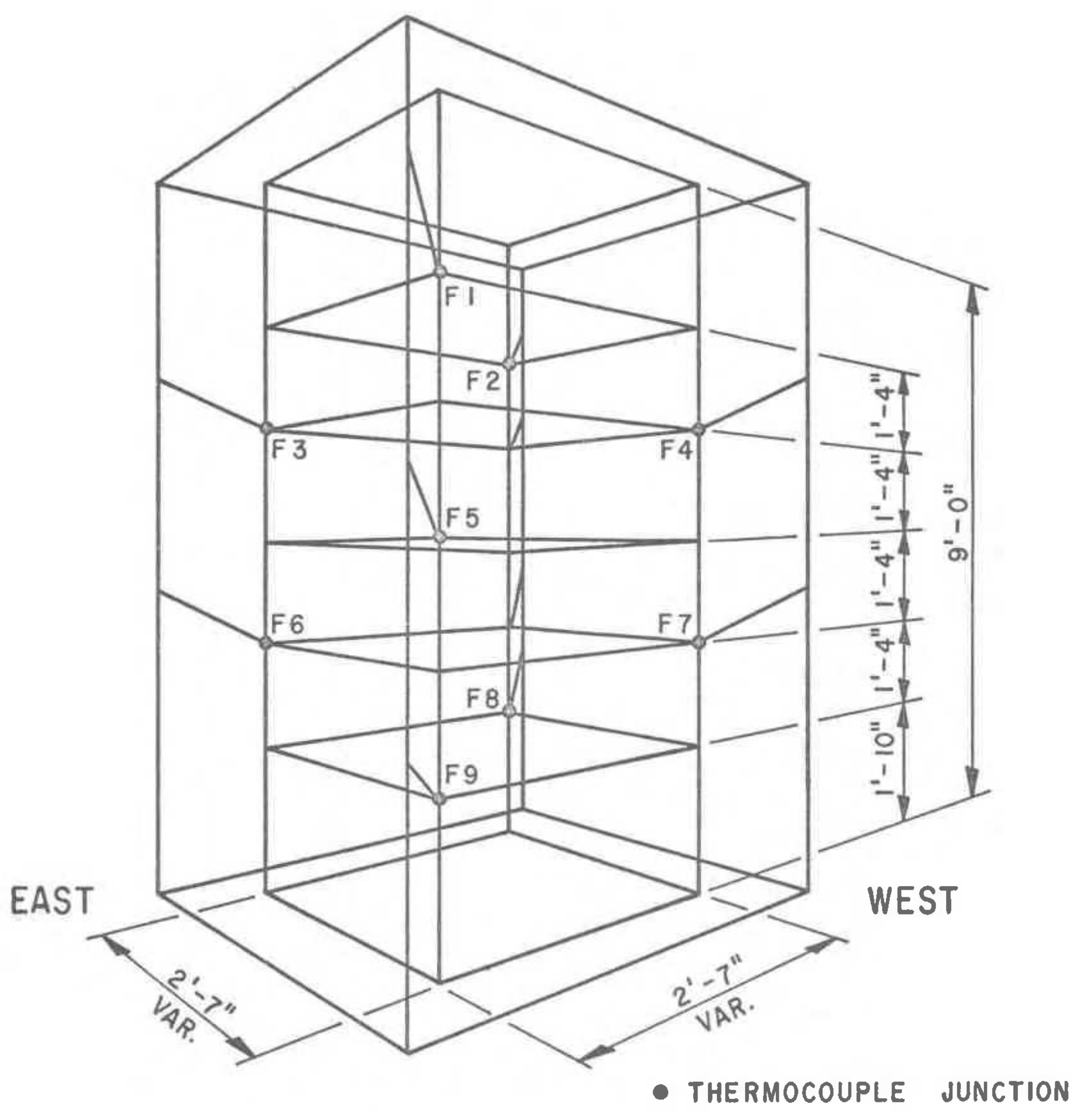
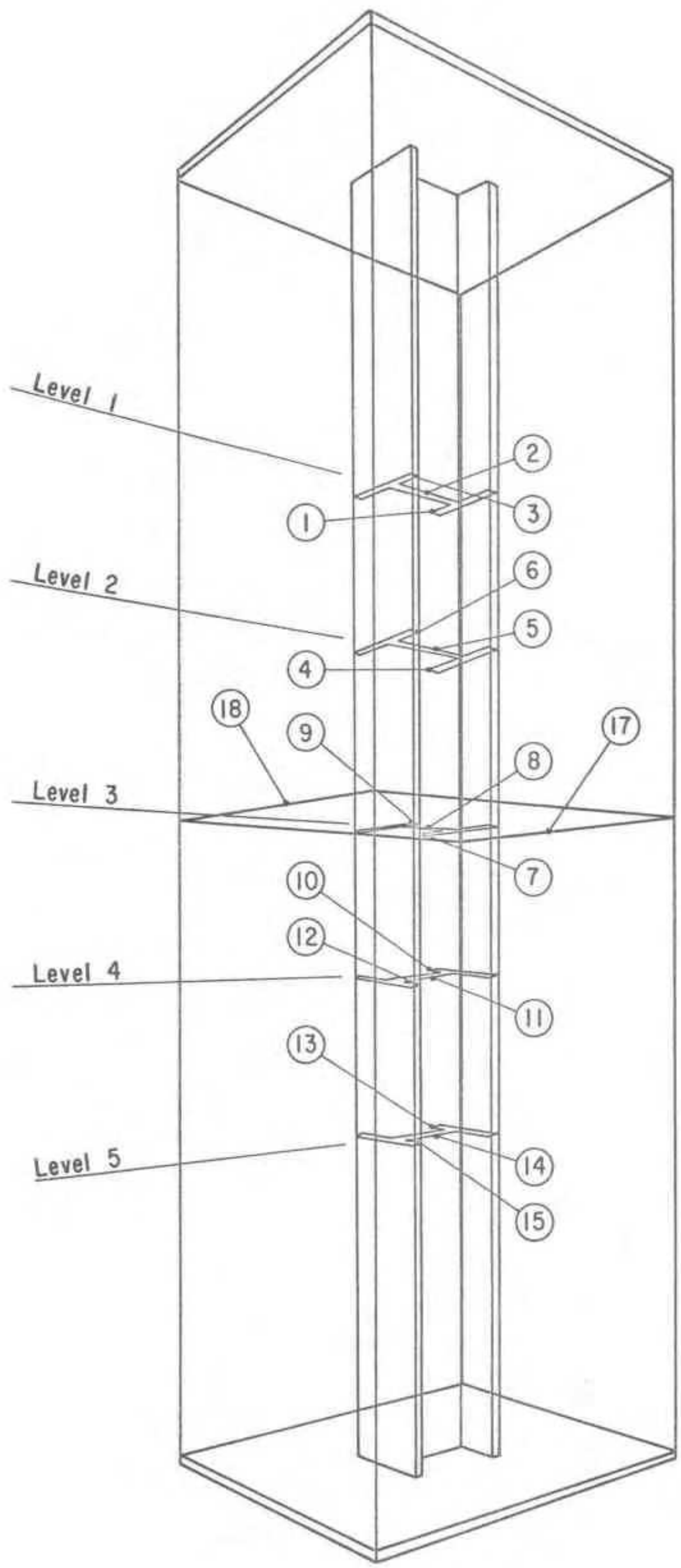


