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EXPERIMENTAL STUDIES ON THE FIRE RESISTANCE OF HOLLOW STEEL COLUMNS FILLED WITH PLAIN CONCRETE

by

T. T. Lie and M. Chabot

ABSTRACT

Experimental studies were carried out to determine the fire resistance of circular and square hollow structural steel columns filled with plain concrete. The results of 44 full-scale fire resistance tests are described. The study variables included the column dimensions, steel section wall thickness, concrete strength, type of concrete aggregate, effective length, load intensity and eccentricity. These studies were conducted as part of a research program aimed at developing methods capable of predicting the fire resistance of concrete-filled hollow steel columns.

1. INTRODUCTION

Steel Hollow Structural Sections (HSS) are very efficient structural sections in resisting compression loads. By filling these sections with concrete, a substantial increase in load-bearing capacity can be achieved. Also, fire resistance can be obtained without the necessity of external fire protection for the steel section. The elimination of such external surface protection increases usable space in the building, and allows the steel outer surface to be left exposed. Furthermore, the tubular sections eliminate the need for formwork during erection.

These perceived benefits have resulted in research into the structural and fire performance of concrete-filled hollow steel columns in several organizations around the world [1-8]. For a number of years, the National Fire Laboratory of the Institute for Research in Construction, National Research Council of Canada, has also been engaged in studies to develop methods for predicting the fire resistance of these composite columns. These studies were supported by the Canadian Steel Construction Council and the American Iron and Steel Institute. A multi-phase program, which involves mathematical modelling and experiments, was set up. The study variables included the column cross-section shape and dimensions, thickness of steel section wall, effective length, concrete strength, type of concrete aggregate, percentage of steel reinforcement in the concrete as well as load intensity and eccentricity.

The report deals with the first phase of this program which focussed on hollow steel columns filled with plain concrete. The results of 44 tests on full-size circular and square columns, including the column cross-section temperature, axial deformation and fire resistance, are described in detail. The results of these tests can be used in two ways. First, the results can be used to assess, by interpolation, the fire resistance of columns in particular applications. Secondly and most importantly, they can be used to validate mathematical models which predict the behaviour of concrete-filled hollow steel columns exposed to fire [9].

This report includes all information previously published in two intermediate test reports by the Institute for Research in Construction in 1988 [10,11].

2. DESCRIPTION OF TEST SPECIMENS

2.1. Dimensions

All 44 columns were 3810 mm (12 ft 6 in.) long from end plate to end plate. Thirty-eight columns had a circular cross-section and 6 columns had a square cross-section. The outer diameter of the circular columns ranged from 141.3 mm to 406.4 mm, while the steel wall thickness varied from 4.78 mm to 12.70 mm. The outside width of the square columns ranged from 152.4 mm to 304.8 mm and the thickness of the steel wall was 6.35 mm. The dimensions of each column are listed in Table 1. In this table, the columns whose number starts with "C" are circular, and those with a number starting with "SQ" are square.

2.2. Materials

2.2.1. Steel

Steel hollow structural sections (HSS) meeting the requirements of CSA Standard G40.20-M [12], Class H, were used. The sections were made with grade 300W and 350W steels (CSA Standard G40.21-M [13]) with minimum yield strengths of 300 MPa and 350 MPa respectively. The sections were supplied by Stelco Inc.

The end plates were constructed using mild steel.

2.2.2. Concrete

Two types of concrete were used, i.e., siliceous and carbonate aggregate concretes. Of the 44 columns, 24 were filled with siliceous aggregate concrete and the others with carbonate aggregate concrete. Twelve pours were made in the National Fire Laboratory of the Institute for Research in Construction to fill the 44 columns. Batch quantities and specifics of the concrete mixes used in each pour are given in Tables 2, 3 and 4. The pours were numbered sequentially for the entire concrete-filled hollow steel column project according to the date of pouring.

In all pours, but Pour No. 10, a general purpose Type 10 Portland cement for construction of concrete structures was used. In Pour 10, a high early strength Type 30 Portland cement was used.

The concrete mixes in Pour Nos. 1, 2, 3, 4 and 17 were made with siliceous aggreate concrete. The aggregates were of nearly homogeneous siliceous composition. Rose quartz (coarse aggregate) from Northbrook, Ontario and siliceous sand (fine aggregate) supplied by Indusmin Ltd. from St Canut, Quebec were used in Pour Nos. 1-4. In Pour No. 18, the coarse and fine siliceous aggregates were supplied by Daubois Inc. from Saint-Leonard, Québec.

The aggregates in Pour Nos. 5, 6, 7, 8, 10, 11 and 18, were dominantly of carbonate composition. Carbonate stone from Ottawa (supplied by Dufferin Concrete) was used as aggregate in Pour Nos. 5, 6, 7, 8 and 11, while dolomite stone from Kingston, Ontario, was used in Pour No. 10. The fine aggregate used was silica based sand from Ottawa (supplied by Dufferin Concrete).

In Pour Nos. 10 and 11 (Column Nos. 42 and 46), additives were included in the mixes to increase the concrete compressive strength. These were silica fume and fly ash. In some cases, superplasticizer Mithty 150 and retarding admixtures Master Builders 100 XR and Mulco TCDA 727 were added to the mix to improve workability.

Compression tests on 150 mm cylinders were conducted for each pour at 28 days and on the test dates. The 28-day cylinder compressive strength ranged from 23 to 43 MPa. In the case of the concrete mixes with fly ash and silica fume, however, higher strengths were achieved. The 28-day cylinder strength of the mixes with fly ash was 49 MPa and that of the mix with silica fume was 90 MPa. The concrete strengths at 28 days and on the test dates are given in Table 1 for each column.

2.3. Fabrication

The columns were fabricated by cutting the supplied hollow steel sections to appropriate lengths. Steel end plates were then welded to the section extremities. The hollow steel sections and end plates were first joined by a groove weld. Secondly, a fillet weld was added around the outside diameter of the hollow steel section. AWS 5.18 Type E705-6 welding rods were used for both welds. Plate thickness and dimensions varied with the diameter of the hollow steel sections as shown in Figure 1. The hollow steel sections were cut to length so that the column length was 3810 mm including the end plate thickness. Accurate centering and perpendicularity of the end plates were given special attention.

Before assembly, a hole was cut in each plate to provide an opening through which the concrete was poured. The hole was approximately 25.4 mm smaller in diameter than the inner diameter of the hollow steel section, thus creating a lip of 13 mm between the inner surface of the section and the edges of the opening in the end plate, as shown in Figure 2.

Five small holes were drilled in the wall of the steel hollow sections. Two pairs, 13 mm in diameter, located 457 mm from each end of the columns, were provided as vent holes for the water vapour pressure produced during the experiment. The fifth hole, located near the top end plate, was used for entry of the thermocouple wires (see Figure 1).

The columns were then put in an upright position and filled with concrete. The concrete was mixed in a truck mixer, except for Pour No. 10 where a 0.17 m^3 drum type mixer was used. A concrete placement bucket and a funnel were used to deposit the concrete in the steel column. An internal vibrator was carefully applied to consolidate the concrete. The top surface of the column was finished with a small trowel. To avoid possible moisture leaks, the section was sealed at both ends with plastic sheet and tape. The columns were left upright for 28 days, then stored horizontally at room temperature with no particular curing measures being taken, until the test date. In general, seven months or more elapsed between the time a column was poured and the time it was tested. In a few cases, however, the curing period was limited to 4 to 5 months.

Before each test, the moisture condition in the concrete core of the column was measured by inserting a resistance moisture sensor in a hole drilled in the concrete through one of the vent holes. In general, a moisture content corresponding to approximately 85 to 95% RH was measured.

2.4. Instrumentation

Type K chromel-alumel thermocouples, with a thickness of 0.91 mm, were used for measuring concrete temperatures at several locations across the mid-height section of the columns. The thermocouples were tied to a steel rod that was secured to a bar running along the longitudinal axis of the column. The bar was fixed at both ends of the column (see Figure 3). In addition, a thermocouple was attached to the steel wall of each column at mid-height. The locations of the thermocouples are shown in Figures 4 to 6.

3. TEST APPARATUS

The tests were carried out by exposing the columns to heat in a furnace specially built for testing loaded columns and walls. The test furnace was designed to produce the conditions to which a member might be exposed during a fire; i.e., temperatures, structural loads and heat transfer. It consisted of a steel framework supported by four steel columns, with the furnace chamber inside the framework (Figure 7). The characteristics and instrumentation of the furnace are described in detail in Reference [14]. Only a brief description of the furnace and the main components is given here.

3.1 Loading device

A hydraulic jack with a capacity of 9778 kN produced the load along the axis of the test column. The jack was located at the bottom of the furnace chamber.

3.2. Furnace chamber

The furnace chamber had a floor area of 2642 × 2642 mm and was 3048 mm high. The interior faces of the chamber were lined with ceramic fibre materials that efficiently transfer heat to the specimen. There were 32 propane gas burners in the furnace chamber, arranged in eight columns containing four burners each. The total capacity of the burners was 4700 kW. Each burner can be adjusted individually, which gave a high degree of temperature uniformity in the furnace chamber. The pressure in the furnace chamber was also adjustable and was set somewhat lower than atmospheric pressure.

3.3 Instrumentation

The furnace temperatures were measured with the aid of eight chromel-alumel thermocouples. The junction of each thermocouple was located 305 mm (1 ft) from the test specimen, at various heights. Two thermocouples were placed opposite each other at intervals of 610 mm (2 ft) along the height of the furnace chamber. The location of their junctions and their numbering are shown in Figure 8. The temperatures measured by the thermocouples were averaged automatically and the average temperature used as the criterion for controlling the furnace temperature.

The loads were controlled and measured using pressure transducers. The accuracy of controlling and measuring loads is about 5% at lower load levels and relatively better at higher loads.

The axial deformation of the test specimen was determined by measuring the displacement of the jack that supports the column. The displacement was measured using transducers with an accuracy of 0.002 mm.

4. TEST CONDITIONS AND PROCEDURES

4.1 End conditions

Most tests were carried out with both ends of the columns fixed, i.e., restrained against rotation and horizontal translation. For this purpose, eight 19 mm bolts spaced regularly around the column were used at each end to bolt the end plates to the loading head at the top and the hydraulic jack at the bottom. Three columns (Column Nos. C-06, C-15 and C-16), however, were tested under hinged end conditions, i.e., with restraint against horizontal translation only. In these cases, the column end plates were bolted to the receiving plate with a roller bearing at each end.

4.2. Loading

All columns were tested under a concentric load, except Column No. C-16 where the load was eccentric by 34 mm. The applied load ranged from 9 to 47% of the factored compressive resistance of the columns (C_{rc}) or 46 to 165% of the factored compressive resistance of the concrete core (C'_r), determined according to CSA Standard CSA/CAN-S16.1-M89 [15]. The factored compressive resistances of each column, as well as the applied loads, are given in Table 1. The effective length factors, K, used in the calculation the factored compressive resistances were those recommended in CSA/CAN-S16.1-M89 for the given end conditions, i.e., 0.65 for fixed ends and 1 for pinned ends. The effective lengths, KL, were thus 2.48 m for fixed ends and 3.81 m for pinned ends.

The load was applied approximately 45 min before the start of the test, until a condition was reached at which no further increase of the axial deformation could be measured. This condition was selected as the initial condition for the column axial deformation. The load was maintained constant throughout the test.

4.3. Fire exposure

The ambient temperature at the start of each test was approximately 20°C. During the test, the column was exposed to heating controlled in such a way that the average temperature in the furnace followed as closely as possible the ASTM-E119 [16] or CAN/ULC-S101 [17] standard temperature-time curve. This curve can be approximated by the following equation:

$$T_f = 20 + 750\,[\,1 - \exp(-3.79533\sqrt{t}\,)] + 170.41\,\sqrt{t}$$

where:

T_f = Furnace temperature (°C)
t = Time (hours)

4.4. Failure criterion

The columns were considered to have failed, and the tests were terminated, when the hydraulic jack, which has a maximum speed of 76 mm/min (3 in./min), could no longer maintain the load.

4.5 Recording of results

The furnace, concrete and steel temperatures, as well as the axial deformations of the columns were recorded at 2, 5 or 10 min intervals.

The test program was conducted over a ten year period, i.e., from 1981 to 1990. During that period, modifications to the furnace equipment, such as the temperature controller, burners and lining materials, as well as improvements in the data acquisition system were made which may have some influence on the results. Special attention was given, however, to ensure that the test conditions, such as temperature uniformity and heat transfer from the furnace to the columns, remained essentially unaltered.

5. RESULTS AND DISCUSSION

The results of the 44 column tests are summarized in Table 1. Specific information, test conditions, fire resistance and failure modes are given for each column. The failure mode, which varied from buckling to compression, was determined by visual observation. A column was considered to have failed by buckling when bending was apparent.

The concrete and steel temperatures, as well as the axial deformations of the columns as a function of time, are presented in Tables A1 to A44 and plotted in Figures A1 to A44, in Appendix A. Positive axial deformation values indicate expansion of the column. Finally, Figures B1 to B44, in Appendix B show photographs of the column specimens taken after the fire tests.

As mentioned earlier, these tests were carried out essentially for the purpose of validating methods capable of calculating the fire resistance of hollow steel columns filled with plain concrete for any value of the significant variables which determine fire resistance. The development of such methods is at an advanced stage at the National Fire Laboratory and will be presented in a future paper. The test results given in this report can also be used for assessing the fire resistance of hollow steel columns filled with plain concrete – in particular, applications which fit within the range of values of the significant variables considered in the test series. The following discussion on the behaviour of the columns in fire and the influence of the study variables should provide additional information for the fire resistance design of hollow steel columns filled with plain concrete.

5.1 Behaviour of concrete filled hollow steel columns in fire

The behaviour of a concrete-filled hollow steel column in fire can be determined by examining the axial deformation curve of the column in the fire test. The axial deformation curve of Column No. 34 in Figure A23 represents a typical example.

At ambient temperature, the applied column load is carried by both the hollow steel section and the concrete core. When the column is exposed to fire, both the steel section and concrete core start to expand. This is indicated by the steep increase in axial deformation in Figure A23. During that stage, the steel section carries all of the applied load because it expands more rapidly than the concrete core. As the temperature increases, however, the steel loses its ability to support the load and the column suddenly contracts until, usually after 20-30 min, the concrete takes over. This is often accompanied by local bulging of the steel section. The load is then gradually transferred to the concrete core which loses strength more slowly than the steel due to the lower thermal conductivity and higher heat capacity of the concrete. The column then progressively continues to contract, as the concrete temperature increases, and ultimately fails, either by buckling or

compression, depending on the slenderness of the column. At failure, the load is usually almost entirely carried by the concrete core.

Thus, it is the load-carrying capacity of the concrete core, during exposure to fire, that determines the fire resistance of concrete filled steel columns. Because the concrete section alone cannot support the full design load, a high fire resistance can only be achieved by reducing the applied load.

5.2 Influence of study variables

Load intensity

The load intensity is defined as the ratio of the applied load to the column resistance (load bearing capacity) at room temperature. Two values of the load intensity are given in Table 1 for each column test, one as a fraction of the factored compressive resistance of the composite column (C/C_{rc}) and the other as a fraction of the factored compressive resistance of the concrete core only (C/C'_r), determined in accordance with CAN/CSA-S16.1-M89. For fire resistance design, the ratio of applied load to the factored compressive resistance of the concrete core (C/C'_r) was considered as more representative of the actual intensity of loading because, as mentioned earlier, of the dominant contribution of the concrete filling in carrying the applied load. The strength of the hollow steel section, which is included in the calculation of C_{rc}, decreases very quickly in fire and can practically be neglected. The ratio C/C'_r, rather than C/C_{rc}, should thus be used for comparing different test results.

The influence of the load intensity on the fire resistance of the column is illustrated in Figure 9 for three different column diameters. As expected, the load intensity has a significant influence on the fire resistance of the column. For example, the fire resistance of Column Nos. C-20, C-21 and C-22 decreased from 133 to 70 min as the applied load increased from 74 to 141% of the factored compressive resistance of the concrete core. The influence of the load intensity had a relatively larger influence for columns having a larger diameter.

Outside diameter or width of column

In general, for the same load intensity, the fire resistance increased with the outer diameter or width of the columns. The reason is that the heat capacity of the concrete core increases with its mass. As a result, the temperature at comparable depths inside the concrete core rises more slowly in large columns than in small columns.

The fire resistances of circular columns were relatively higher than those of square columns, for equivalent cross-section area.

Steel wall thickness

The influence of the steel wall thickness was investigated in Test Nos. C-05, C-09, C-11 and C-17, as well as C-35 and C-37. All these columns had a relatively small outer diameter, namely 219.1 mm or less. As expected, it was found that the wall thickness had little influence on the fire resistance of the columns. For Column Nos. C-05 and C-09, for example, which were tested under the same load, the fire resistance increased from 76 to 81 min by increasing the wall thickness from 4.78 to 6.35 mm. In the case of Column Nos. C-35 and C-37, the opposite effect was observed, i.e., that the fire resistance decreased with increasing wall thickness.

It seems reasonable, for practical applications, to neglect the influence of the wall thickness. Hollow steel sections with thin wall thickneses thus appear more cost-effective.

Type of aggregate

Tests on conventional reinforced concrete columns, 305 mm by 305 mm, carried out at NRC [18], showed that, for columns having comparable strengths, carbonate aggregate concrete provides substantially higher fire resistances than siliceous aggreagate concrete, particularly for long fire resistance durations or implicitly for low load intensities. Under an applied load of 58% of the design load, for example, the fire resistance of a carbonate aggregate concrete column was more than twice as high as that of a comparable siliceous aggregate concrete column. The reason is that carbonate aggregate has a substantially higher heat capacity than siliceous aggregate concrete as a result of an endothermic reaction that occurs in carbonate aggregate around 700°C.

The results obtained in the series of tests on concrete filled hollow steel columns, however, were less conclusive regarding the influence of the type of aggregate, because the siliceous and carbonate aggregate mixes had somewhat different compressive strengths, and the carbonate aggregate mixes were not pure but contained silica-based sand. There are indications, however, that better performance can be expected by using carbonate aggregate concrete, such as lower temperature deep in the concrete core and extremely high fire resistances (234, 274 and 294 min) under loads of approximately 55% of C'_r.

Concrete strength

Here again, it is difficult to draw conclusions on the influence of the concrete strength on the fire resistance of the columns for the same reasons mentioned in the previous section. There are indications, however, that, for a given load, the fire resistance increases with concrete strength, when the 28-day strength ranges between 25 and 45 MPa. The fire resistance of Columns No. C-59 and C-60, for example, increased from 125 to 152 min with an increase of the concrete strength from 33 to 43 MPa.

Effective length

The influence of the effective length was examined for two different column diameters, i.e., 168.3 mm and 219.1 mm (Column Nos. C-05, C-06, C-15 and C-17). As expected, for the same applied load, the fire resistance decreased with increase of effective length. For example, for the columns with a diameter of 168.3 mm, the fire resistance decreased from 76 min to 60 min when the effective length was increased from 2477 mm to 3810 mm. The reduction in fire resistance with increase of effective length varied with the slenderness of the column.

Eccentricity

Only one test was conducted to examine the influence of the load eccentricity (Column No. C-16). The column had a diameter of 219.1 mm and the eccentricity of the applied load was 34 mm. As expected, the eccentricity had a significant effect on the fire resistance of the column. For the same applied load, the fire resistance decreased from 73 min to 33 min as a result of the eccentricity of loading. Because concrete has practically no tensile strength, it is not recommended that hollow steel columns filled with plain concrete be used for applications where the load is eccentric.

5.3 Repeatability of test results

In this test series, a column can be placed in two classes based on its failure mode. The columns with a small diameter, i.e., 219.1 mm or less, failed by buckling whereas the larger columns, 323.9 mm or more in diameter, failed in compression. The failure mode of the columns with a diameter of 273.1 mm varied between buckling and compression. In general, the results obtained for the small columns are consistent from test to test. The performance of the larger columns in the tests, however, was sometimes erratic, especially when the load was high. In some cases, the failure by compression occurred very suddenly, without warning. This behaviour is probably due to the development of local excessive stresses and cracks which propagates through the concrete core due to the absence of steel reinforcement and lack of containment of the concrete. Increased brittleness of the concrete with higher concrete strength may also be a contributing factor.

REFERENCES

1. Flemington, R.A., Fire Protection of Hollow Structural Sections, Technical Bulletin 21, Stelco Inc., Hamilton, Ontario, 1980.

2. Granjean, G., Grimault, J.P. and Petit, L., Détermination de la Durée au Feu des Profils Creux Remplis de Béton, Rapport Final, Commission des Communautés Européennes, Recherche Technique Acier, Luxembourg, 1981.

3. Kordina, E.H.K. and Klingsch, W., Brandverhalten von Stahlstützen im Verbund mit Beton und von massiven Stahlstützen ohne Beton, Teil 1: Bericht, Institut für Baustoffe, Massivbau und Brandschultz Lehrstuhl für Massivbau, Technische Universität Braunschweig, West Germany, 1983.

4. *Design Manual for SHS Concrete Filled Columns*, British Steel Corporation, Corby Technical Centre, U.K., 1984.

5. Kruppa, J., Méthode de Prévision par le Calcul du Comportement au Feu des poteaux Mixtes (Acier + Béton), *Construction Métallique*, No. 3, 1988.

6. Twilt, L., Design Charts for the Fire Resistance of Concrete Filled HSS Columns under Centric Loading, TNO Institute for Building Materials and Structures, Netherlands, 1988.

7. Klingsch, W. and Wittbecker, F.W., Fire Resistance of Hollow Section Composite Columns of Small Cross Sections, Bergische Universität, Wuppertal, West Germany, 1988.

8. *Fire Technical Design Manual for Composite Columns with Concrete Filled Hollow Steel Sections*, Finnish Constructional Steelwork Association, Helsinki, 1989.

9. Lie, T.T. and M. Chabot, A Method to Predict the Fire Resistance of Circular Concrete Filled Hollow Steel Columns, *Journal of Fire Protection Engineering*, Vol. 2, No. 4, 1990, pp 111-126. (Reprinted by the National Research Council of Canada as NRCC 32372).

10. T.T. Lie and S.E. Caron, *Fire Resistance of Circular Hollow Steel Columns Filled with Siliceous Aggregate Concrete: Test Results*, Internal Report No. 570, Institute for Research in Construction, National Research Council of Canada, Ottawa, Canada, August 1988.

11. T.T. Lie and S.E. Caron, *Fire Resistance of Circular Hollow Steel Columns Filled with Carbonate Aggregate Concrete: Test Results*, Internal Report No. 573, Institute for Research in Construction, National Research Council of Canada, Ottawa, Canada, November 1988.

12. *General Requirements for Rolled or Welded Structural Quality Steel - G40.20-M*, Canadian Standards Association, Toronto.

13. *Structural Quality Steels - G40.21-M*, Canadian Standards Association, Toronto.

14. Lie, T.T., New Facility to Determine Fire Resistance of Columns, *Canadian Journal of Civil Engineering*, Vol. 7, No. 3, 1980, pp 551-558. (Reprinted by the National Research Council of Canada as NRCC 18423)

15. *Limit States Design of Steel Structures - CAN/CSA-S16.1-M89*, Canadian Standards Association, Toronto.

16. *Standard Methods of Fire Tests of Building Construction and Materials - E119-83*, American Society for Testing and Materials, Philadelphia, 1985.

17. *Standard Methods of Fire Endurance Tests of Building Construction and Materials - CAN/ULC-S101-M89*, Underwriters' Laboratories of Canada, Scarborough, Canada, 1982.

18. Lie, T.T. and Woollerton, J.L., Fire Resistance of Reinforced Concrete Columns – Test Results, Internal Report No. 569, Institute for Research in Construction, National Research Council of Canada, Ottawa, Canada, 1988.

Table 1. Summary of test parameters and results

Column No.	Test Date	Dia.	Wall Thick.	Yield Strength	Concrete Strength		Aggregate	Pour No.	End Cond.	Ecc.	Factored Resistance		Test Load	Load Intensity		Fail. Mode	Fire Resistance
					28 day	test					C'r	Crc	C	C/C'r	C/Crc		
		(mm)	(mm)	(MPa)	(MPa)	(MPa)				(mm)	(kN)	(kN)	(kN)				(min)
C-02	89/03/01	141.3	6.55	350	28.6	33.1	siliceous	#4	F-F	-	143	928	110	0.77	0.12	B	55
C-04	83/09/22	141.3	6.55	350	28.6	31.0	siliceous	#4	F-F	-	143	928	131	0.92	0.14	B	57
C-05	89/03/10	168.3	4.78	350	28.6	32.7	siliceous	#4	F-F	-	250	965	150	0.60	0.16	B	76
C-06	90/03/29	168.3	4.78	350	28.6	32.7	siliceous	#4	P-P	-	179	798	150	0.84	0.19	B	60
C-08	85/02/13	168.3	4.78	350	28.6	35.5	siliceous	#4	F-F	-	250	965	218	0.87	0.23	B	56
C-09	89/03/22	168.3	6.35	350	28.6	35.4	siliceous	#4	F-F	-	238	1177	150	0.63	0.13	B	81
C-11	84/12/03	219.1	4.78	350	24.3	31.0	siliceous	#3	F-F	-	408	1399	492	1.21	0.35	B	80
C-13	84/04/10	219.1	4.78	350	24.3	32.3	siliceous	#3	F-F	-	408	1399	384	0.94	0.27	B	102
C-15	90/01/18	219.1	8.18	350	24.3	31.9	siliceous	#3	P-P	-	319	1849	525	1.65	0.28	B	73
C-16	90/03/19	219.1	8.18	350	24.3	31.9	siliceous	#3	P-P	34	-	1128	525	-	0.47	B	33
C-17	84/07/10	219.1	8.18	350	24.3	31.7	siliceous	#3	F-F	-	379	2039	525	1.39	0.26	B	82
C-20	82/05/07	273.1	5.56	350	26.3	28.6	siliceous	#1	F-F	-	708	2243	574	0.81	0.26	B	112
C-21	82/06/18	273.1	5.56	350	26.3	29.0	siliceous	#1	F-F	-	708	2243	525	0.74	0.23	B	133
C-22	83/07/21	273.1	5.56	350	26.3	27.2	siliceous	#1	F-F	-	708	2243	1000	1.41	0.45	B	70
C-23	89/08/01	273.1	12.70	350	26.3	27.4	siliceous	#1	F-F	-	629	3991	525	0.83	0.13	B	143
C-25	83/01/18	323.9	6.35	350	23.5	27.6	siliceous	#2	F-F	-	903	3090	699	0.77	0.23	C	145
C-26	85/08/29	323.9	6.35	350	23.5	24.3	siliceous	#2	F-F	-	903	3090	1050	1.16	0.34	C	93
C-28	85/09/16	355.6	6.35	350	23.5	23.8	siliceous	#2	F-F	-	1099	3570	1050	0.96	0.29	C	111
C-29	85/10/15	355.6	12.70	350	23.5	25.4	siliceous	#2	F-F	-	1018	5801	1050	1.03	0.18	C	170
C-30	86/02/26	406.4	12.70	350	23.5	27.6	siliceous	#2	F-F	-	1360	7051	1900	1.40	0.27	C	71

Table 1 (cont'd). Summary of test parameters and results

Column No.	Test Date	Dia.	Wall Thick.	Yield Strength	Concrete Strength		Aggregate	Pour No.	End Cond.	Ecc.	Factored Resistance		Test Load	Load Intensity		Fail. Mode	Fire Resistance
					28 d.	test d.					C'r	Crc	C	C/C'r	C/Crc		
		(mm)	(mm)	(MPa)	(MPa)	(MPa)				(mm)	(kN)	(kN)	(kN)				(min)
C-31	89/06/08	141.3	6.55	300	35.9	30.2	carbonate	#6	F-F	-	171	858	80	0.47	0.09	B	82
C-32	89/06/21	141.3	6.55	300	33.0	34.8	carbonate	#5	F-F	-	160	847	143	0.89	0.17	B	64
C-34	86/03/07	219.1	4.78	300	33.0	35.4	carbonate	#5	F-F	-	546	1399	500	0.92	0.36	B	111
C-35	89/02/01	219.1	4.78	300	43.0	42.7	carbonate	#7	F-F	-	699	1551	560	0.80	0.36	B	108
C-37	89/02/15	219.1	8.18	350	35.9	28.7	carbonate	#6	F-F	-	548	2204	560	1.02	0.25	B	102
C-40	86/03/17	273.1	6.35	350	43.0	46.5	carbonate	#7	F-F	-	1127	2869	1050	0.93	0.37	C	106
C-41	85/10/30	273.1	6.35	350	43.0	50.7	carbonate	#7	F-F	-	1127	2869	1050	0.93	0.37	C	76
C-42	87/01/12	273.1	6.35	350	49.3	55.4	carb. + fly ash	#11	F-F	-	1286	3026	1050	0.82	0.35	C	90
C-44	84/11/15	273.1	6.35	350	33.0	38.7	carbonate	#5	F-F	-	872	2616	715	0.82	0.27	B	178
C-45	84/12/19	273.1	6.35	350	35.9	38.2	carbonate	#6	F-F	-	947	2689	712	0.75	0.26	C	144
C-46	86/12/02	273.1	6.35	350	90.5	82.2	carb. + sil. fume	#10	F-F	-	2291	4023	1050	0.46	0.26	C	48
C-50	89/04/05	323.9	6.35	300	43.0	42.4	carbonate	#7	F-F	-	1639	3513	820	0.50	0.23	C	234
C-51	86/03/27	323.9	6.35	300	43.0	47.5	carbonate	#7	F-F	-	1639	3513	1180	0.72	0.34	C	114
C-53	86/06/18	355.6	6.35	300	40.8	42.4	carbonate	#8	F-F	-	1900	4017	1335	0.70	0.33	C	149
C-55	89/04/24	355.6	12.70	300	40.8	40.7	carbonate	#8	F-F	-	1758	5857	965	0.55	0.16	C	274
C-57	86/09/03	406.4	6.35	300	40.8	44.0	carbonate	#8	F-F	-	2516	5029	1400	0.56	0.28	C	294
C-59	86/10/01	406.4	12.70	300	33.0	37.4	carbonate	#5	F-F	-	1907	6786	1900	1.00	0.28	C	125
C-60	86/10/31	406.4	12.70	300	43.0	45.1	carbonate	#7	F-F	-	2480	7356	1900	0.77	0.26	C	152

Table 1 (cont'd). Summary of test parameters and results

Column No.	Test Date	Width	Wall Thick.	Yield Strength	Concrete Strength		Aggregate	Pour No.	End Cond.	Ecc.	Factored Resistance		Test Load	Load Intensity		Fail. Mode	Fire Resistance
					28 d.	test d.					C'r	Crc	C	C/C'r	C/Crc		
		(mm)	(mm)	(MPa)	(MPa)	(MPa)				(mm)	(kN)	(kN)	(kN)				(min)
SQ-01	90/08/22	152.4	6.35	350	43.5	58.3	siliceous	#17	F-F	-	358	1462	376	1.05	0.26	B	66
SQ-02	90/11/16	152.4	6.35	350	40.2	46.5	carbonate	#18	F-F	-	334	1439	286	0.86	0.20	B	86
SQ-07	90/06/01	177.8	6.35	350	43.5	57.0	siliceous	#17	F-F	-	541	1866	549	1.01	0.29	B	80
SQ-17	90/07/26	254.0	6.35	350	43.5	58.3	siliceous	#17	F-F	-	1257	3220	1096	0.87	0.34	C	62
SQ-20	90/11/27	254.0	6.35	350	40.2	46.5	carbonate	#18	F-F	-	1164	3127	931	0.80	0.30	C	97
SQ-24	90/12/19	304.8	6.35	350	43.5	58.8	siliceous	#17	F-F	-	1868	4247	1130	0.60	0.27	C	131

Notes:

End conditions:

F-F = Fixed - Fixed

P-P = Pinned - Pinned

Factored Resistance:

C'r = Factored compressive resistance of concrete core as per CAN3-S16.1-M89

Crc = Factored compressive resistance of composite column as per CAN3-S16.1-M89

Failure Mode:

B = Buckling

C = Compression

Table 2. Batch quantities and properties of siliceous aggregate concrete mixes

	Pour No. 1 81/06/09 Siliceous	Pour No. 2 81/10/08 Siliceous	Pour No. 3 81/10/22 Siliceous	Pour No. 4 81/11/05 Siliceous	Pour No. 17 89/11/06 Siliceous
Cement (kg/ cu.m)	366	366	377	380	380
Coarse aggregate (kg/cu. m)					
19 - 15.9 mm (3/4 - 5/8 in.)	435	435	437	438	438
15.9 - 9.5 mm (5/8 - 3/8 in.)	435	435	437	438	438
9.5 - 4.8 mm (3/8 - 3/16 in.)	250	237	239	240	240
Total	1120	1107	1113	1116	1116
Fine aggregate (kg/cu. m)					
#10	111	112	112	113	113
#16	222	222	224	225	225
#24	85	85	85	86	86
#40	137	138	138	143	143
#70	105	104	106	106	106
Total	660	661	665	673	673
Additives (kg/cu. m)	-	-	-	-	-
Water (kg/cu. m)	190	190	193	186	167
Water/Cement ratio	0.52	0.52	0.51	0.49	0.44
Superplasticizer	-	-	-	-	Mighty 150
Retarding admixture	-	-	-	-	Mulco TCDA 727
28 day compressive strength (MPa)	26.3	23.5	24.3	28.6	43.5

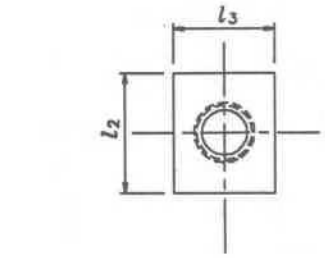
Table 3. Batch quantities and properties of carbonate aggregate concrete mixes

	Pour No. 5 84/04/18 Carbonate	Pour No. 6 84/07/18 Carbonate	Pour No. 7 85/07/04 Carbonate	Pour No. 8 85/08/01 Carbonate	Pour No. 18 89/11/28 Carbonate
Cement (kg/ cu.m)	355	439	439	439	439
Coarse aggregate (kg/cu. m)					
19 mm (3/4 in.)	-	788	788	788	788
9.5 mm (3/8 in.)	1014	340	340	340	340
Total	1014	1128	1128	1128	1128
Fine aggregate (kg/cu. m)	855	621	621	621	621
Additives (kg/cu. m)	-	-	-	-	-
Water (kg/cu. m)	173	161	161	161	161
Water/Cement ratio	0.49	0.37	0.37	0.37	0.37
Superplasticizer	-	Mighty 150	Mighty 150	Mighty 150	Mighty 150
Retarding admixture	Master Builders 100 XR	Master Builders 100 XR	Master Builders 100 XR	Master Builders 100 XR	Mulco TCDA 727
28 day compressive strength (MPa)	33.0	35.9	43.0	40.8	40.2

Table 4. Batch quantities and properties of high strength carbonate aggregate concrete mixes

	Pour No. 10 86/07/15 Carbonate	Pour No. 11 86/08/07 Carbonate
Cement (kg/ cu.m)	500*	444
Coarse aggregate (kg/cu. m)	Dolomite stone	
12.7 mm (1/2 in)	440	-
9.5 mm (3/8 in)	330	1146
6.5 mm (1/4 in)	330	-
Total	1100	1146
Fine aggregate (kg/cu. m)	700	554
Additives (kg/cu. m)	(silica fume) 30	(fly ash) 110
Water (kg/cu. m)	135	160
Water/Cement ratio	0.27	0.36
Sand moisture content	2.1%	-
Superplasticizer	Mighty 150	Mighty 150
Retarding admixture	-	Master Builders 100 XR
28 day compressive strength (MPa)	90.5	49.3

* High early strength cement Type 30



COLUMN NO.	END PLATE DIMENSIONS		
	l_1	l_2	l_3
C-02 to C-09 C-31 to C-32	19 mm	356 mm	356 mm
C-11 to C-23 C-34 to C-46 S-01 to SQ-24	25 mm	508 mm	610 mm
C-25 to C-30 C-50 to C-60	38 mm	508 mm	610 mm