FIGURE 6
FURNACE THERMOCOUPLE LOCATIONS

BR 4026-2



DISTANCE FROM
THE BOTTOM PLATE

Level 5, 2'-1¼"
Level 4, 3'-1¼"
Level 3, 4'-1¼"
Level 2, 5'-1¼"
Level 1, 6'-1¼"

FIGURE 7
LOCATION OF THERMOCOUPLES

BR 4026-3

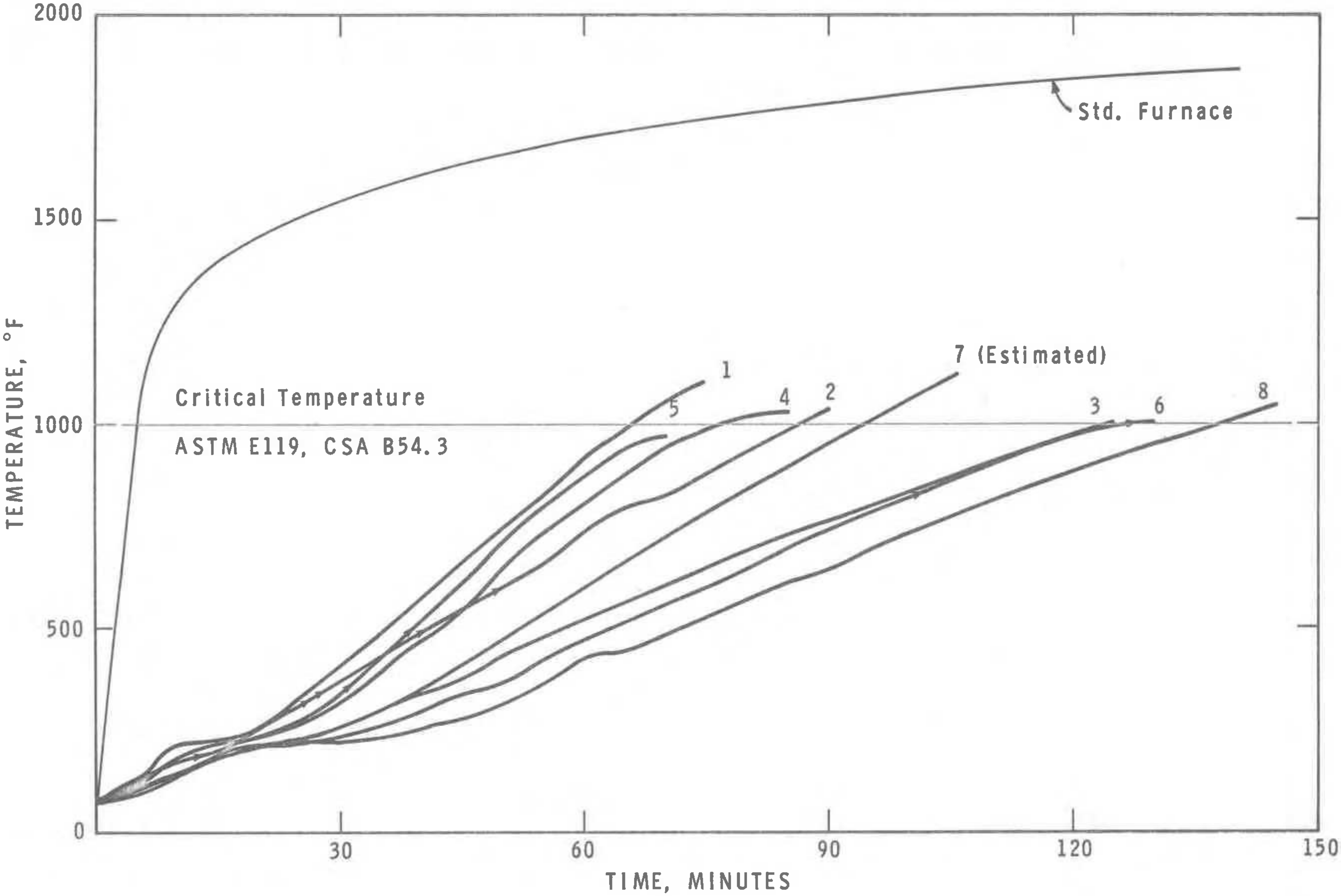