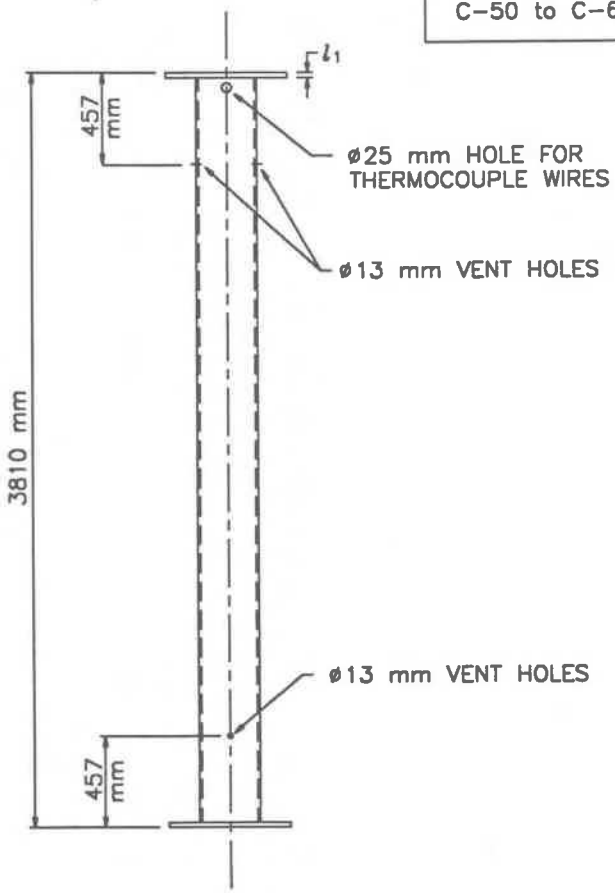


Figure 1. Column specimen details and dimensions

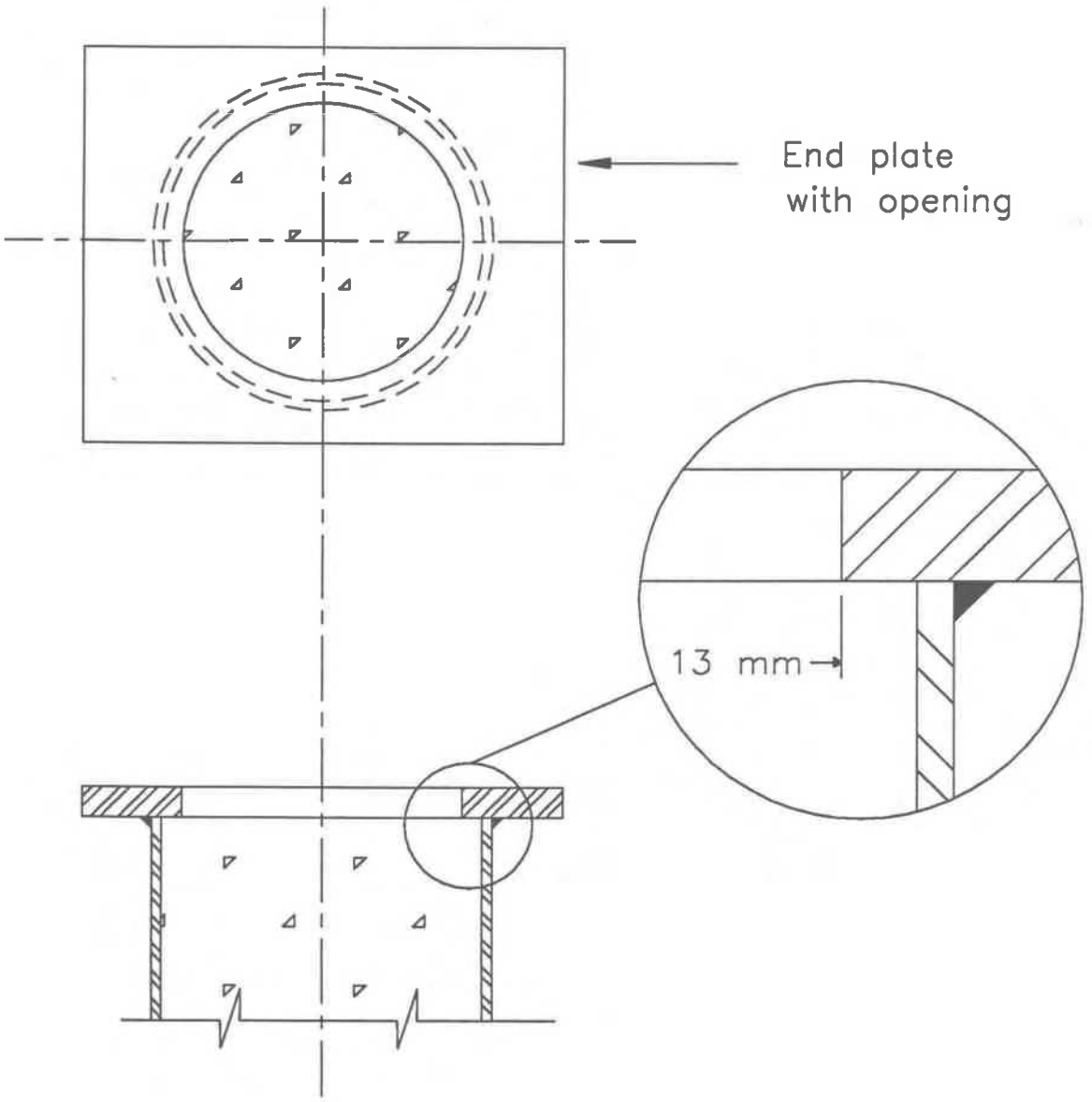


Figure 2. Welded end plate connection

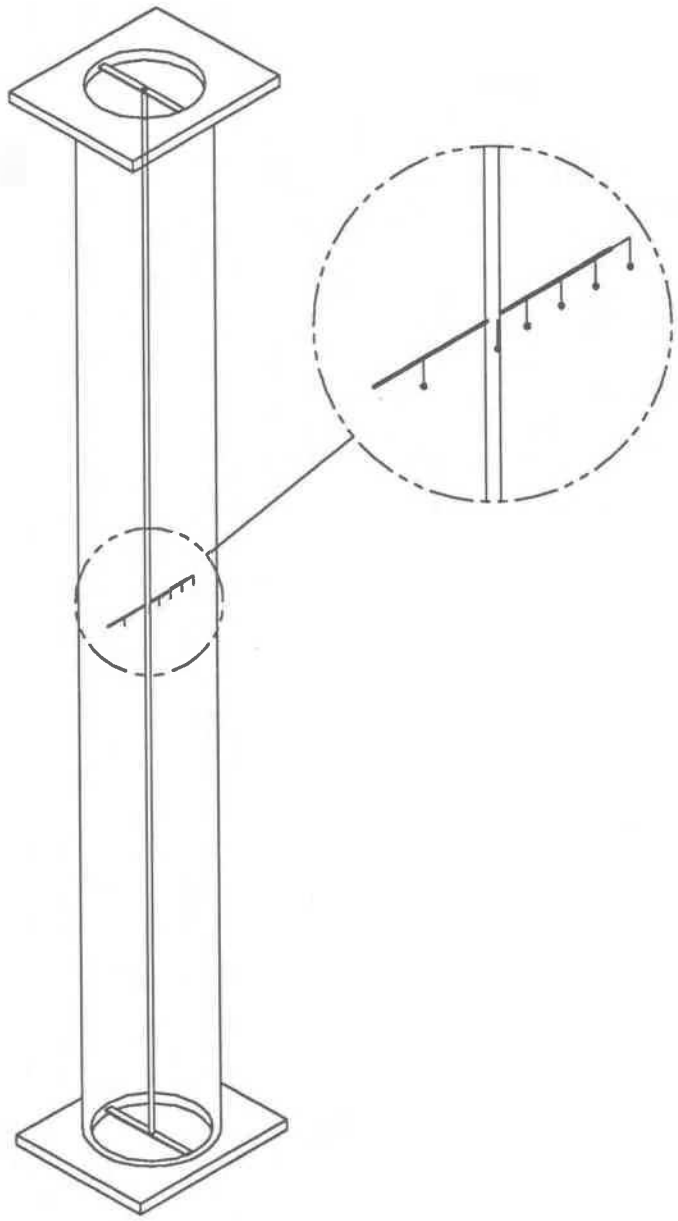
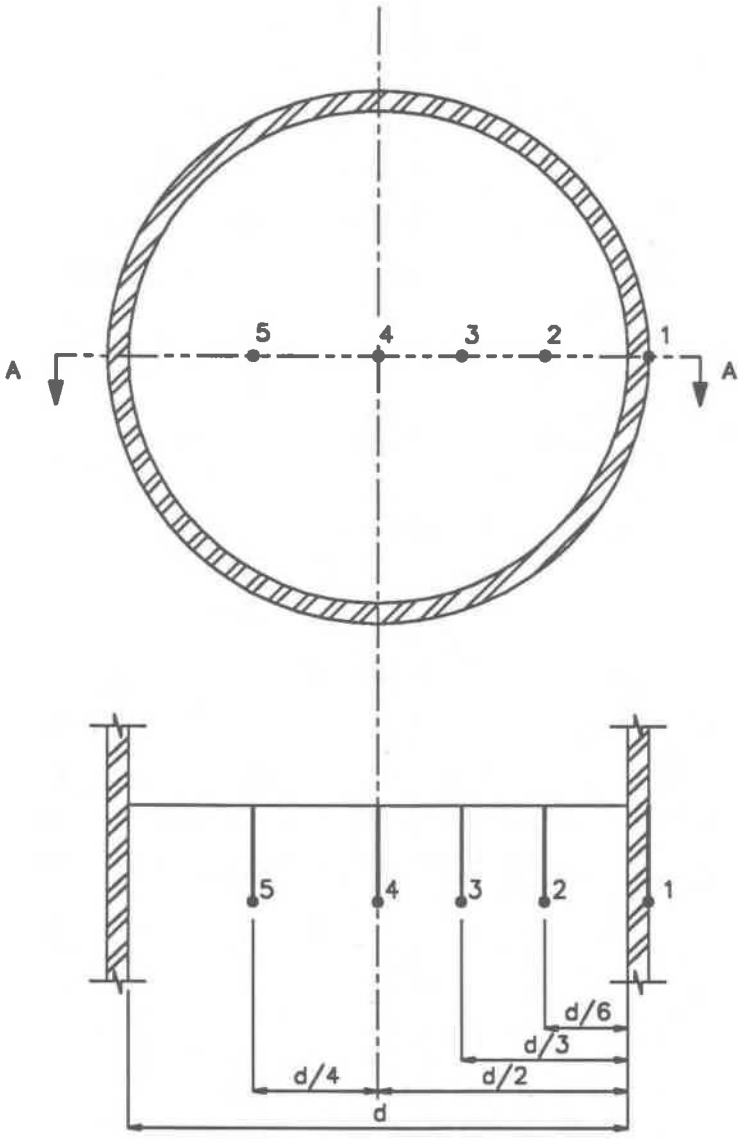


Figure 3. Layout of thermocouple frame in column



SECTION A–A

Figure 4. Locations of thermocouples in cross-section of Column Nos. C-02 to C-09 and C-31 to C-32

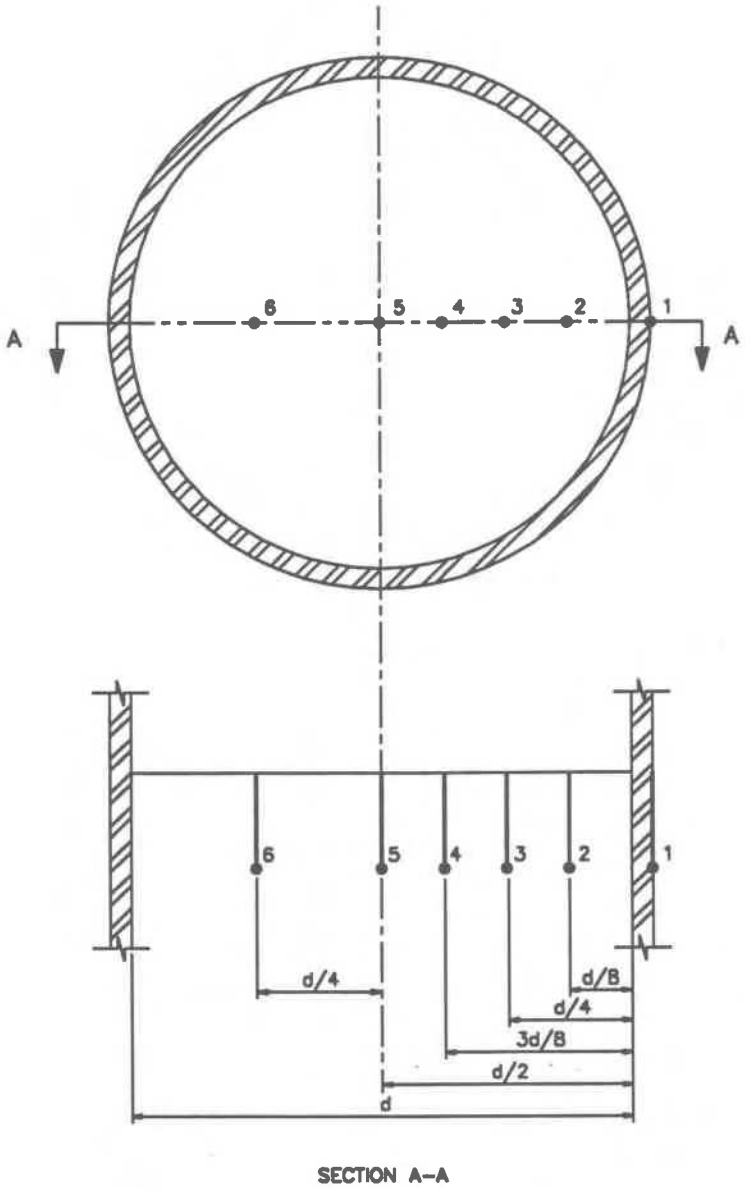


Figure 5. Locations of thermocouples in cross-section of Column Nos. C-11 to C-30 and C-34 to C-60

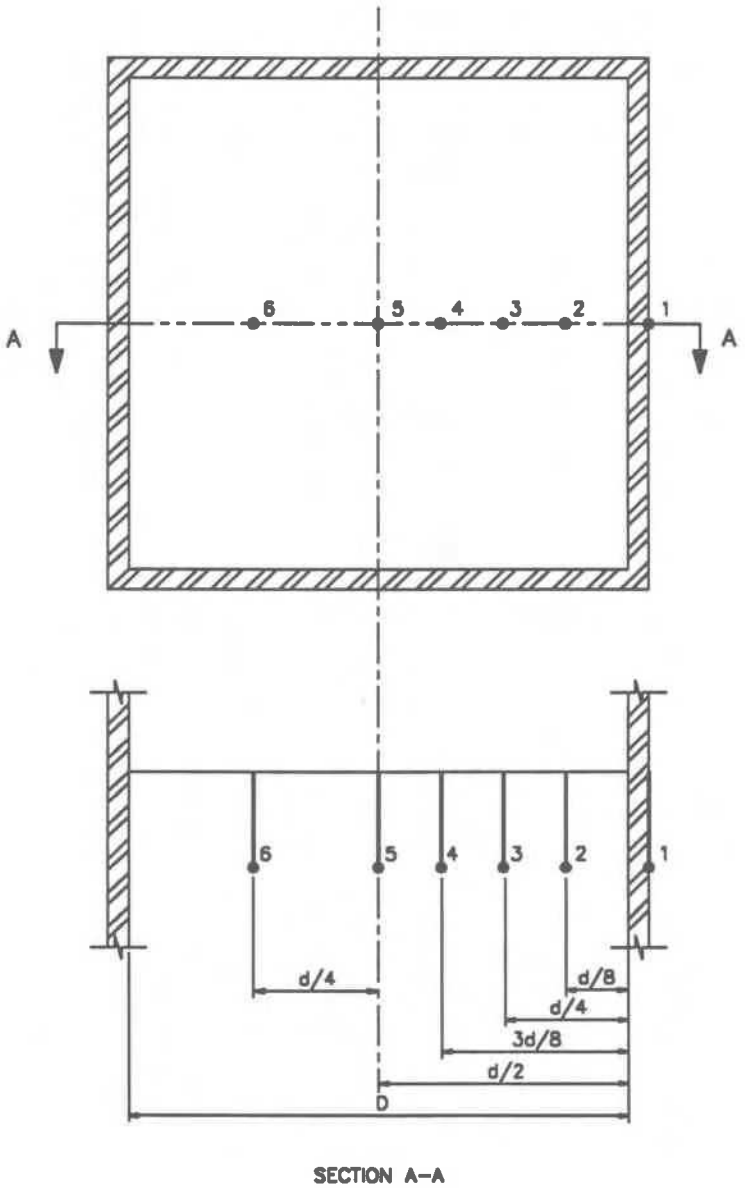


Figure 6. Locations of thermocouples in cross-section of Column Nos. SQ-01 to SQ-24

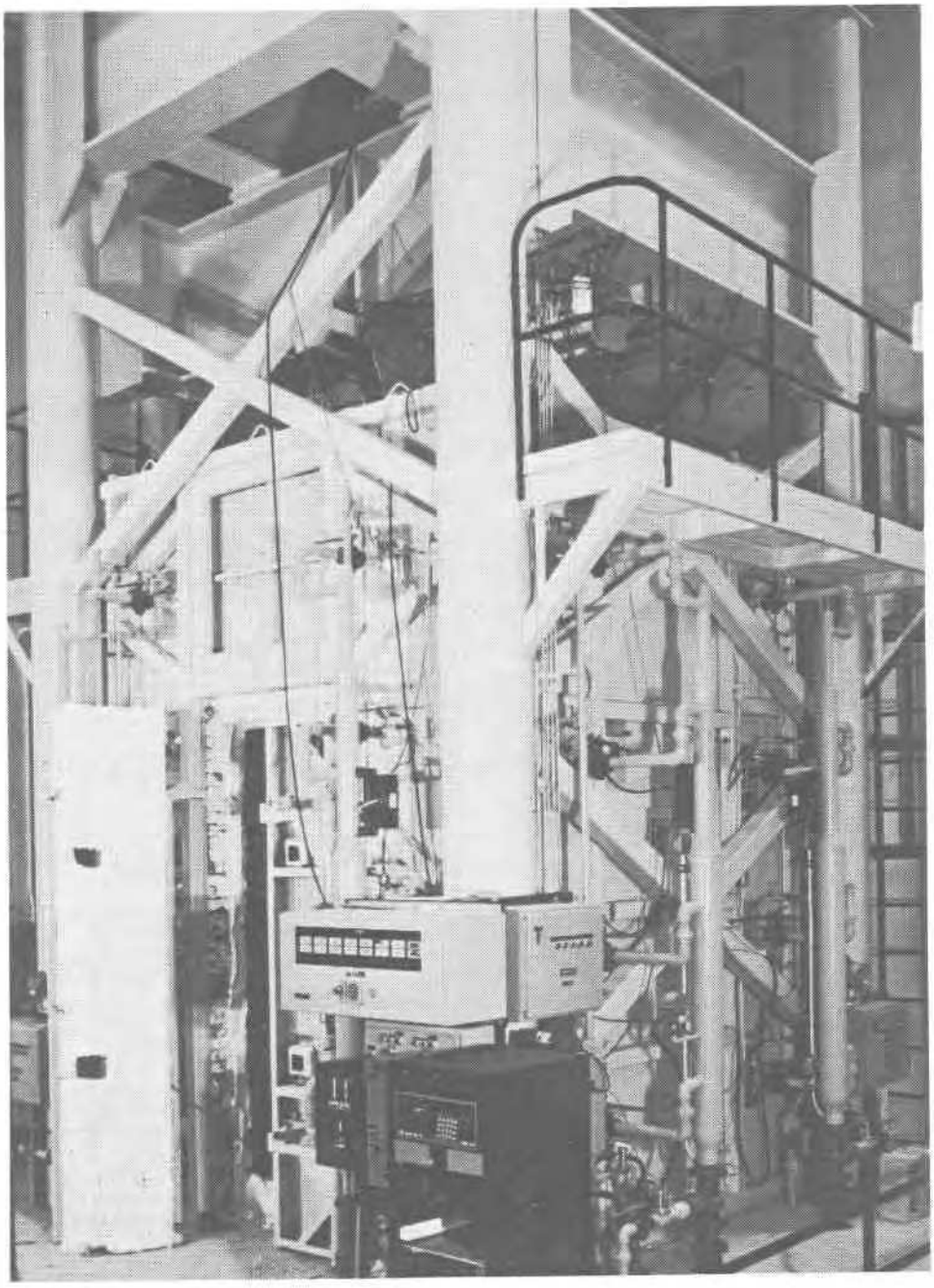


Figure 7. Column test furnace

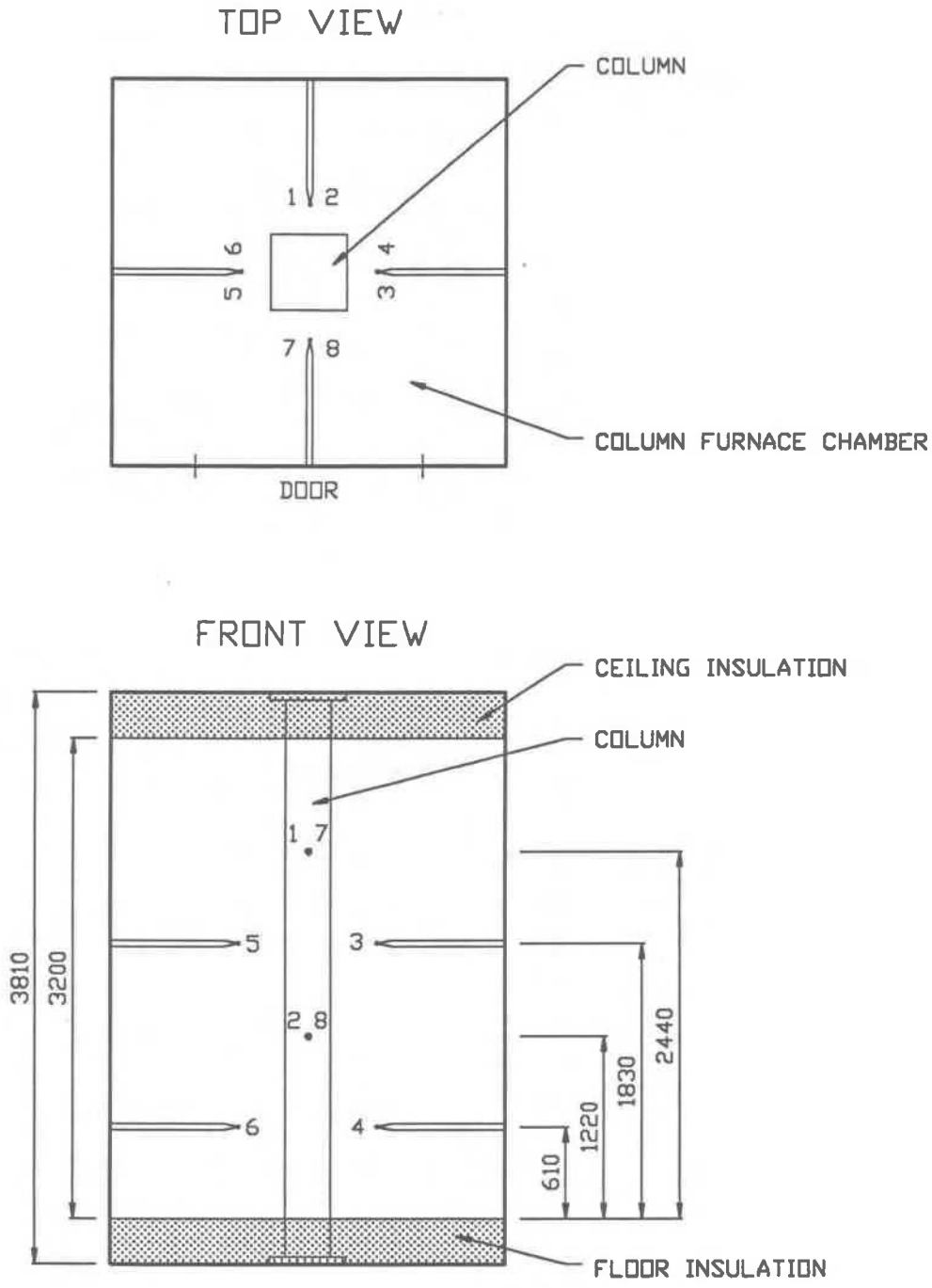


Figure 8. Locations of thermocouples in furnace chamber

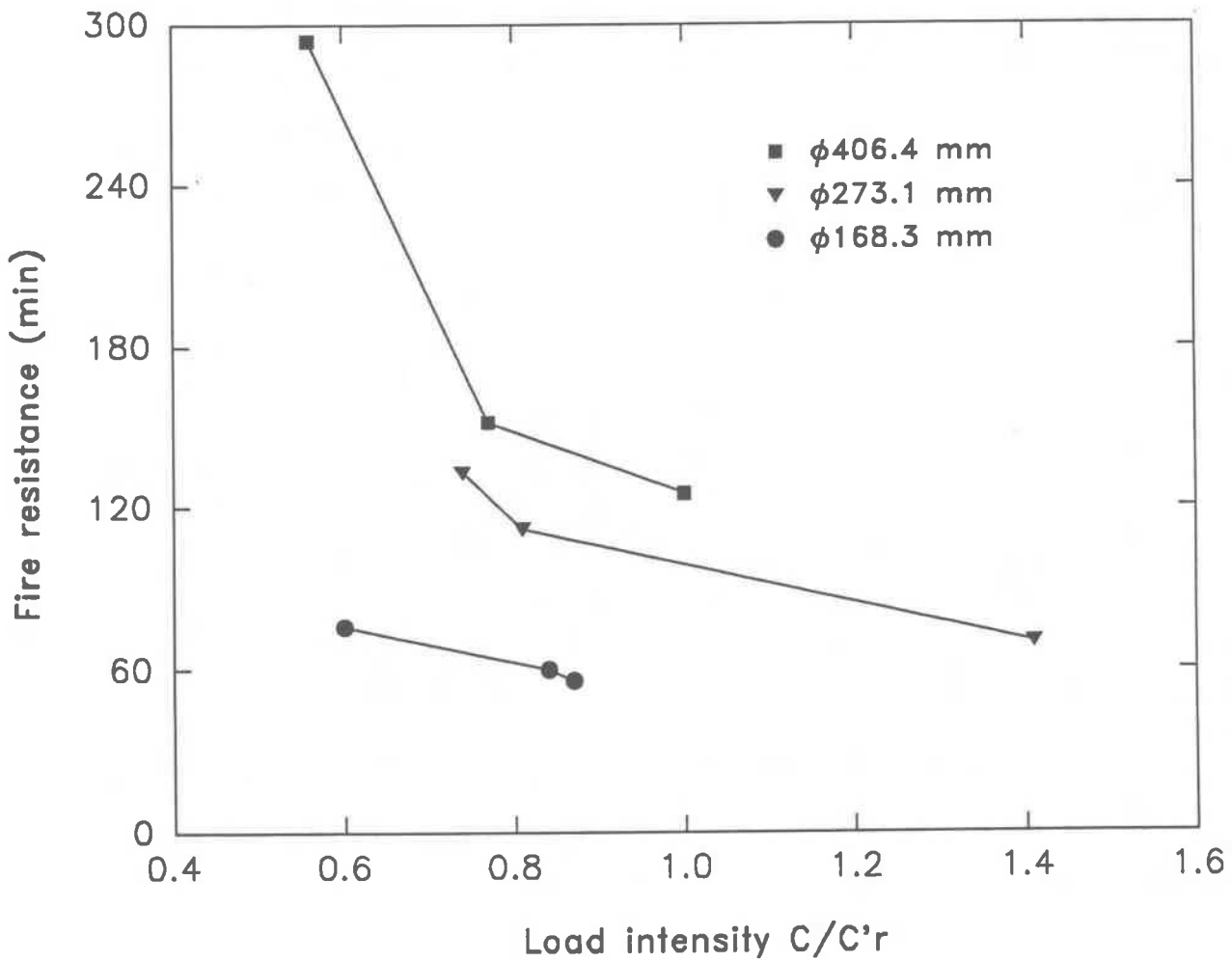


Figure 9. Influence of load intensity C/C'r on fire resistance of hollow steel columns filled with plain concrete

APPENDIX A

Table A1. Temperatures and axial deformation of Column No. C-02

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	Axial Def. (mm)
0	20	49	32	18	18	18	18	0.00
2		175	68	20	18	18	19	0.17
4		266	95	27	20	19	24	0.83
6		320	116	38	25	23	32	1.55
8		397	148	50	32	30	42	2.49
10	704	686	285	118	51	74	55	6.01
12		734	381	127	93	126	83	10.29
14		739	443	151	111	138	112	13.80
16		751	500	151	122	117	138	16.30
18		768	536	150	132	144	157	18.48
20	795	782	566	150	152	153	155	20.61
22		797	603	168	147	147	153	22.56
24		808	630	203	140	140	163	23.99
26		822	657	240	136	135	185	24.57
28		827	679	276	142	134	207	24.27
30	843	839	700	308	161	144	231	22.44
32		849	719	335	189	171	257	19.89
34		858	732	360	219	203	283	17.28
36		860	741	385	247	232	311	14.74
38		864	754	411	275	259	338	12.84
40	878	871	769	439	303	286	363	11.05
42		882	783	468	330	312	389	9.30
44		889	796	497	356	337	414	7.53
46		894	809	526	381	360	440	5.81
48		894	822	554	407	381	467	4.09
50	905	900	832	585	432	398	494	2.01
52		906	842	607	455	419	519	-1.10
54		910	852	627	477	439	543	-7.83

*** Measurements not reliable

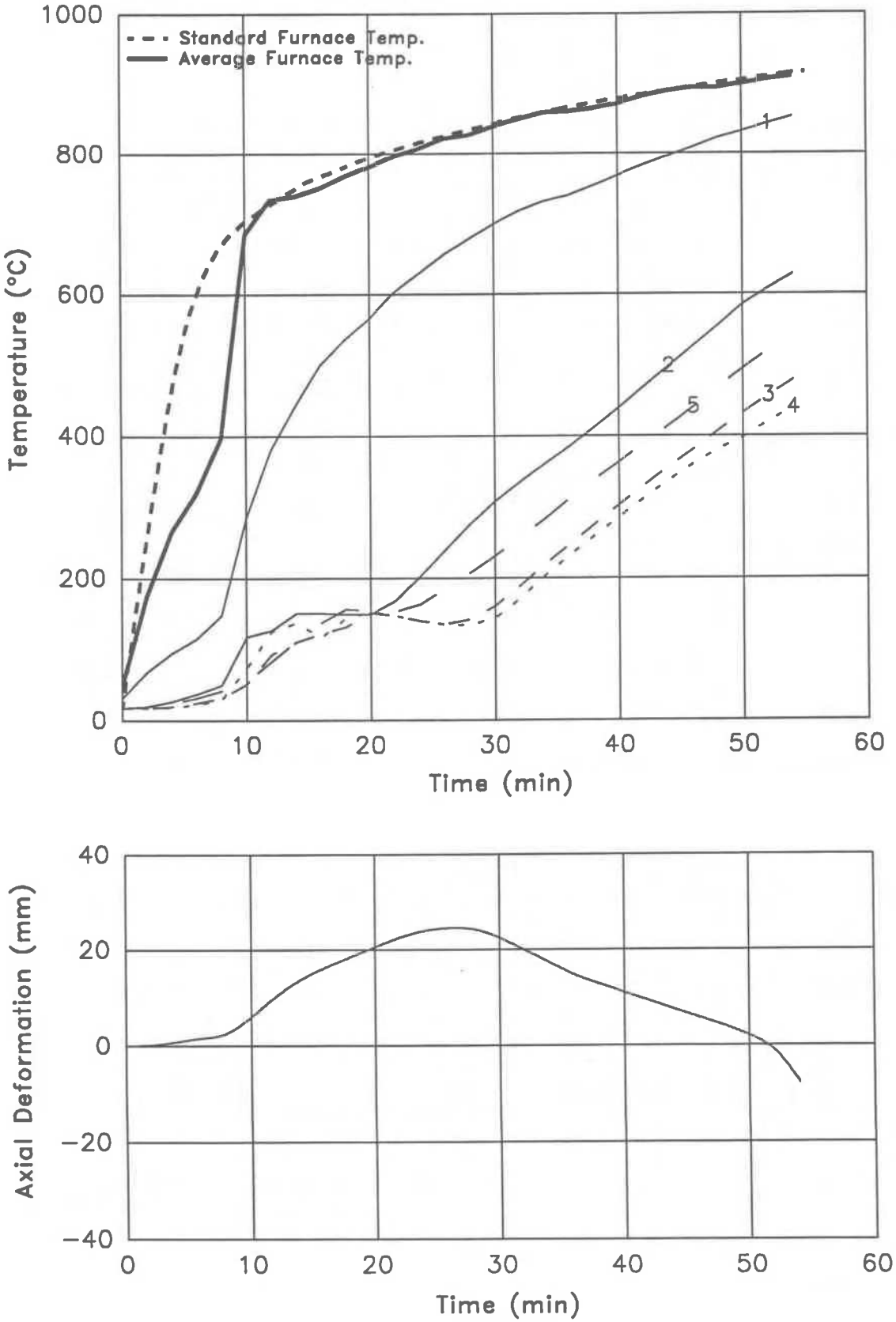


Figure A1. Temperatures and axial deformation of Column No. C-02

Table A2. Temperatures and axial deformation of Column No. C-04

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	Axial Def. (mm)
0	20	15	16	15	15	***	***	0.00
5	538	431	136	90	33	***	***	3.53
10	704	594	247	156	138	***	***	8.03
15	760	678	366	169	156	***	***	13.73
20	795	747	485	***	158	***	***	19.01
25	821	783	581	210	154	***	***	23.15
26		798	600	254	162	***	***	23.62
28		806	627	***	186	***	***	24.09
30	843	810	653	***	210	***	***	23.90
32		824	676	***	236	***	***	22.60
34		834	696	391	262	***	***	20.65
36		843	714	415	287	***	***	18.70
38		852	728	437	311	***	***	16.72
40	878	858	736	464	335	***	***	14.23
42		864	751	489	356	***	***	11.85
44		868	766	514	375	***	***	10.01
46		873	781	538	394	***	***	8.07
48		886	796	560	413	***	***	6.13
50	905	887	811	581	431	***	***	4.20
52		889	823	601	451	***	***	2.25
54		901	837	619	470	***	***	-0.40
56		898	844	636	489	***	***	-8.50

*** Measurements not reliable

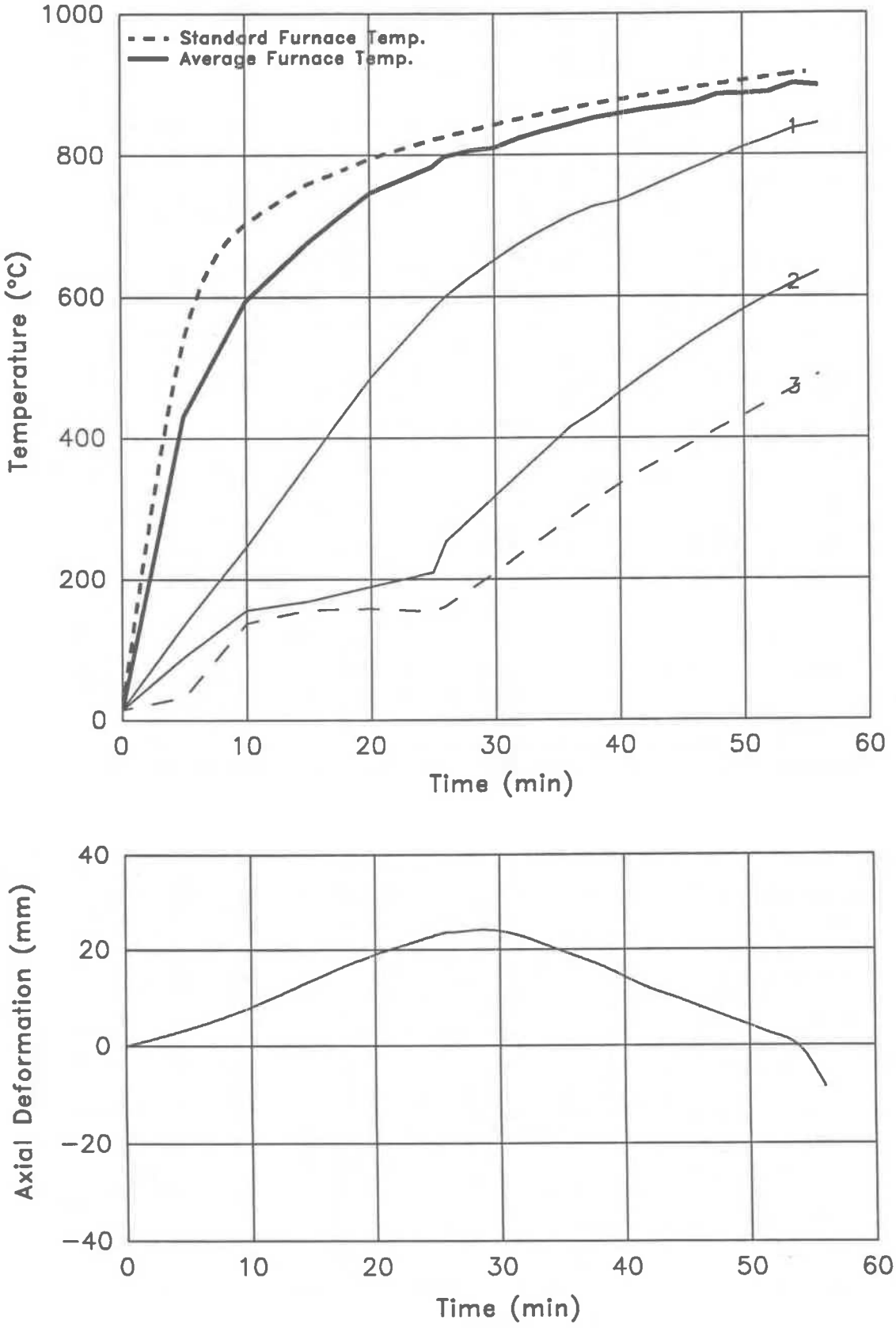


Figure A2. Temperatures and axial deformation of Column No. C-04

Table A3. Temperatures and axial deformation of Column No. C-05

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	Axial Def. (mm)
0	20	49	18	13	13	13	13	0.00
2		185	46	16	13	13	13	0.33
4		286	76	23	15	14	14	1.01
6		434	124	33	19	16	18	2.34
8		673	246	93	86	63	59	6.57
10	704	712	328	122	120	122	121	11.09
12		708	389	117	117	117	117	14.01
14		728	440	121	120	120	120	16.43
16		751	442	126	126	125	149	18.65
18		766	425	129	129	124	132	20.30
20	795	782	458	125	127	126	126	21.63
22		797	501	126	131	126	128	22.64
24		809	562	126	131	130	127	22.77
26		819	598	129	126	130	123	20.61
28		828	625	154	125	124	123	16.96
30	843	837	624	171	126	123	129	14.38
32		846	624	116	119	116	123	12.67
34		854	617	141	119	118	133	11.21
36		862	649	178	123	124	156	10.05
38		867	675	207	132	136	179	9.09
40	878	875	704	243	144	149	201	8.24
42		881	730	289	164	164	222	7.47
44		885	747	336	199	185	243	6.79
46		893	771	376	230	211	263	6.17
48		896	788	410	259	236	283	5.56
50	905	901	803	441	285	280	303	4.95
52		907	816	470	310	302	323	4.34
54		907	829	496	334	323	343	3.76
56		915	843	517	357	342	363	3.14
58		919	854	537	379	360	382	2.39
60	927	922	862	556	400	379	401	1.39
62		929	871	573	417	398	417	0.15
64		930	878	587	436	417	435	-1.40
66		932	883	600	455	434	451	-3.23
68		938	891	610	473	452	469	-5.38
70	946	941	897	617	489	471	482	-8.02
72		944	901	623	503	486	497	-11.31
74		949	908	629	517	501	511	-15.78
76		951	913	634	531	519	521	-23.88

*** Measurements not reliable

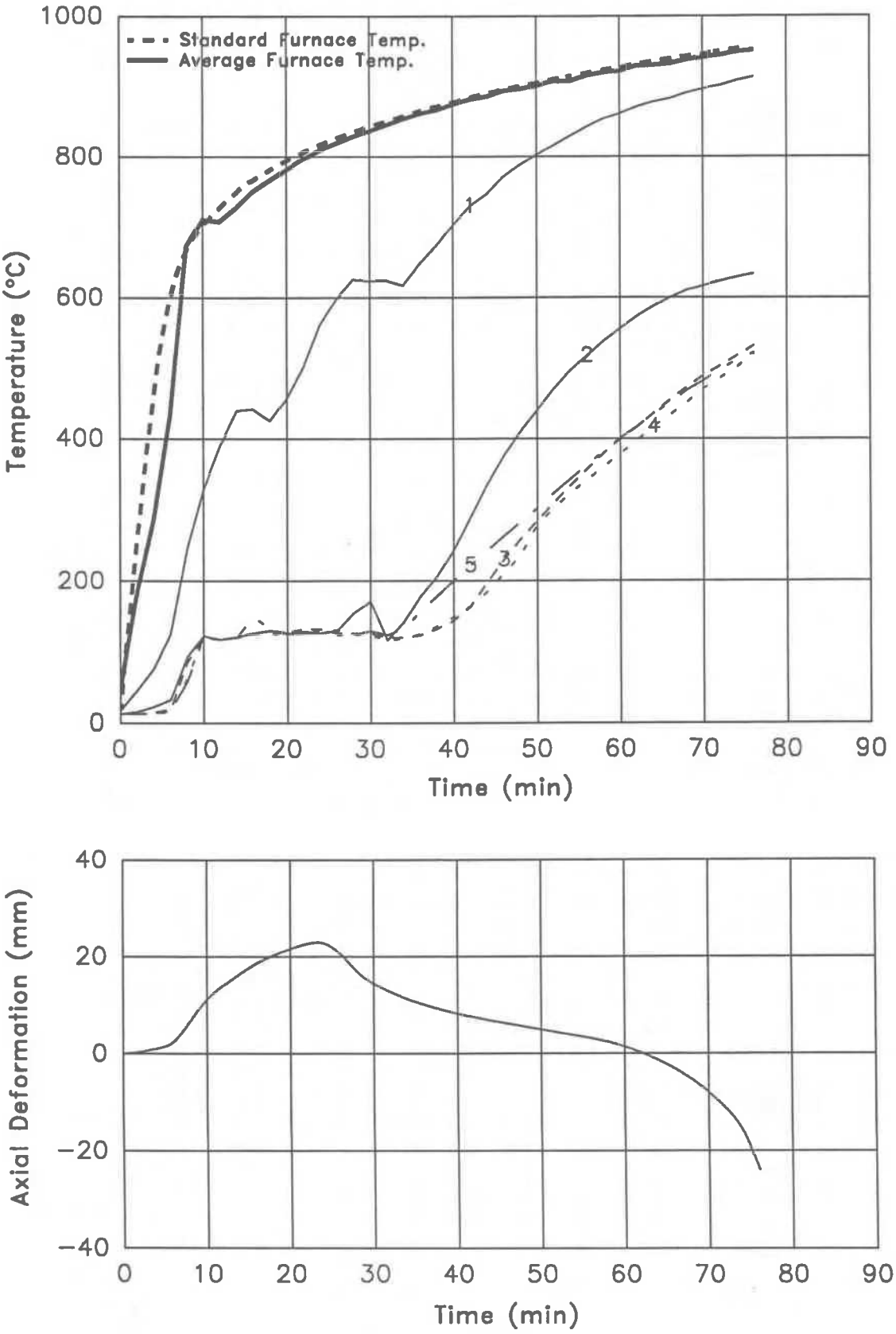


Figure A3. Temperatures and axial deformation of Column No. C-05

Table A4. Temperatures and axial deformation of Column No. C-06

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	Axial Def. (mm)
0	20	50	26	21	21	21	21	0.00
2		444	124	22	21	21	22	1.03
4		569	190	26	22	22	25	4.21
6		626	254	56	49	41	44	7.54
8		647	308	83	108	91	70	9.95
10	704	666	363	98	95	100	90	12.83
12		695	411	110	77	90	106	14.78
14		715	440	125	84	92	120	16.49
16		733	475	136	126	112	132	17.90
18		711	494	139	142	139	140	18.43
20	795	763	538	139	141	138	141	20.14
22		786	580	146	136	134	141	21.58
24		799	628	159	131	128	153	21.66
26		813	663	173	127	123	177	19.65
28		828	684	188	127	125	197	16.64
30	843	837	705	203	132	133	217	13.98
32		845	724	215	137	138	232	12.03
34		856	739	226	143	148	247	10.37
36		860	751	241	157	161	265	9.08
38		866	767	260	175	179	284	8.03
40	878	875	782	281	198	201	304	7.12
42		880	796	303	222	224	324	6.33
44		883	806	326	245	247	344	5.64
46		891	817	349	266	270	364	4.98
48		897	829	371	287	291	383	4.31
50	905	899	839	393	307	314	402	3.69
52		905	849	414	327	334	420	3.12
54		915	860	435	347	355	438	2.50
56		917	867	458	365	374	456	1.53
58		919	878	480	382	393	473	0.13

*** Measurements not reliable

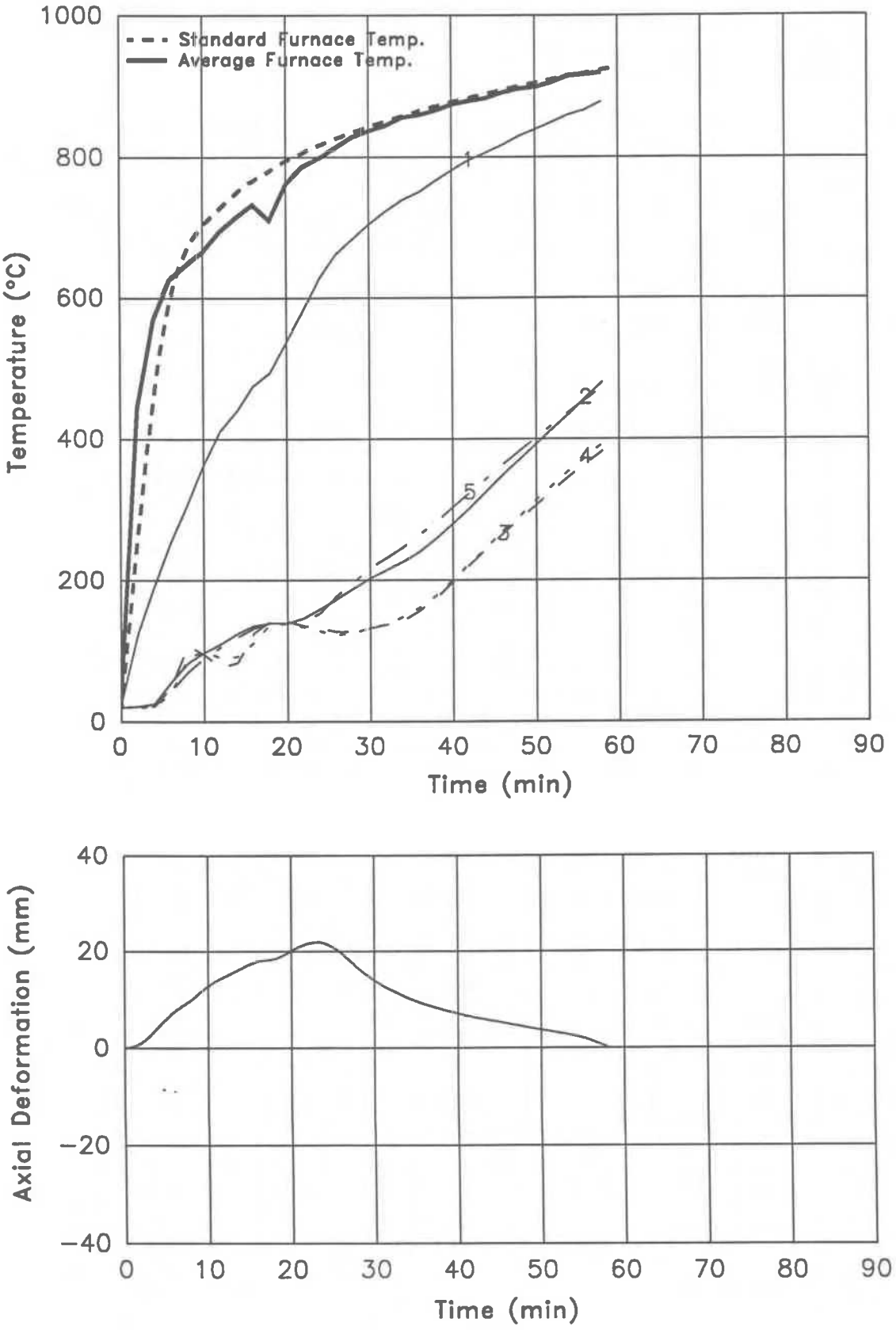


Figure A4. Temperatures and axial deformation of Column No. C-06

Table A5. Temperatures and axial deformation of Column No. C-08

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	Axial Def. (mm)
0	20	52	43	25	26	25	25	0.00
2		483	195	26	26	25	26	1.41
4		557	245	28	27	26	31	3.55
6		621	327	123	112	115	49	6.09
8		646	382	110	126	127	70	8.78
10	704	695	428	102	115	121	90	11.86
12		728	485	111	120	121	112	15.08
14		765	548	122	***	122	123	18.10
16		784	581	124	***	124	125	20.13
18		790	627	120	***	120	121	20.48
20	795	801	659	118	***	118	118	19.80
22		815	683	115	116	116	125	15.26
24		825	696	119	118	120	145	11.93
26		833	708	124	123	124	165	10.01
28		840	719	127	125	125	181	8.55
30	843	848	735	129	124	124	197	7.37
32		856	750	135	124	123	213	6.31
34		862	762	148	129	125	230	5.45
36		871	777	169	141	133	250	4.61
38		884	796	195	160	145	269	3.72
40	878	878	807	221	184	164	290	2.23
42		884	818	246	208	189	312	1.74
44		888	827	270	232	214	333	0.76
46		893	836	293	255	237	354	0.42
48		904	851	316	277	258	374	-1.45
50	905	913	867	339	298	278	395	-3.28
52		905	867	360	319	298	414	-5.09
54		911	876	381	339	317	434	-8.78
56		917	896	401	358	336	453	-39.29