FIGURE 8 AVERAGE TEMPERATURE RISE COLUMNS

BR 4026-4

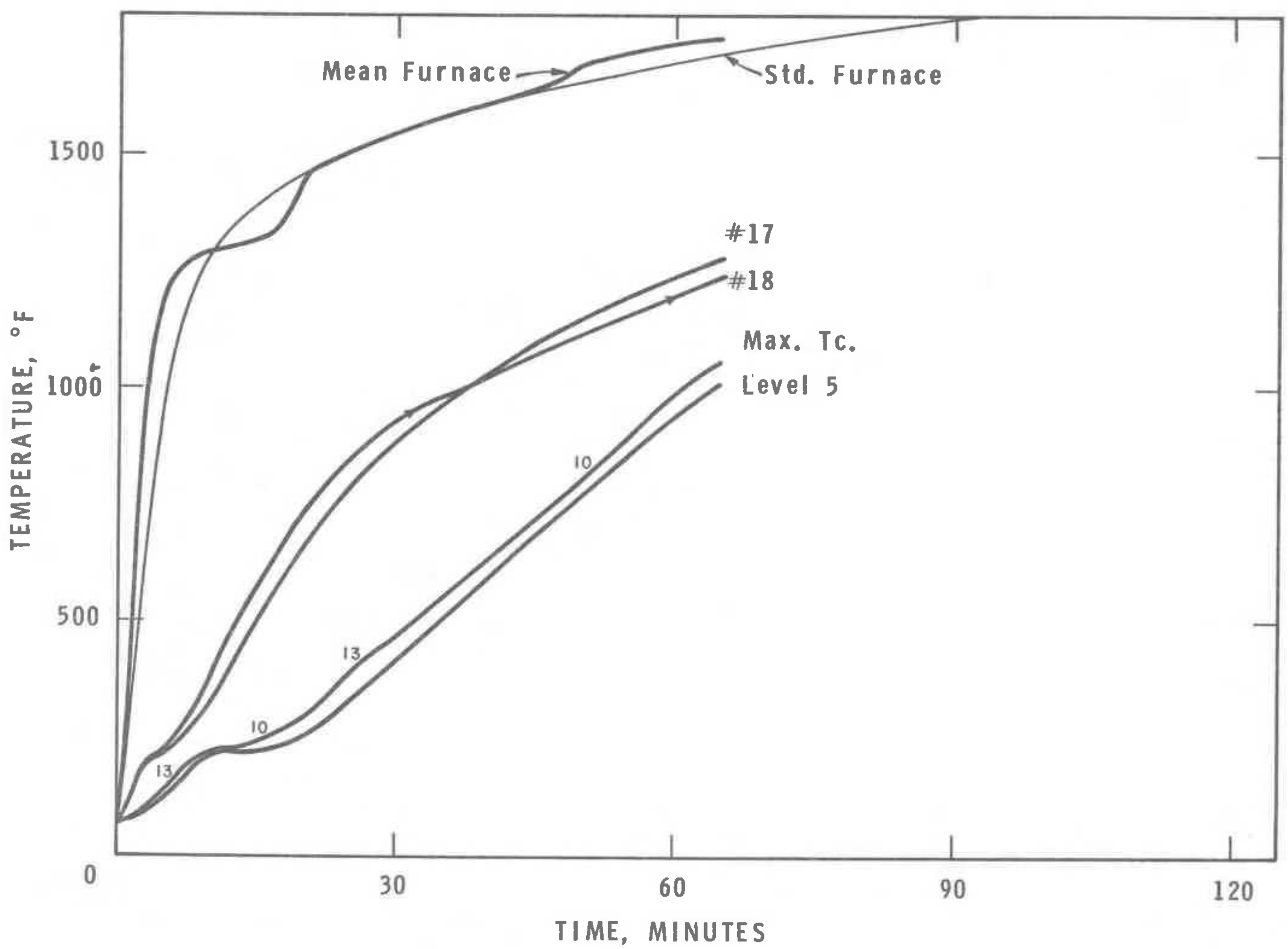


FIGURE 9 TEMPERATURE RISE # 1