*** Measurements not reliable

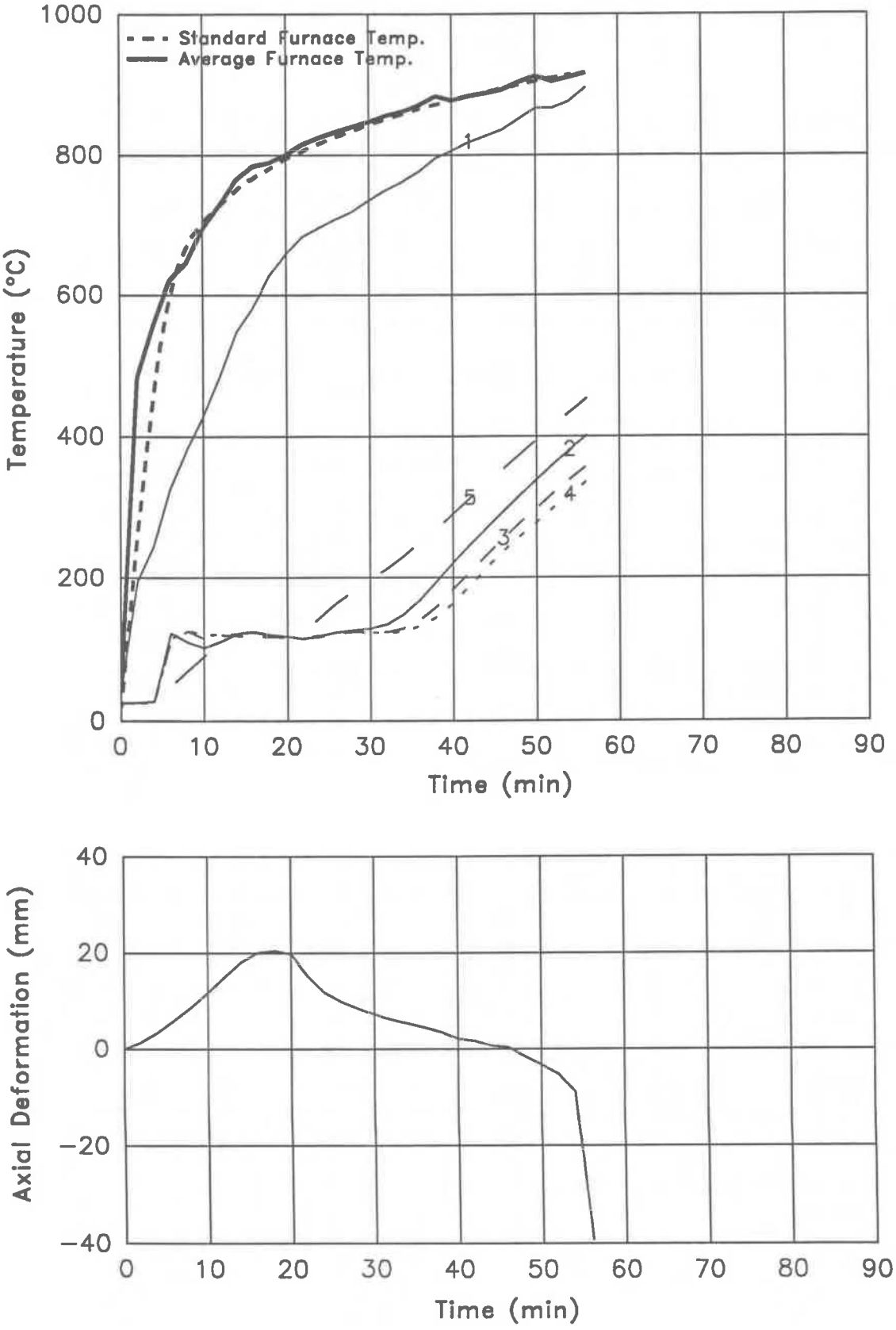


Figure A5. Temperatures and axial deformation of Column No. C-08

Table A6. Temperatures and axial deformation of Column No. C-09

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	Axial Def. (mm)
0	20	49	27	20	20	20	20	0.00
2		232	69	22	21	20	20	0.25
4		518	150	28	24	21	23	1.78
6		656	241	42	31	25	29	5.62
8		645	290	61	44	32	40	8.10
10	704	681	346	84	61	44	54	10.49
12		704	388	118	94	59	70	12.90
14		728	434	136	133	76	88	15.30
16		749	476	145	137	131	110	17.37
18		765	515	158	139	141	135	19.21
20	795	780	555	172	141	139	143	21.08
22		796	594	189	146	132	136	22.77
24		808	627	209	154	127	135	24.17
26		818	655	232	167	128	141	25.17
28		832	678	255	184	135	149	25.70
30	843	844	701	280	202	148	165	25.77
32		840	715	305	224	165	185	25.75
34		853	730	329	248	182	206	25.41
36		862	743	354	272	201	229	24.69
38		870	750	378	296	222	250	23.04
40	878	879	760	402	319	240	288	20.63
42		875	771	427	342	262	311	18.14
44		887	784	450	365	284	335	16.32
46		894	797	474	387	305	357	14.62
48		889	805	496	408	327	379	13.04
50	905	902	815	518	429	348	400	11.71
52		910	826	539	451	369	420	10.37
54		904	834	559	473	390	441	8.96
56		916	844	577	492	409	461	7.76
58		923	856	593	511	428	481	6.59
60	927	920	862	611	527	447	501	5.38
62		931	873	630	546	471	519	4.30
64		926	878	648	564	491	537	3.00
66		934	884	665	580	508	553	1.54
68		943	894	681	594	526	569	-0.11
70	946	936	897	698	609	542	584	-2.16
72		947	905	713	629	557	597	-4.45
74		944	910	728	648	571	613	-7.29
76		951	914	741	666	585	631	-10.73
78		958	922	754	681	593	649	-15.20
80	963	950	923	767	697	612	666	-21.79

*** Measurements not reliable

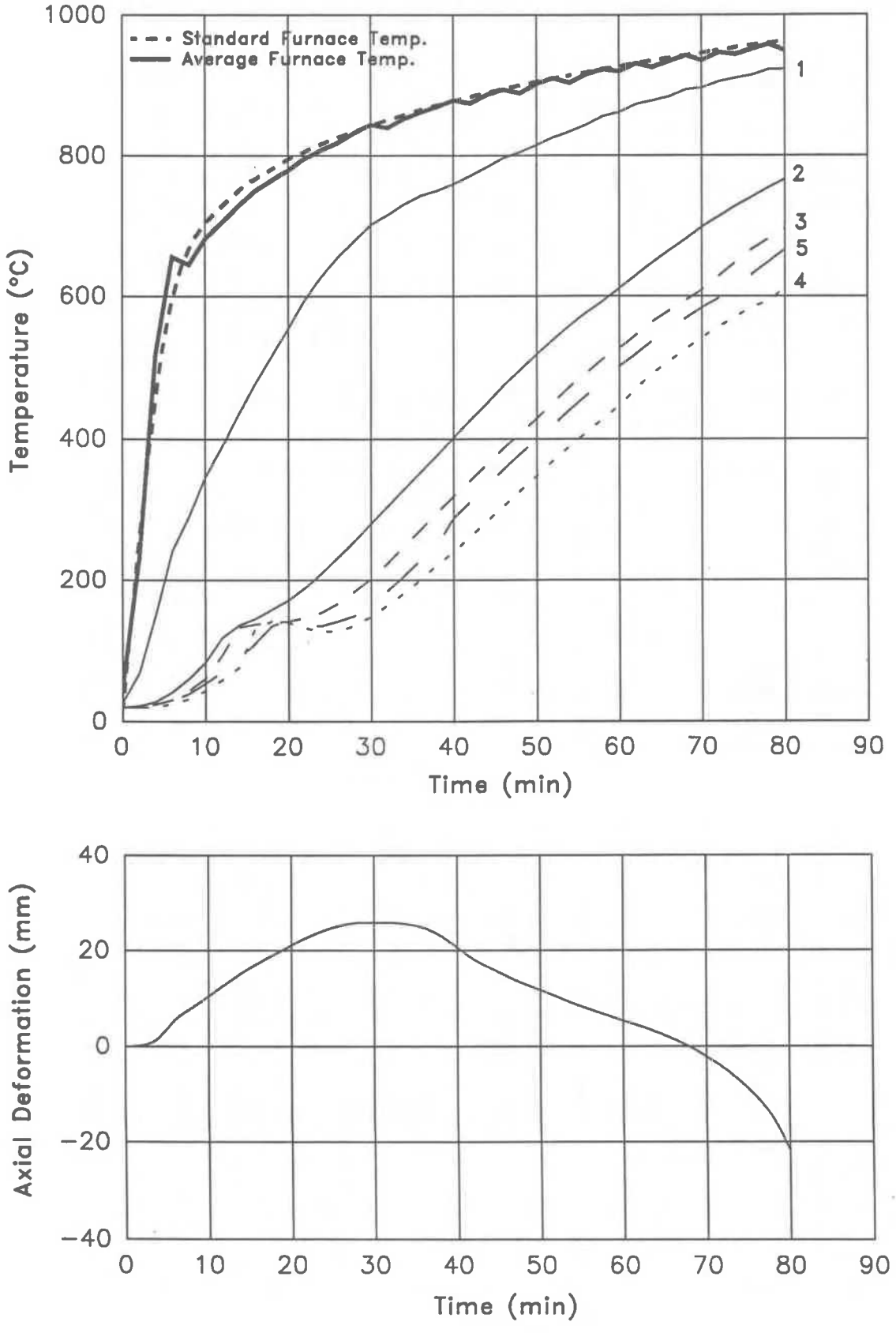


Figure A6. Temperatures and axial deformation of Column No. C-09

Table A7. Temperatures and axial deformation of Column No. C-11

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	65	40	23	22	22	22	22	0.00
2		528	179	27	23	22	22	22	1.36
4		588	250	42	26	22	22	22	4.17
6		615	301	59	37	27	30	29	6.96
8		661	356	76	53	51	68	48	9.53
10	704	686	408	92	65	60	66	57	12.03
12		708	457	114	75	65	67	64	13.99
14		726	502	129	88	71	69	69	15.97
16		752	528	133	115	95	71	74	17.51
18		774	545	133	118	116	101	83	18.13
20	795	791	572	147	122	121	120	110	17.44
22		805	606	165	123	124	125	120	11.99
24		819	611	240	125	129	129	129	9.03
26		824	628	228	128	133	134	136	7.72
28		834	655	241	132	136	136	138	6.91
30	843	845	677	258	137	136	136	139	6.21
32		849	695	270	143	137	138	136	5.59
34		859	709	281	148	135	134	134	5.02
36		866	724	296	155	132	132	132	4.66
38		870	736	312	165	130	130	130	4.11
40	878	874	744	329	177	132	130	130	3.85
42		886	760	347	193	133	133	133	3.16
44		889	777	367	208	138	136	136	2.62
46		894	793	388	224	143	137	138	2.27
48		894	802	409	242	151	141	142	1.64
50	905	898	811	428	258	158	169	145	1.27
52		904	822	448	275	168	160	152	0.84
54		912	835	468	290	177	158	161	0.43
56		918	846	488	305	187	159	174	0.17
58		922	854	506	320	198	167	189	-0.08
60	927	926	863	519	335	212	178	205	-0.74
62		915	862	536	349	225	186	219	-1.28
64		923	868	555	363	239	202	234	-1.97
66		926	872	571	378	252	216	249	-2.83
68		934	882	587	392	265	232	265	-4.12
70	946	940	889	602	406	278	246	280	-5.36
72		943	896	613	419	292	265	291	-7.14
74		943	899	625	433	304	280	285	-8.99
76		947	904	640	447	316	295	297	-11.82
78		950	910	***	461	328	311	309	-15.25
80	963	951	924	***	475	341	324	323	-26.06

*** Measurements not reliable

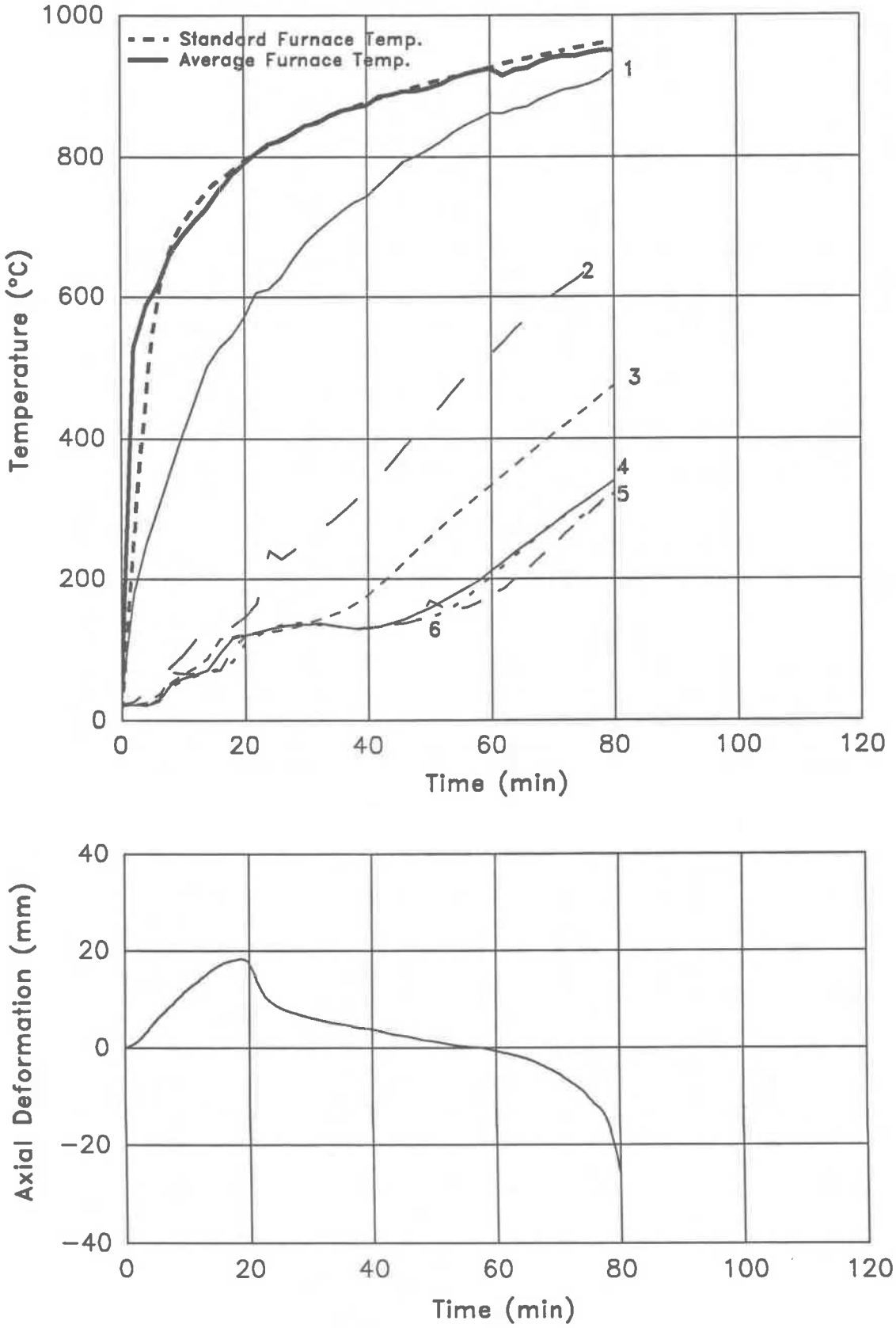


Figure A7. Temperatures and axial deformation of Column No. C-11

Table A8. Temperatures and axial deformation of Column No. C-13

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	59	32	24	23	23	23	23	0.00
5	538	568	229	48	28	24	23	26	4.40
10	704	666	378	93	58	50	96	60	10.89
15	760	739	506	114	84	66	67	76	16.65
20	795	779	573	141	119	118	117	119	18.77
25	821	815	649	185	117	116	118	115	11.55
30	843	835	690	240	138	130	132	131	8.60
35	862	857	728	284	155	136	136	136	7.17
40	878	870	757	324	176	132	131	136	6.09
45	892	889	790	373	211	142	134	156	5.22
50	905	897	816	426	249	161	138	189	4.27
55	916	908	838	478	287	189	144	226	3.52
60	927	924	861	526	325	221	170	263	3.25
65	937	935	881	567	362	254	211	299	2.52
70	946	935	888	604	398	289	250	336	1.48
75	955	948	906	639	432	322	285	370	0.05
80	963	954	917	672	468	354	318	404	-2.58
85	971	959	927	701	500	385	348	436	-5.89
90	978	970	936	724	526	414	376	466	-9.11
95	985	975	947	744	547	440	399	***	-14.72
100	991	973	954	***	575	464	420	***	-24.50
102		979	960	***	581	472	430	***	-27.91

*** Measurements not reliable

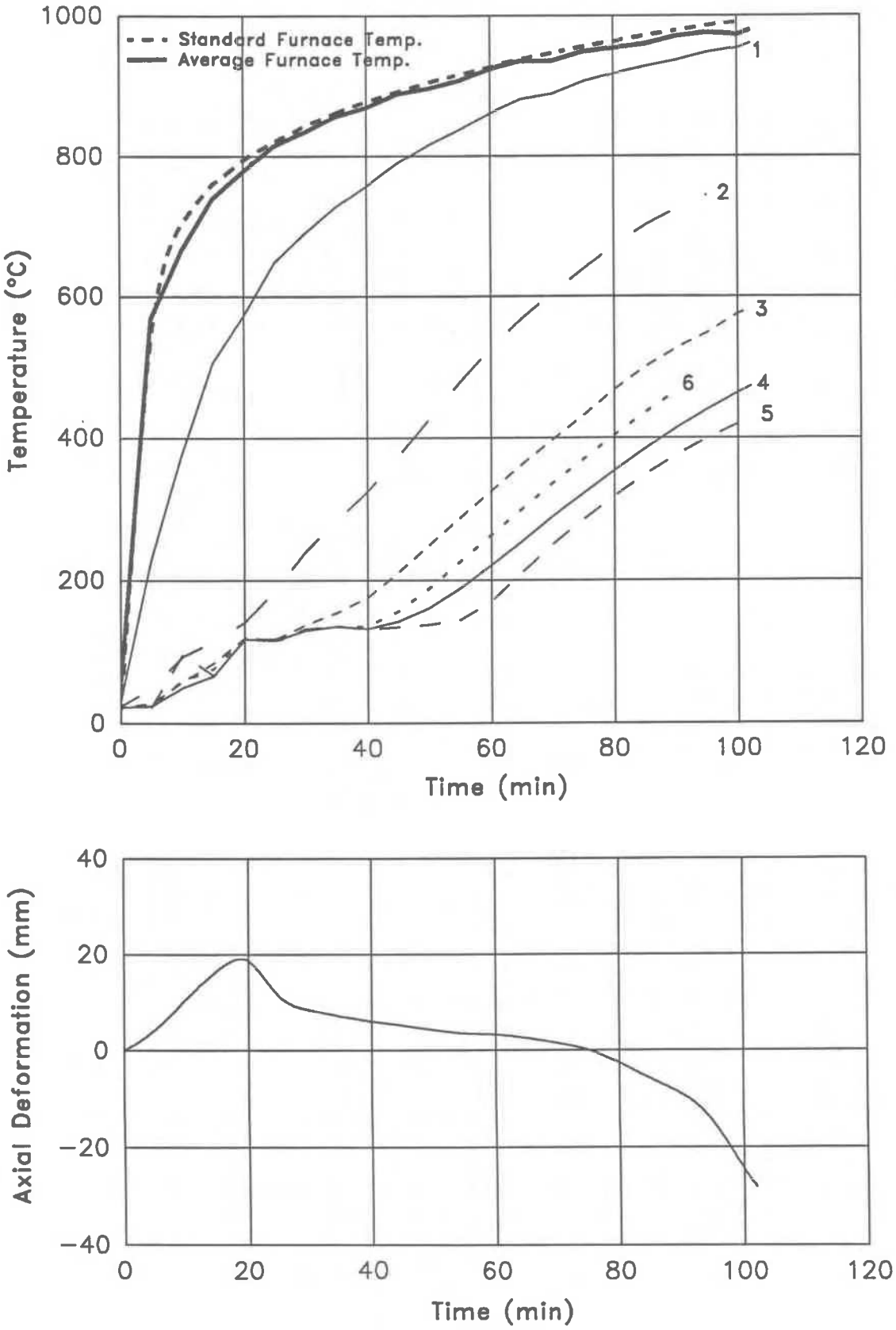


Figure A8. Temperatures and axial deformation of Column No. C-13

Table A9. Temperatures and axial deformation of Column No. C-15

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	49	15	10	9	9	9	9	0.00
2		427	76	11	9	9	9	10	0.57
4		562	134	19	11	9	9	12	2.74
6		606	182	31	14	11	10	20	5.00
8		634	234	51	25	28	67	47	7.40
10	704	681	286	70	45	53	89	58	10.11
12		707	344	86	60	63	78	76	12.57
14		739	413	98	71	68	79	111	15.13
16		757	476	110	80	72	85	112	17.30
18		769	494	116	90	74	69	116	18.80
20	795	787	481	124	106	83	92	120	19.52
22		796	489	137	120	120	124	125	19.50
24		805	508	135	119	119	120	119	17.09
26		823	554	132	116	117	116	116	12.37
28		831	591	135	118	119	118	119	9.23
30	843	840	604	142	125	126	125	128	7.57
32		847	629	146	128	129	128	131	6.30
34		861	656	148	128	129	128	130	5.36
36		868	683	152	128	128	127	131	4.44
38		868	707	160	131	131	129	136	3.68
40	878	870	726	177	138	139	137	152	3.01
42		877	739	202	146	146	145	176	2.26
44		890	753	241	153	153	151	200	1.61
46		900	774	280	160	159	156	218	0.95
48		896	792	316	168	164	161	235	0.23
50	905	900	805	349	181	167	163	249	-0.42
52		906	819	380	195	168	163	261	-1.21
54		913	834	410	212	166	162	276	-1.98
56		919	848	439	229	164	161	289	-2.67
58		917	856	465	246	161	158	304	-3.53
60	927	924	865	490	263	158	156	318	-4.49
62		930	875	512	281	162	153	333	-5.86
64		934	883	534	300	179	150	349	-7.32
66		933	888	554	319	200	152	365	-9.27
68		937	894	573	337	221	168	382	-11.67
70	946	941	900	592	355	241	193	398	-14.80
72		946	906	609	372	258	218	414	-19.40

*** Measurements not reliable

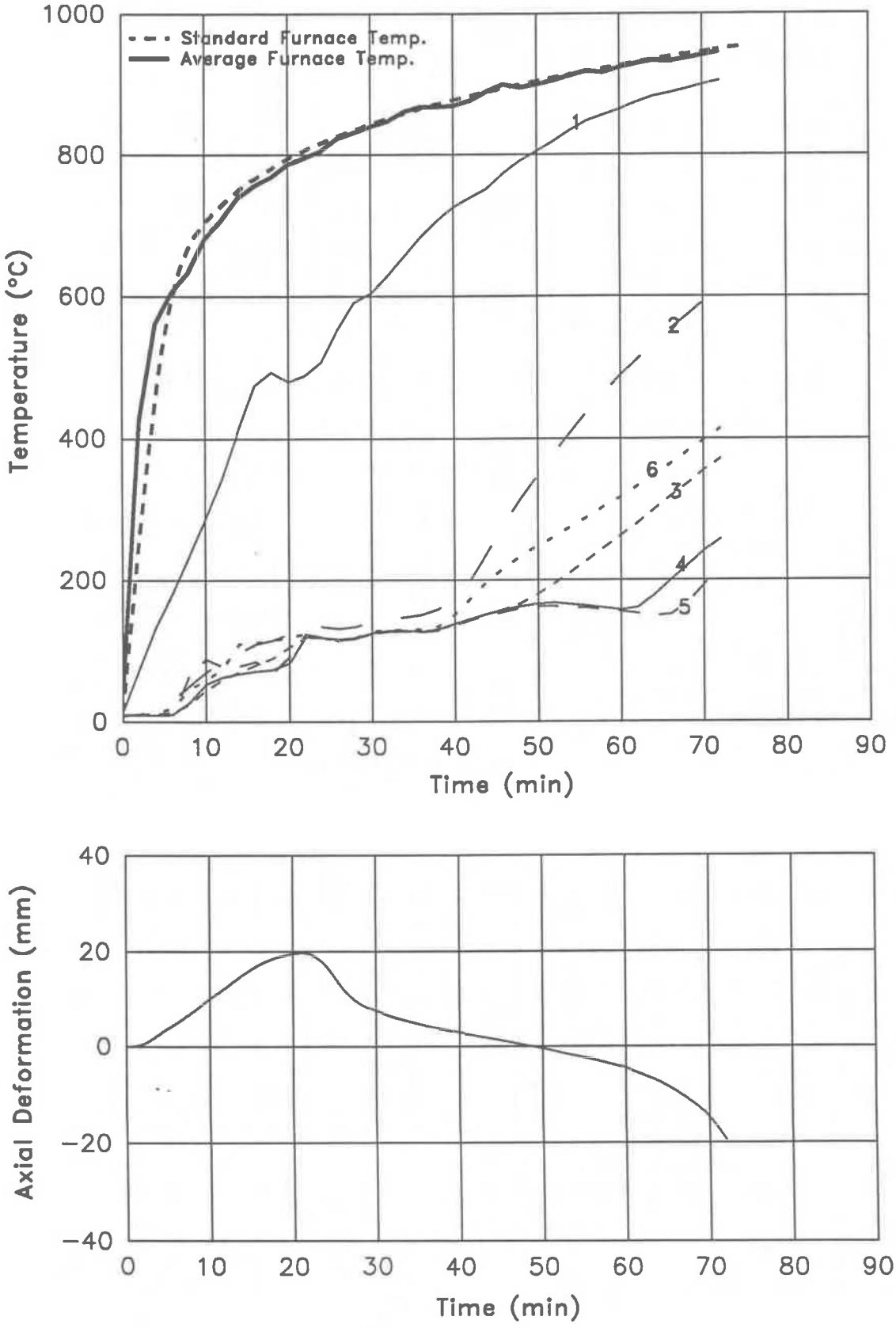


Figure A9. Temperatures and axial deformation of Column No. C-15

Table A10. Temperatures and axial deformation of Column No. C-16

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	53	26	20	19	19	19	19	0.00
2		403	85	21	20	19	19	20	0.56
4		559	164	27	21	20	19	21	3.17
6		611	226	57	24	21	20	38	5.67
8		650	284	106	46	40	71	80	8.19
10	704	678	341	113	110	111	111	113	10.75
12		703	395	112	110	110	110	112	13.23
14		726	444	111	111	111	111	111	15.42
16		751	489	113	112	112	102	112	17.38
18		770	525	115	115	115	98	115	18.59
20	795	786	556	122	117	117	116	117	18.73
22		801	572	118	118	118	117	117	7.11
24		810	596	130	114	114	114	114	1.01
26		822	630	143	113	113	112	112	-3.00
28		834	657	153	116	113	113	113	-6.72
30	843	841	683	163	120	114	114	117	-11.08
32		849	704	172	125	118	118	129	-17.90

*** Measurements not reliable

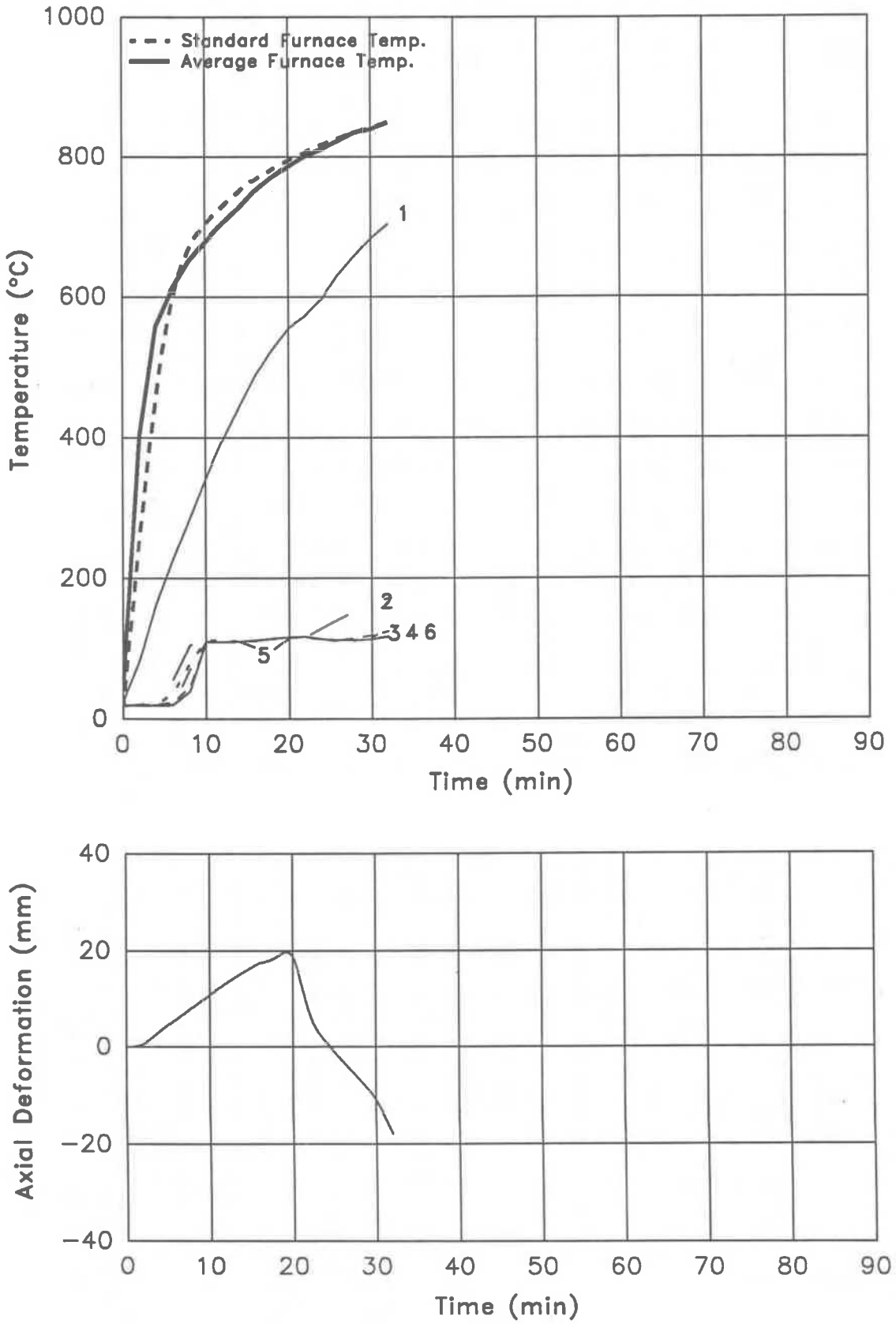


Figure A10. Temperatures and axial deformation of Column No. C-16

Table A11. Temperatures and axial deformation of Column No. C-17

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	53	25	23	23	23	23	23	0.00
5	538	583	197	39	26	23	23	25	3.55
10	704	666	314	88	81	77	109	68	9.42
15	760	728	419	117	94	93	100	83	15.20
20	795	776	442	125	123	101	84	99	19.57
25	821	807	544	128	130	123	133	134	20.36
30	843	815	666	160	129	125	128	134	8.84
35	862	815	740	184	127	123	123	127	3.62
40	878	875	768	262	141	125	125	131	1.33
42		871	770	281	149	126	126	132	1.03
44		***	778	313	166	129	129	142	0.52
46		***	785	342	186	131	130	157	0.34
48		***	797	368	206	132	132	176	0.14
50	905	901	***	393	226	135	133	197	-0.62
52		898	820	417	246	142	135	212	-1.01
54		905	***	438	264	152	137	229	-1.30
56		905	841	459	281	166	141	246	-1.99
58		913	852	478	298	182	153	262	-2.19
60	927	921	***	497	315	200	176	280	-2.80
62		925	873	514	332	218	199	297	-3.22
64		923	878	532	348	237	218	315	-4.01
66		921	881	549	365	254	236	332	-5.00
68		931	***	565	381	271	252	348	-6.06
70	946	935	896	576	***	288	268	363	-7.31
72		941	903	584	***	303	283	377	-8.90
74		943	909	591	***	319	297	391	-10.42
76		940	911	***	***	333	311	402	-12.98
78		943	915	***	***	347	328	414	-16.31
80	963	951	922	***	***	361	338	426	-20.93
82		956	934	***	***	368	350	435	-35.98

*** Measurements not reliable

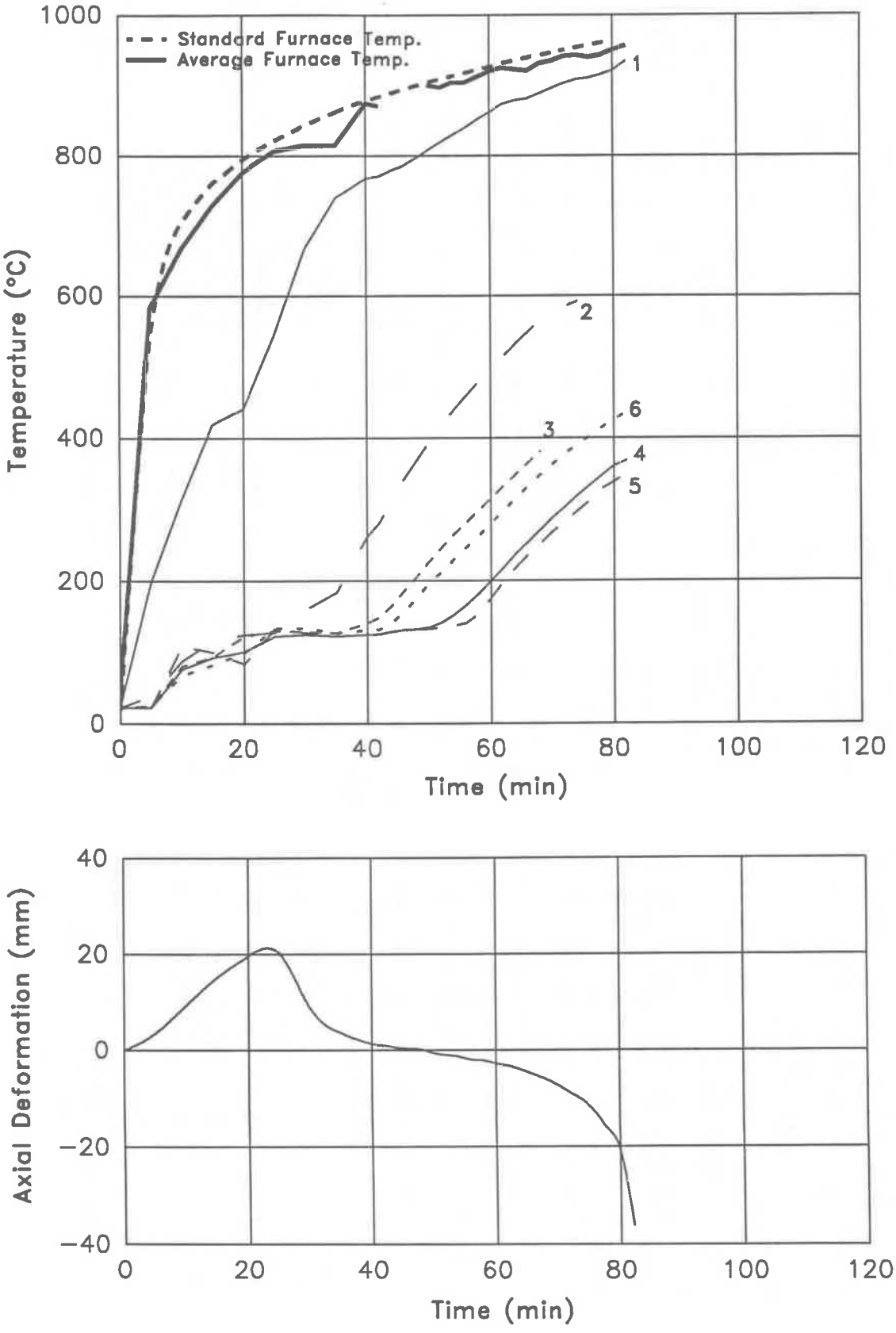
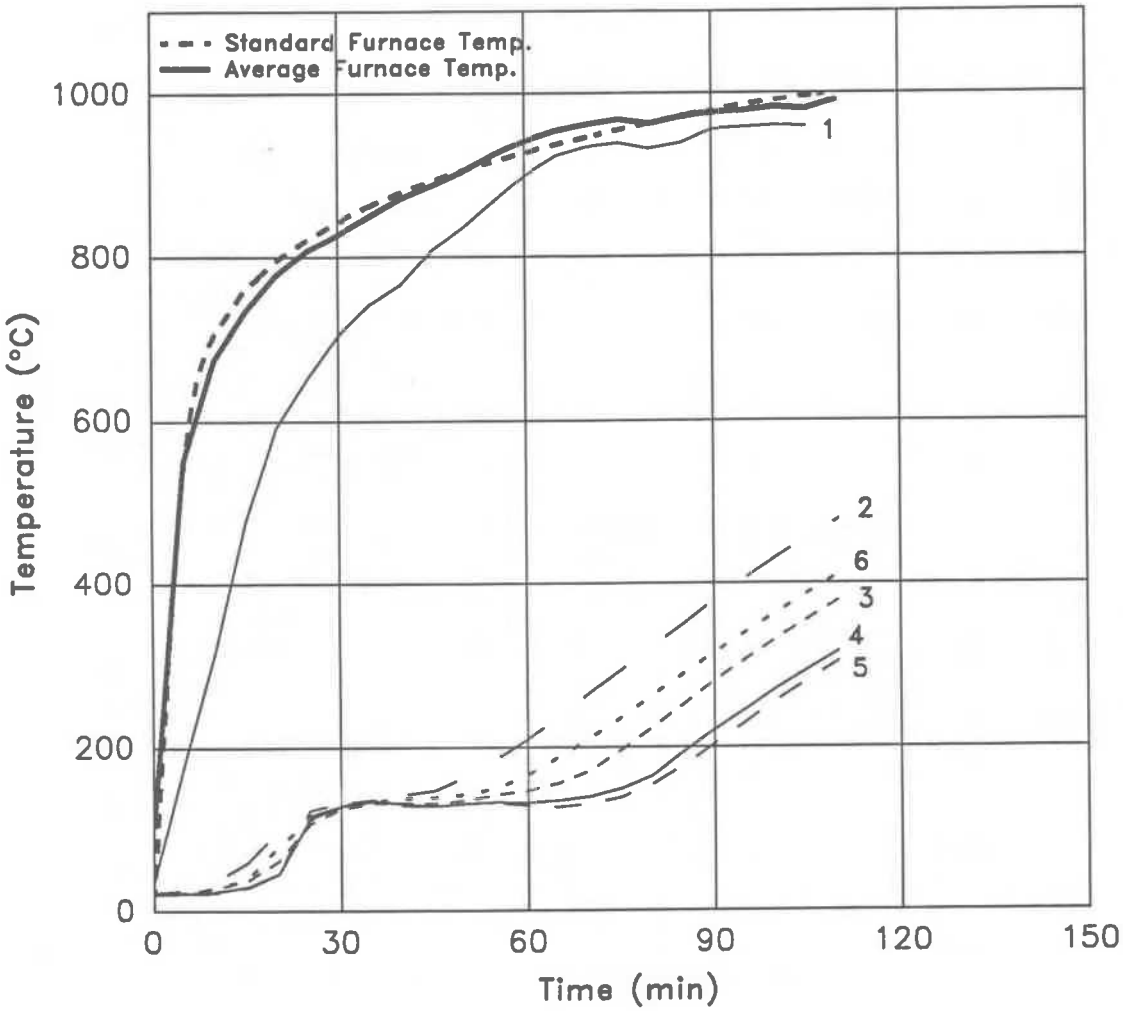


Figure A11. Temperatures and axial deformation of Column No. C-17

Table A12. Temperatures and axial deformation of Column No. C-20

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	104	36	23	22	21	21	22	0.00
5	538	551	183	26	23	22	22	23	3.67
10	704	674	317	37	28	24	23	28	10.94
15	760	733	479	60	38	30	29	40	16.87
20	795	777	593	100	62	45	45	80	19.44
25	821	808	652	117	108	114	124	113	16.08
30	843	827	704	130	126	129	133	126	10.85
35	862	849	741	139	133	135	137	135	8.49
40	878	871	765	142	133	132	130	138	6.32
45	892	887	807	147	132	129	129	139	4.75
50	905	904	835	164	136	132	132	143	3.74
55	916	925	868	186	142	134	133	150	3.08
60	927	942	899	210	147	133	130	166	2.41
65	937	954	923	236	156	135	127	188	1.36
70	946	962	934	265	171	140	131	211	0.12
75	955	968	939	293	197	149	139	236	-1.33
80	963	963	932	322	223	165	155	262	-3.09
85	971	971	939	350	252	194	177	289	-5.15
90	978	976	956	379	280	221	204	315	-7.82
95	985	978	958	406	307	246	230	340	-11.56
100	991	982	961	432	332	271	257	364	-17.27
105	996	980	959	456	356	294	281	388	-31.21
110	1001	992	***	479	379	317	304	411	***