BR 4026-5

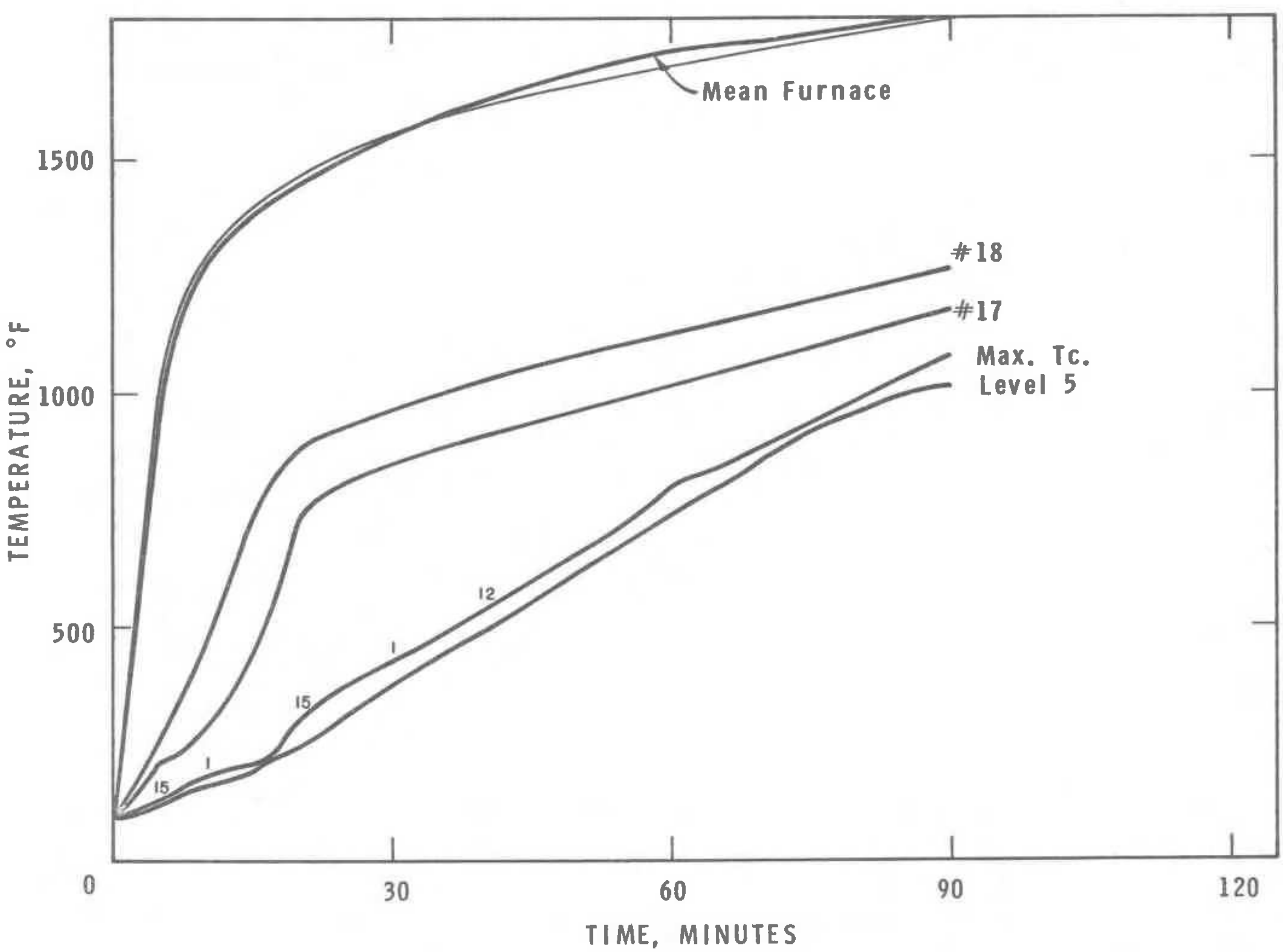


FIGURE 10 TEMPERATURE RISE # 2

BR 4026-6

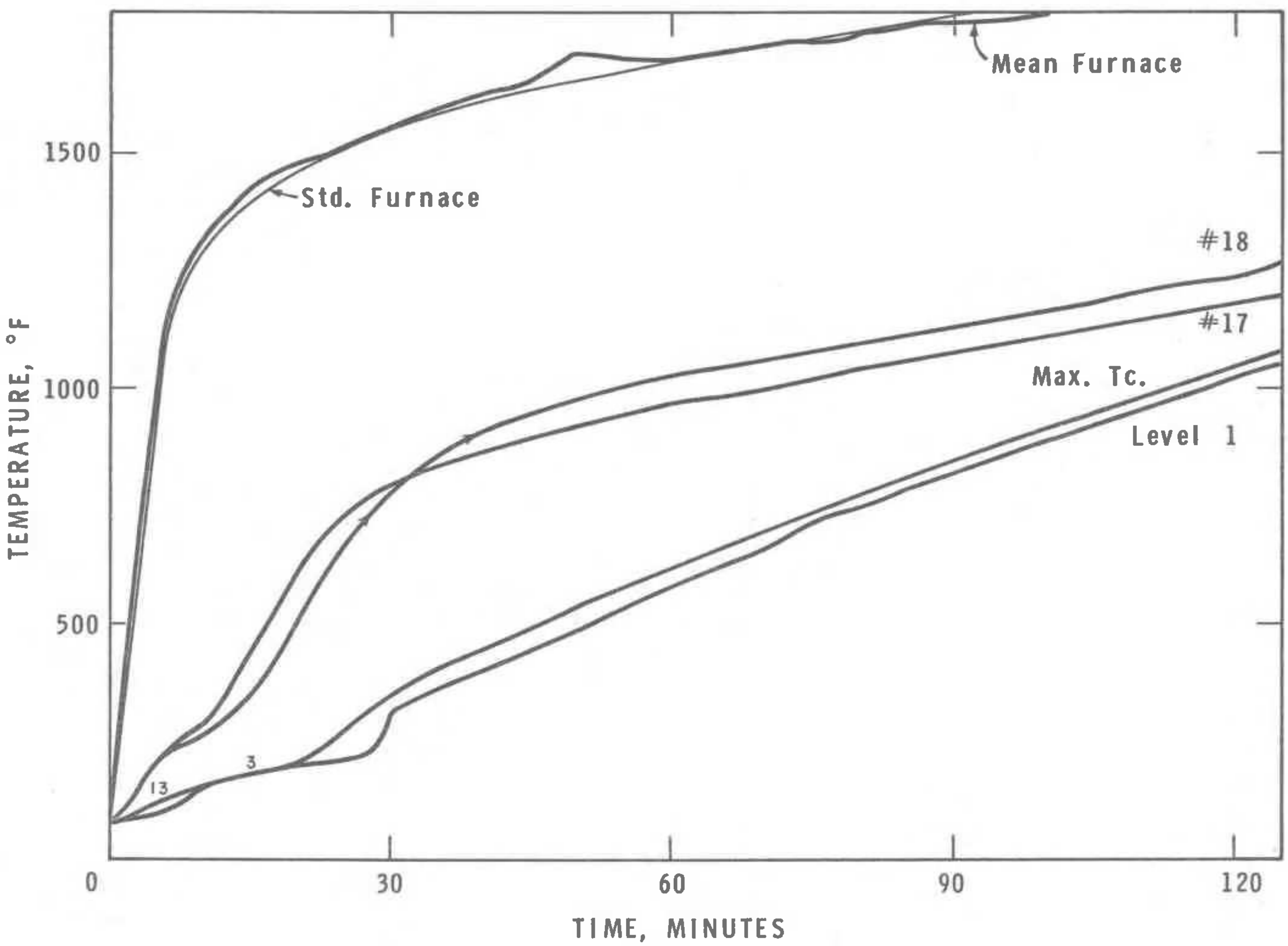


FIGURE 11 TEMPERATURE RISE # 3

BR 4026-7

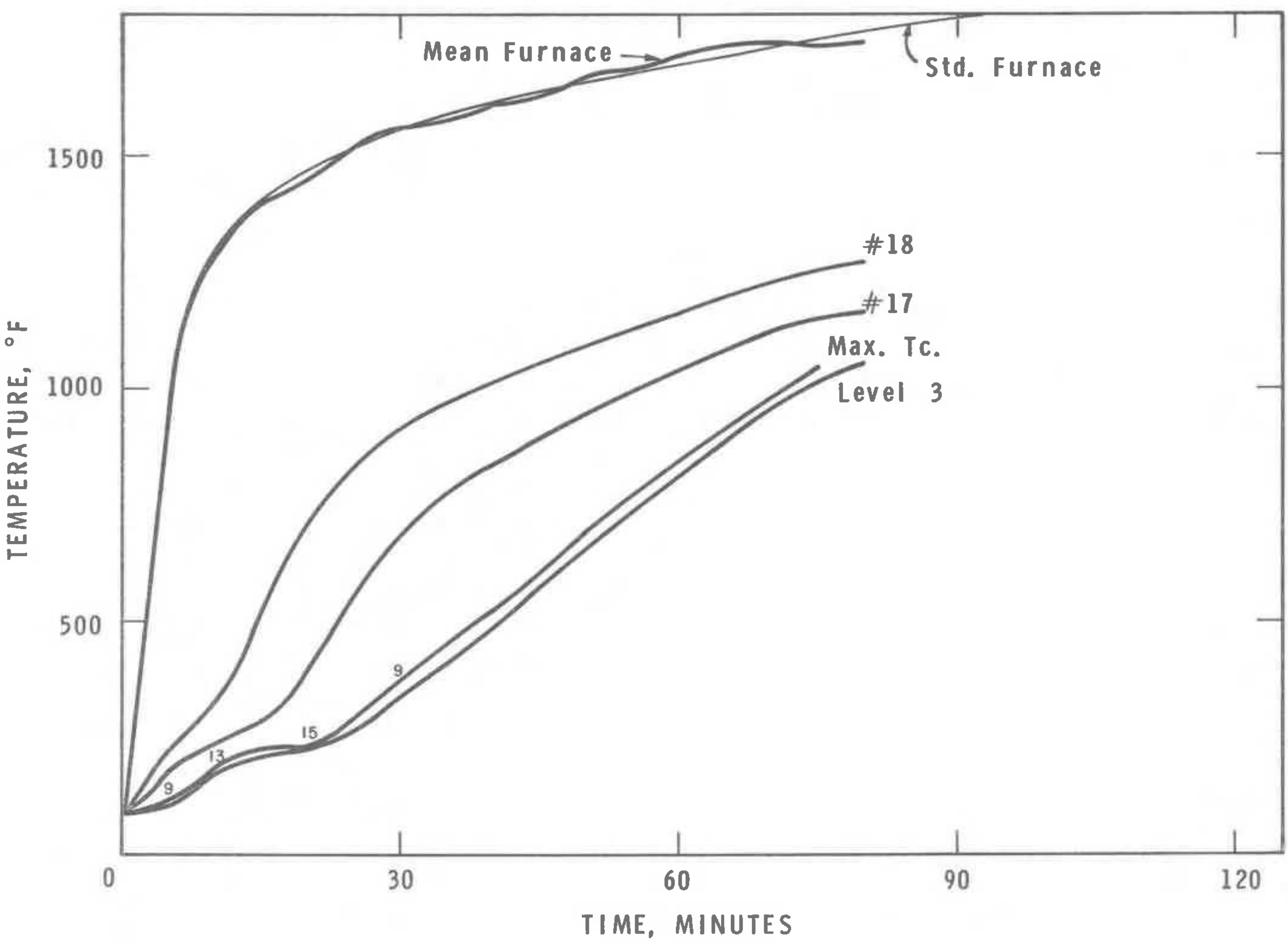


FIGURE 12 TEMPERATURE RISE # 4

BR 4026-8