*** Measurements not reliable



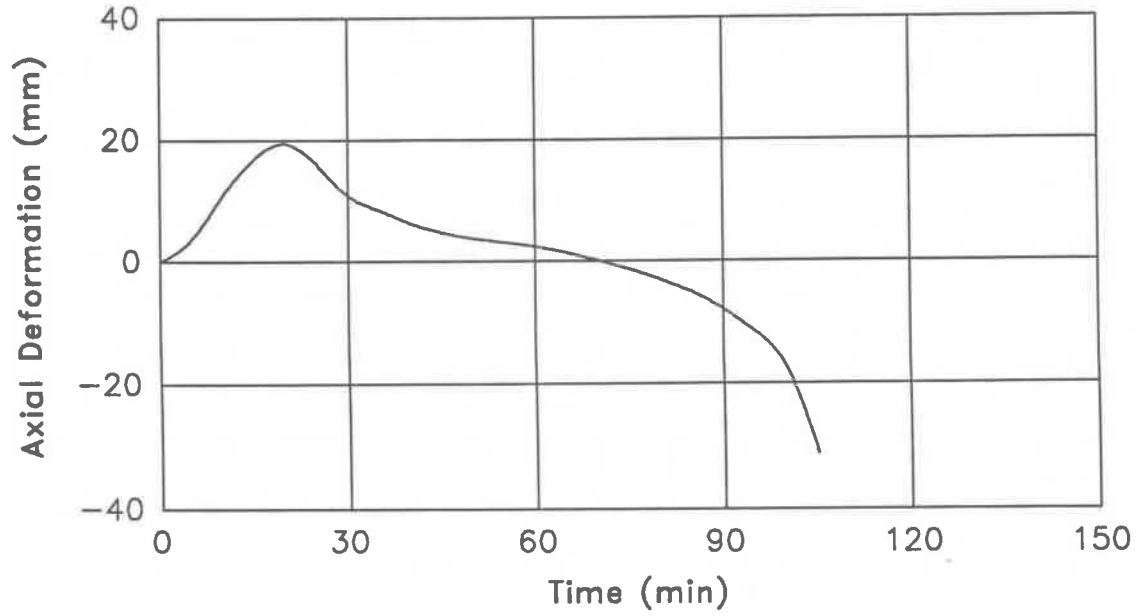
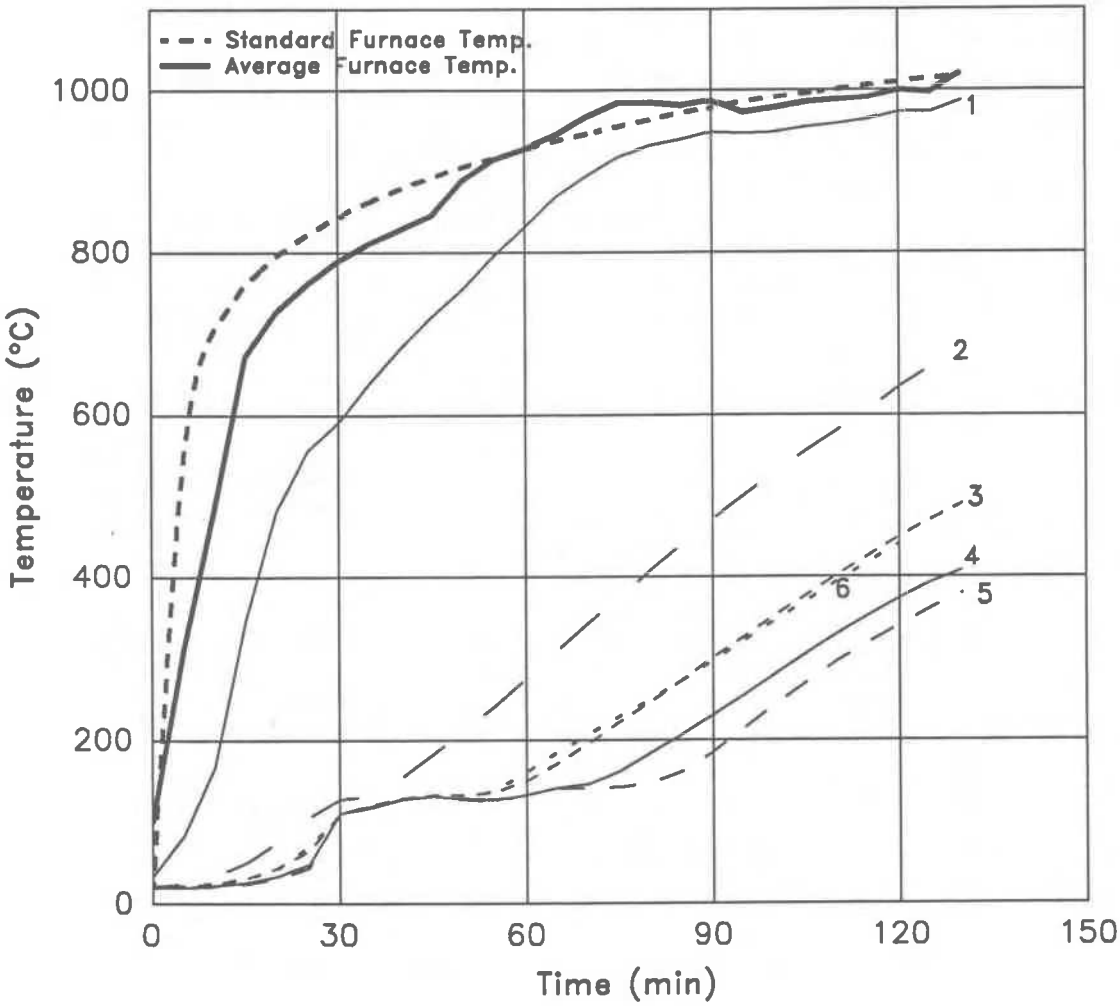


Figure A12. Temperatures and axial deformation of Column No. C-20

Table A13. Temperatures and axial deformation of Column No. C-21

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	100	33	21	20	20	20	20	0.00
5	538	311	84	24	21	20	20	22	0.58
10	704	483	167	33	24	22	21	25	3.18
15	760	672	349	50	31	26	24	31	10.81
20	795	727	481	75	43	33	30	42	16.85
25	821	761	556	106	65	48	43	70	19.94
30	843	789	591	128	110	111	113	109	20.25
35	862	812	639	132	120	118	119	119	17.26
40	878	829	682	154	129	128	129	130	12.26
45	892	846	721	182	134	132	132	133	9.47
50	905	889	755	212	134	129	128	130	7.18
55	916	915	796	242	137	127	126	139	5.31
60	927	928	832	275	150	134	134	161	4.26
65	937	945	869	310	171	142	141	185	3.59
70	946	967	894	343	196	146	141	207	2.94
75	955	984	918	376	222	162	142	229	2.07
80	963	984	931	408	247	184	147	250	0.99
85	971	981	939	440	273	207	161	273	-0.21
90	978	987	949	471	301	231	185	297	-1.59
95	985	972	947	500	327	256	215	322	-3.39
100	991	978	949	529	353	281	244	347	-5.40
105	996	985	955	555	378	307	271	371	-7.83
110	1001	988	959	580	402	331	297	395	-11.04
115	1006	991	964	606	426	353	320	418	-15.16
120	1010	1000	973	633	449	374	341	441	-19.03
125		998	972	658	470	393	362	***	-23.95
130	1017	1021	986	681	490	408	379	***	***

*** Measurements not reliable



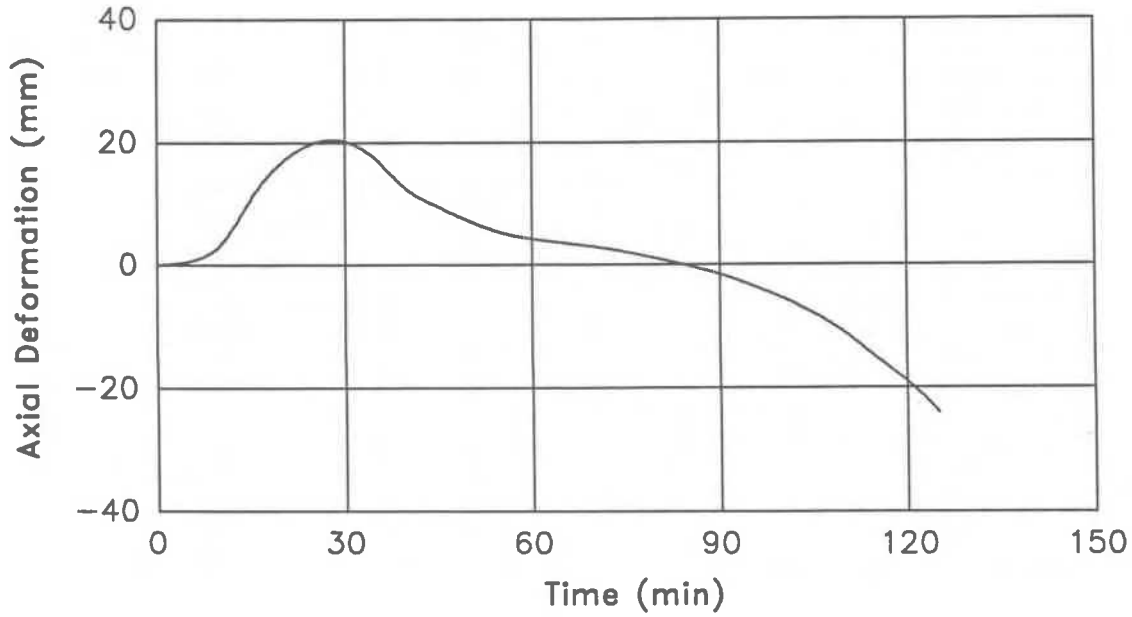
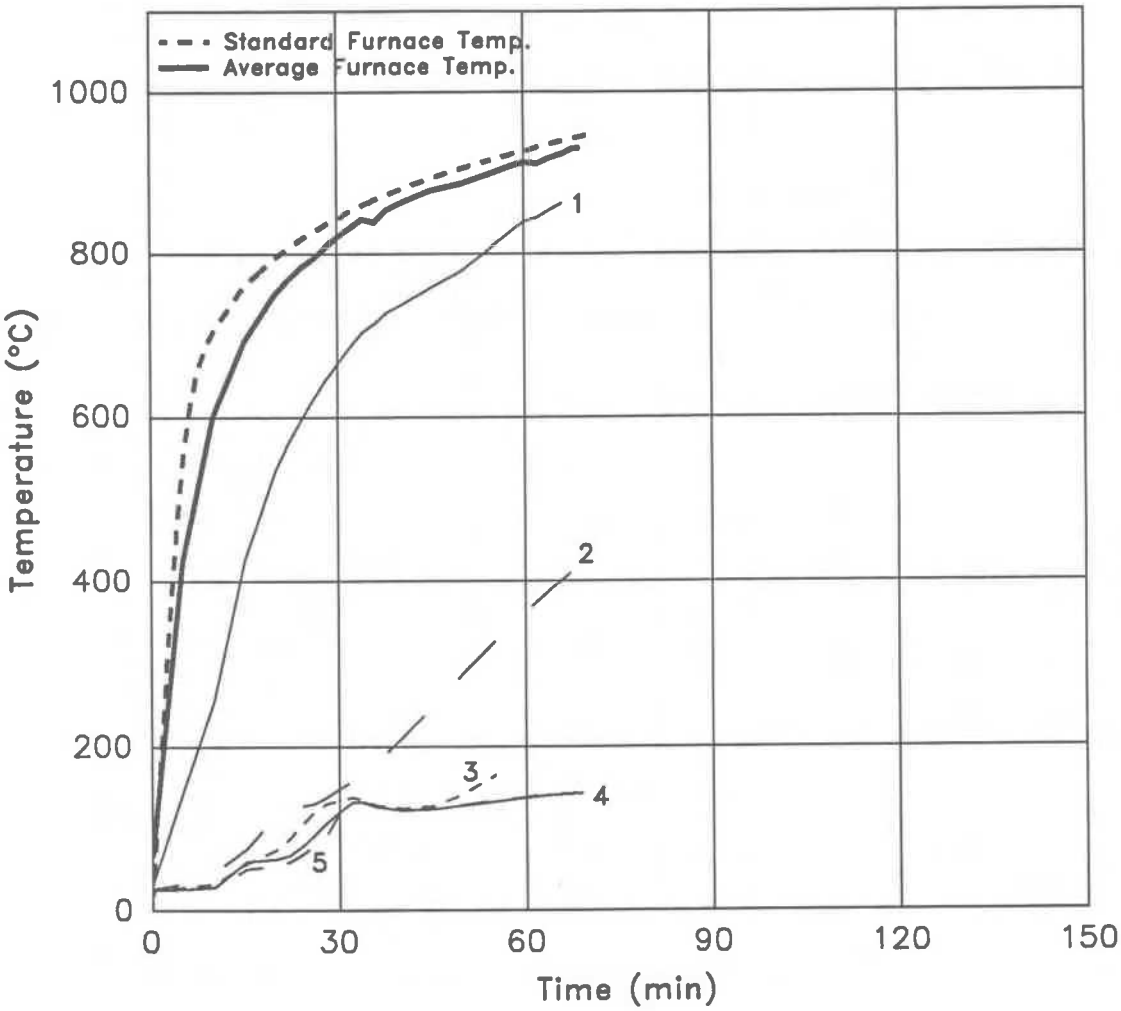


Figure A13. Temperatures and axial deformation of Column No. C-21

Table A14. Temperatures and axial deformation of Column No. C-22

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	67	32	27	27	26	26	***	0.00
5	538	426	147	33	28	27	27	***	0.64
10	704	602	257	48	33	29	28	***	2.07
15	760	693	427	76	58	60	51	***	4.57
20	795	750	535	119	75	63	55	***	5.51
22		767	568	127	89	68	60	***	4.43
24		782	595	128	106	79	69	***	3.32
26		793	620	131	121	93	80	***	2.74
28		806	643	139	131	108	92	***	2.35
30	843	821	665	148	135	121	120	***	2.01
32		831	686	158	139	133	137	***	1.70
34		842	704	168	135	133	132	***	1.43
36		838	714	181	129	128	127	***	1.16
38		853	728	195	127	125	125	***	0.91
40	878	861	735	210	125	123	123	***	0.68
45	892	877	758	249	128	124	125	***	-0.43
50	905	886	779	289	143	129	130	***	-1.67
55	916	900	809	327	165	134	135	***	-2.85
60	927	914	840	363	***	138	139	***	-4.37
62		911	844	377	***	140	141	***	-5.23
64		918	852	389	***	141	142	***	-6.47
66		923	861	402	***	142	143	***	-8.91
68		930	***	414	***	143	144	***	-20.16
69		930	***	***	***	144	143	***	-43.42

*** Measurements not reliable



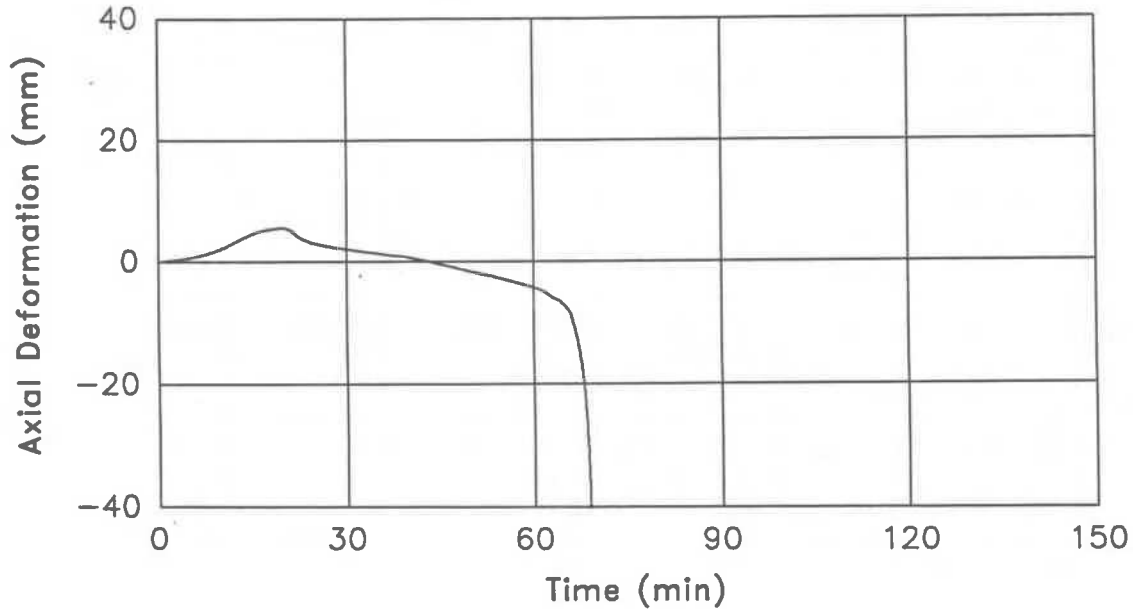
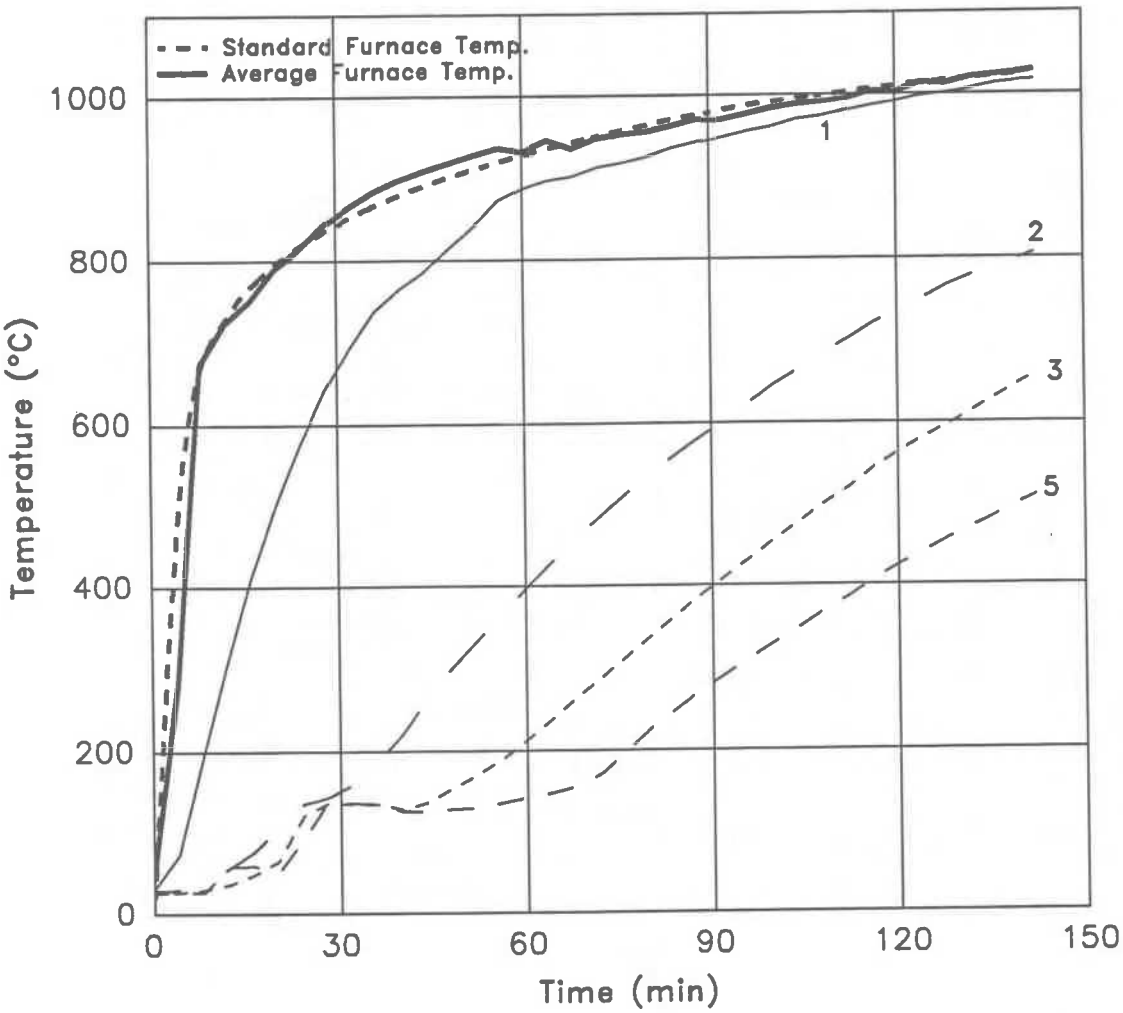


Figure A14. Temperatures and axial deformation of Column No. C-22

Table A15. Temperatures and axial deformation of Column No. C-23

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	49	31	28	27	***	26	***	0.00
4		279	73	29	27	***	27	***	0.52
8		674	192	37	29	***	27	***	4.38
12		724	310	56	36	***	58	***	10.10
16		750	413	76	48	***	59	***	15.12
20	795	789	500	106	65	***	51	***	19.43
24		813	576	136	121	***	92	***	22.56
28		843	641	144	137	***	138	***	24.61
32		864	693	159	136	***	137	***	25.85
36		883	737	187	135	***	136	***	26.09
40	878	897	764	221	128	***	126	***	21.54
44		908	785	262	137	***	125	***	14.98
48		917	813	299	153	***	128	***	10.39
52		927	841	332	170	***	130	***	7.88
56		936	872	365	190	***	136	***	6.81
60	927	932	887	397	213	***	142	***	6.16
64		945	897	428	237	***	147	***	5.57
68		935	901	457	262	***	155	***	5.03
72		947	912	485	287	***	171	***	4.63
76		952	918	511	313	***	199	***	4.15
80	963	955	925	536	338	***	226	***	3.66
84		962	935	559	363	***	249	***	3.10
88		969	942	581	387	***	271	***	2.44
92		969	947	602	410	***	291	***	1.60
96		976	955	623	433	***	311	***	0.69
100	991	983	961	645	455	***	330	***	-0.46
104		988	969	664	477	***	349	***	-1.71
108		991	973	683	498	***	368	***	-3.27
112		995	980	701	519	***	386	***	-5.00
116		1004	986	720	543	***	406	***	-7.07
120	1010	1003	991	734	562	***	424	***	-9.53
124		1014	998	749	580	***	440	***	-12.32
128		1012	1001	765	596	***	456	***	-15.62
132		1020	1006	778	613	***	471	***	-19.33
136		1023	1012	790	631	***	486	***	-23.62
140	1024	1026	1015	800	648	***	501	***	-28.47
142		1028	1016	805	656	***	508	***	-31.11