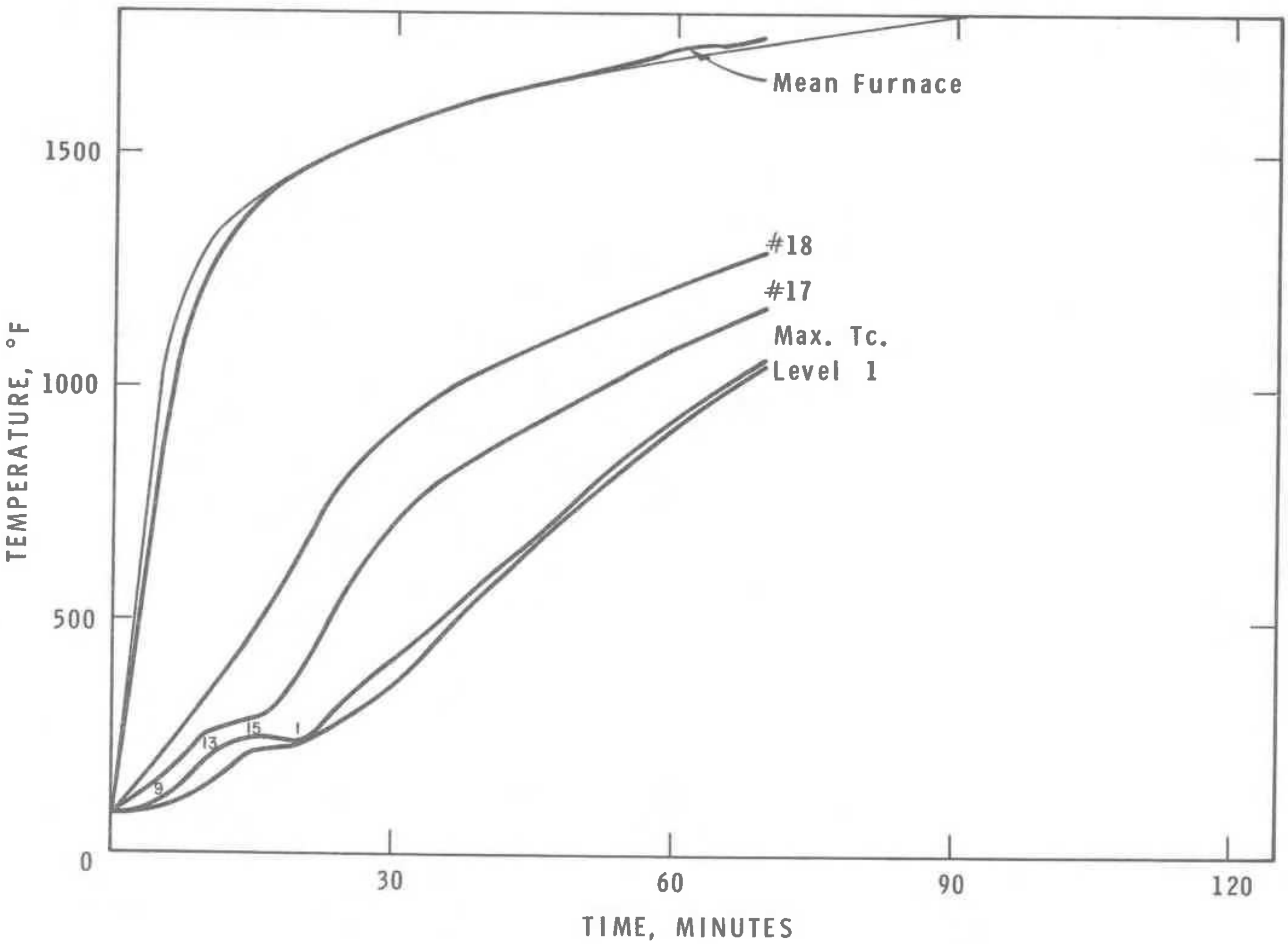


FIGURE 13 TEMPERATURE RISE #5

BR 4026-9

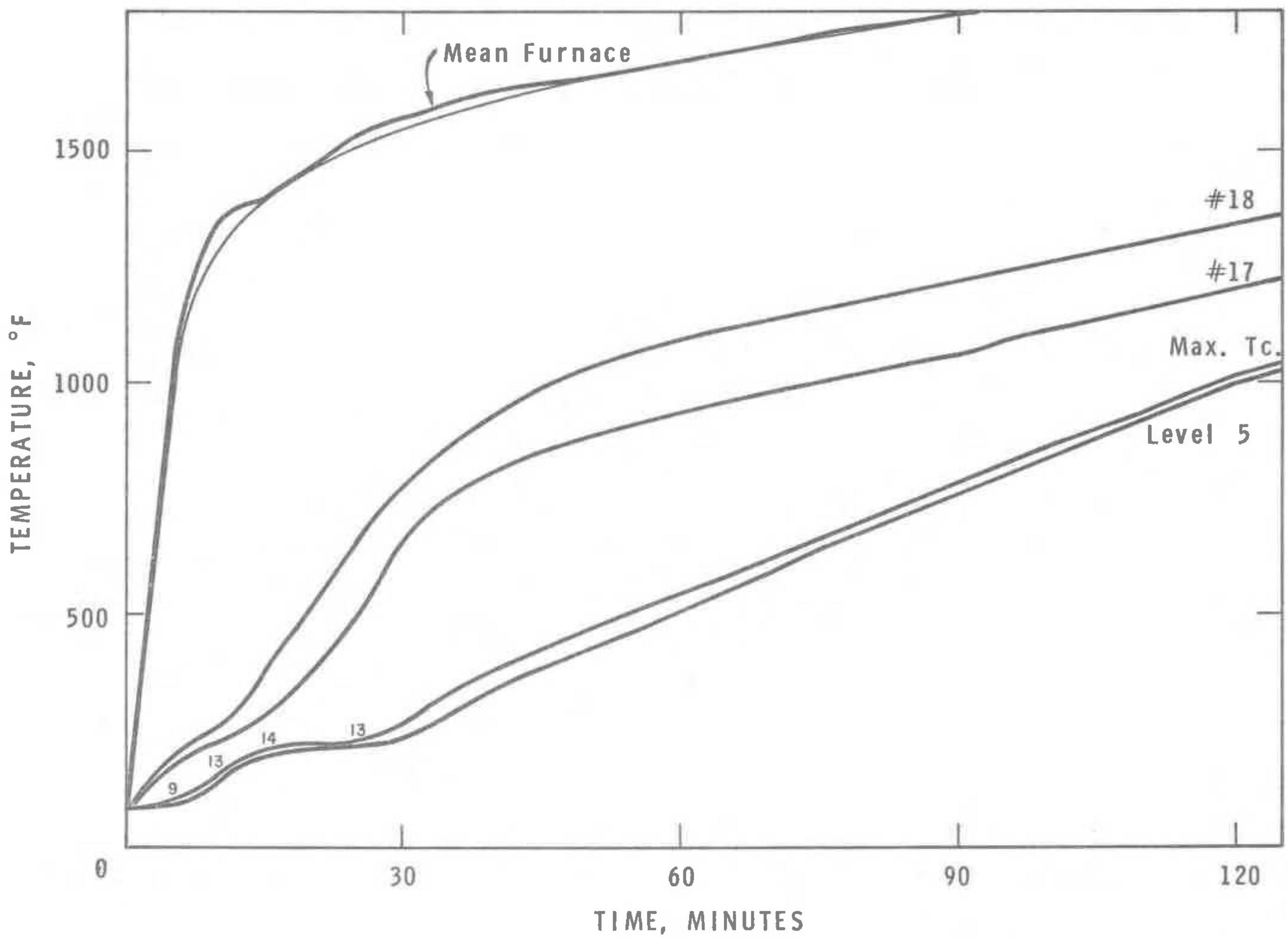


FIGURE 14 TEMPERATURE RISE # 6

BR 4026-10

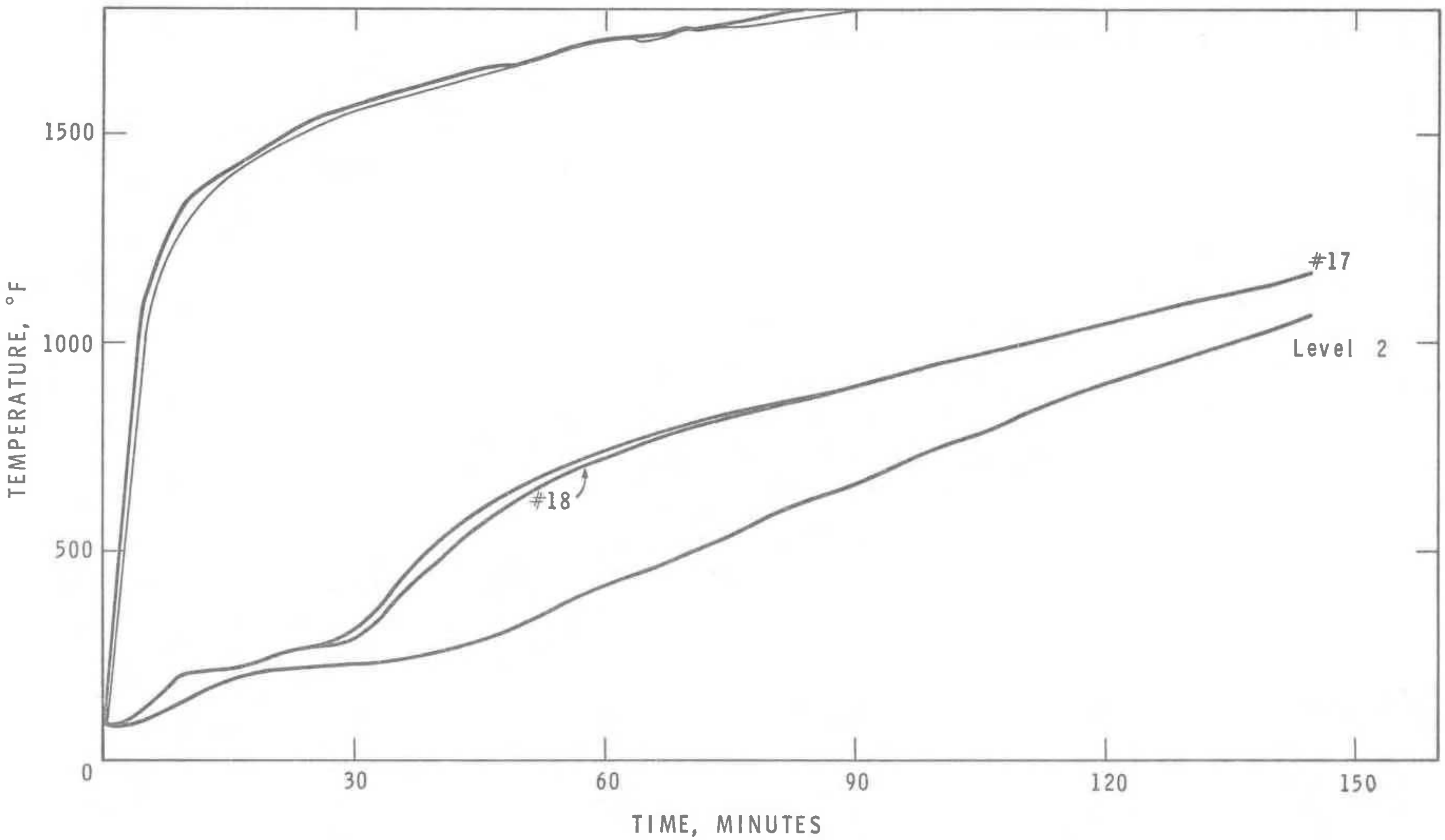


FIGURE 15 TEMPERATURE RISE #8

BR 4028-11