*** Measurements not reliable



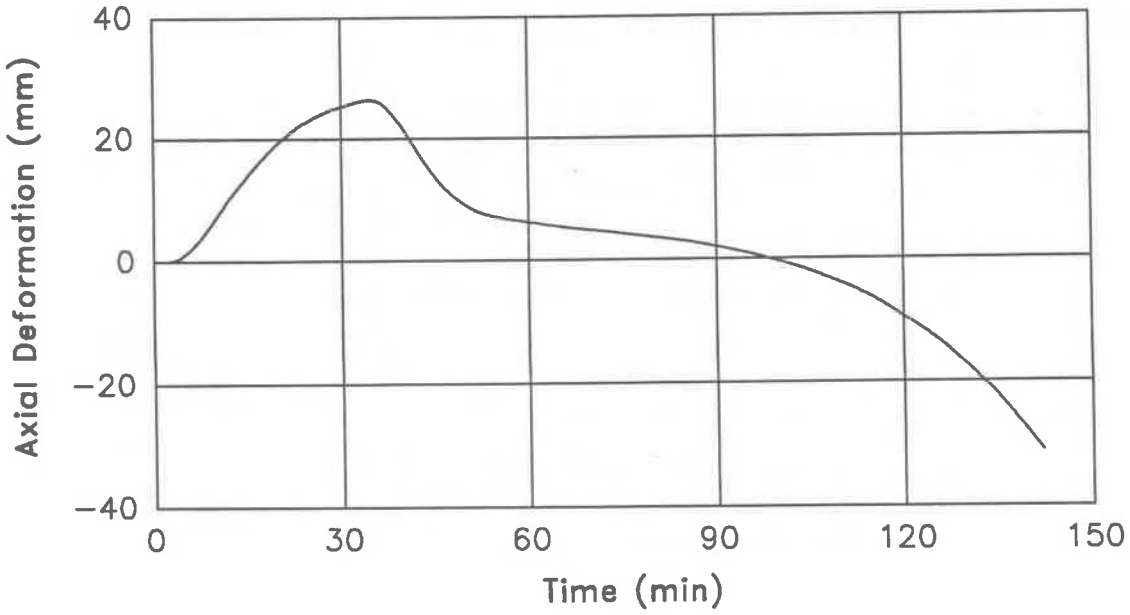


Figure A15. Temperatures and axial deformation of Column No. C-23

Table A16. Temperatures and axial deformation of Column No. C-25

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	69	21	19	19	19	19	19	0.00
5	538	530	***	21	20	19	19	20	2.86
10	704	606	***	31	21	20	19	23	9.06
15	760	626	***	46	27	22	20	30	11.93
20	795	685	511	64	38	28	27	41	15.37
25	821	746	573	83	53	40	42	59	18.38
30	843	786	600	100	75	74	75	90	17.91
35	862	822	669	111	94	114	120	108	10.67
40	878	843	***	126	114	123	128	121	8.28
45	892	856	***	140	128	133	133	131	6.74
50	905	875	***	143	131	127	127	129	5.61
55	916	887	***	155	125	122	122	124	4.69
60	927	902	***	185	129	127	127	129	4.18
65	937	911	***	219	137	135	135	137	3.83
70	946	926	***	251	145	141	140	146	3.57
75	955	927	***	281	155	144	144	161	3.25
80	963	941	***	308	170	145	145	179	2.90
85	971	947	***	335	188	144	144	199	2.40
90	978	947	***	360	206	143	143	219	1.80
95	985	953	***	385	224	146	141	240	1.12
100	991	966	***	408	243	158	140	260	0.23
105	996	973	***	430	261	173	139	280	-0.94
110	1001	973	***	451	279	188	140	301	-2.40
115	1006	982	***	472	297	204	150	321	-4.05
120	1010	989	***	493	314	221	163	341	-6.08
125		995	***	512	332	238	190	359	-8.60
130	1017	997	***	***	349	255	214	377	-11.85
135		1007	***	549	366	274	237	394	-16.45
140	1024	1012	***	567	384	291	256	409	-24.19
145		1016	***	582	400	308	273	422	-101.44

*** Measurements not reliable

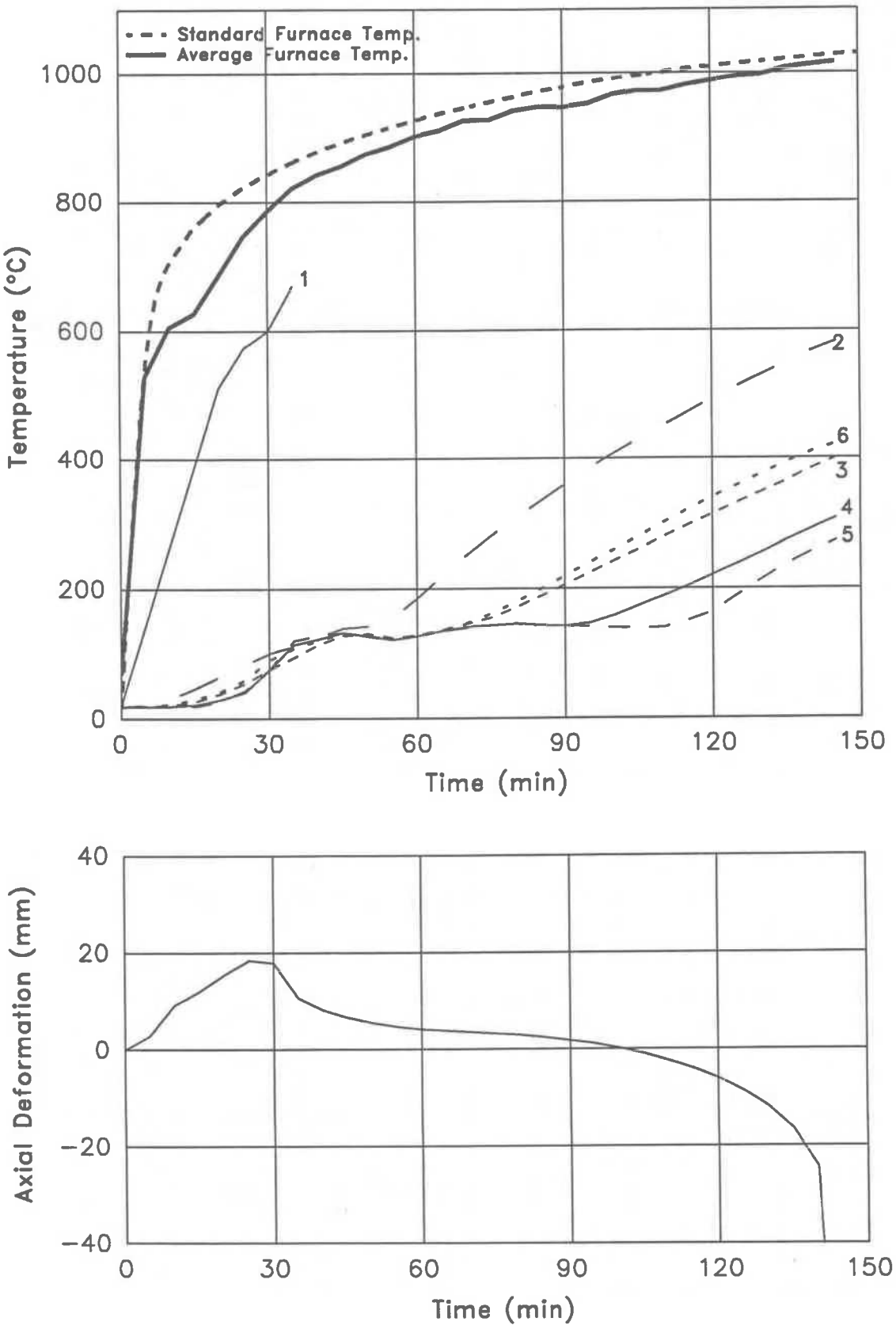


Figure A16. Temperatures and axial deformation of Column No. C-25

Table A17. Temperatures and axial deformation of Column No. C-26

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	192	***	20	20	20	20	20	0.00
10	704	695	***	44	***	20	20	23	11.26
15	760	749	***	67	***	22	21	30	15.76
20	795	785	***	109	***	27	26	42	15.25
25	821	817	***	110	***	49	42	69	7.06
30	843	847	***	110	***	81	90	93	4.92
35	862	861	***	142	***	105	118	112	3.82
40	878	877	***	126	***	117	125	127	2.95
45	892	895	***	137	***	121	120	133	1.65
50	905	904	***	191	***	118	118	134	0.25
55	916	899	***	224	***	121	122	131	-0.88
60	927	929	***	259	***	128	129	135	-1.91
65	937	933	***	290	***	136	138	143	-3.22
70	946	945	***	317	***	141	142	152	-4.75
75	955	953	***	343	***	143	143	165	-6.72
80	963	960	***	374	***	132	131	178	-9.76
85	971	965	***	402	***	126	126	196	-12.98
90	978	974	***	429	***	123	123	217	-19.18

*** Measurements not reliable

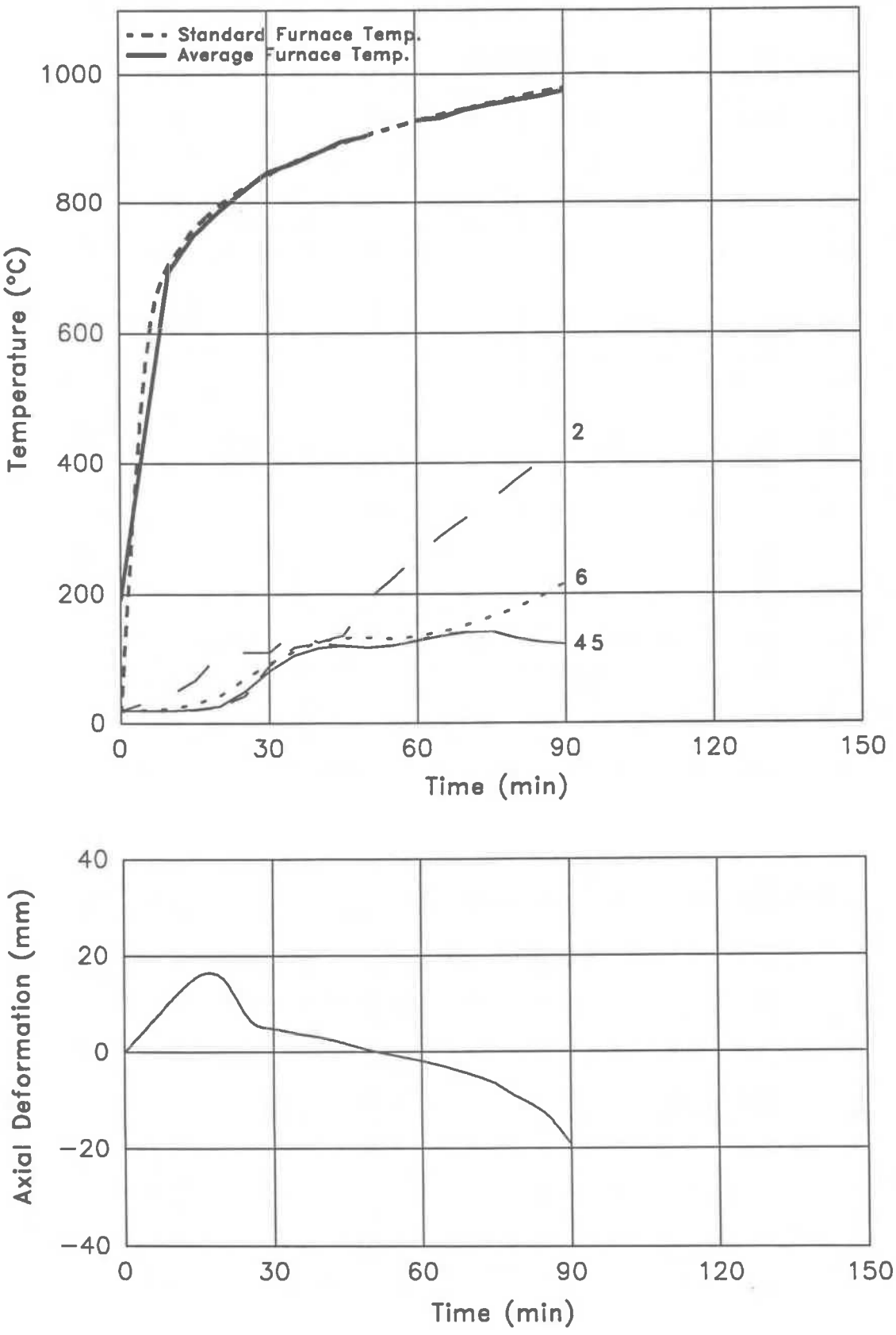


Figure A17. Temperatures and axial deformation of Column No. C-26

Table A18. Temperatures and axial deformation of Column No. C-28

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	62	29	18	18	18	18	18	0.00
5	538	572	205	23	18	18	18	18	3.05
10	704	686	341	40	20	18	18	20	10.03
15	760	741	474	68	26	19	19	25	15.46
20	795	786	596	96	36	23	21	34	16.08
25	821	811	662	116	62	32	26	51	7.34
30	843	861	724	131	88	54	41	74	5.55
35	862	855	745	142	111	85	65	91	4.12
40	878	882	715	161	120	113	91	121	3.30
45	892	892	689	173	119	115	108	123	2.57
50	905	903	732	180	117	116	117	120	1.78
55	916	914	772	193	118	117	119	120	1.21
60	927	929	812	213	123	121	123	124	0.76
65	937	933	844	239	132	129	130	132	0.35
70	946	944	844	269	139	136	138	139	-0.07
75	955	955	867	302	143	141	142	142	-0.78
80	963	961	886	335	147	143	145	144	-1.78
85	971	961	917	365	152	138	139	139	-2.83
90	978	981	935	393	162	133	134	161	-4.01
95	985	979	936	419	175	130	130	184	-5.61
100	991	988	944	443	190	128	128	205	-7.31
106		996	950	470	208	126	125	228	-10.50
110	1001	1000	950	486	220	129	123	242	-15.28

*** Measurements not reliable

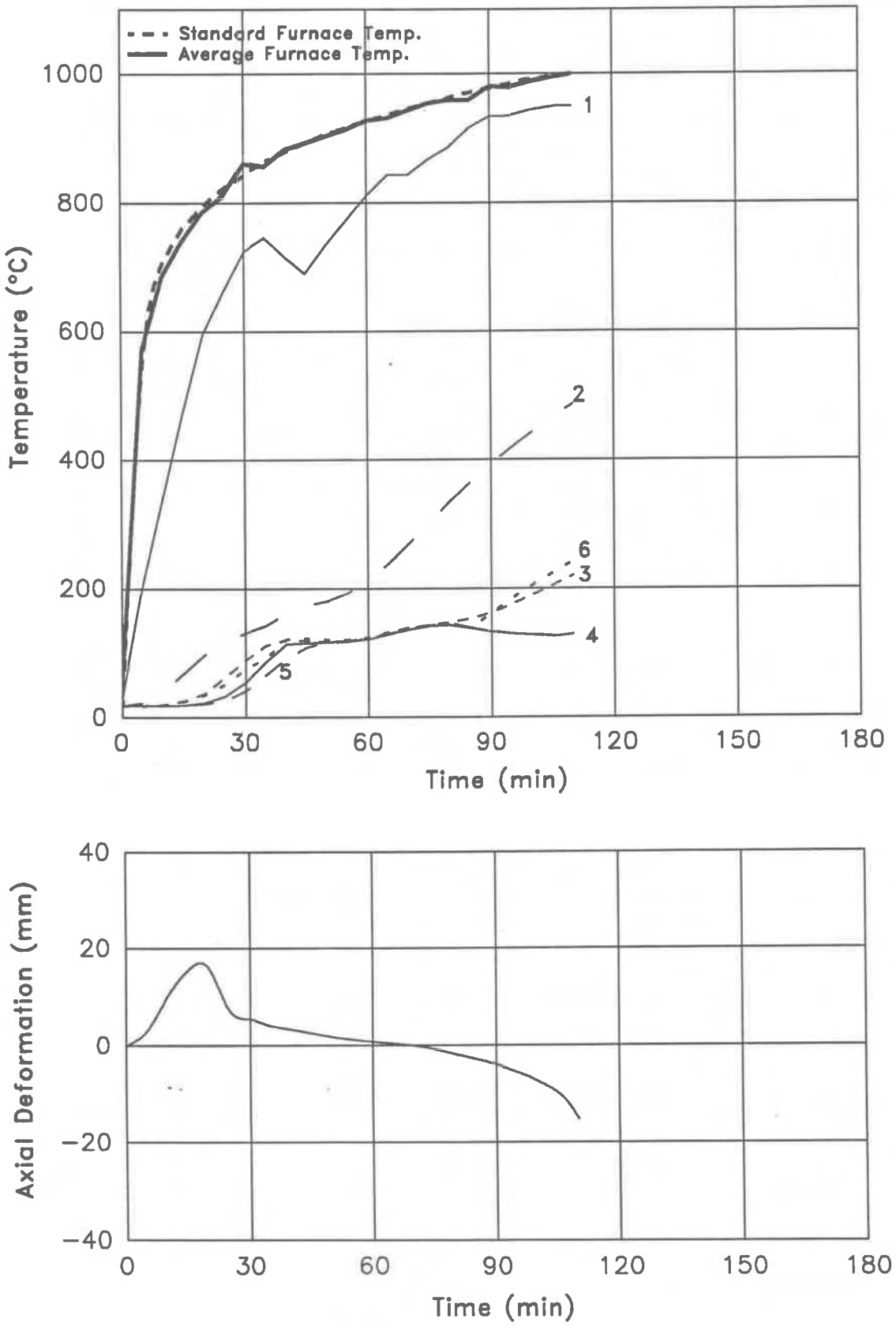
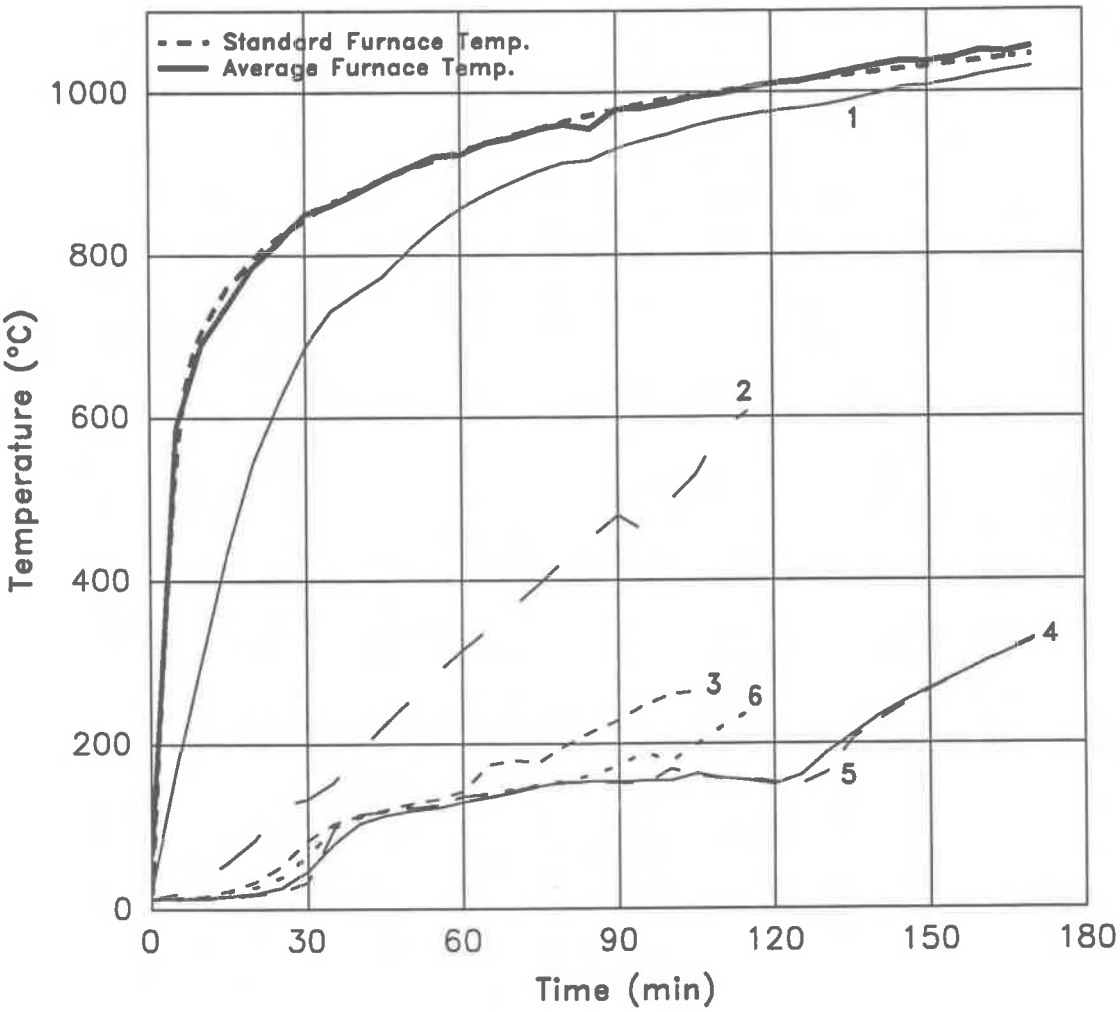


Figure A18. Temperatures and axial deformation of Column No. C-28

Table A19. Temperatures and axial deformation of Column No. C-29

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	66	22	13	13	13	13	13	0.00
5	538	588	174	19	14	13	13	13	2.44
10	704	690	308	35	16	14	13	15	7.74
15	760	737	439	57	23	16	15	22	14.08
20	795	786	545	83	32	19	17	27	19.55
25	821	815	620	126	51	26	21	38	22.23
30	843	850	687	134	83	45	32	64	22.51
35	862	860	730	153	103	78	95	98	17.79
40	878	876	752	190	113	104	115	112	11.58
45	892	892	773	223	120	113	118	119	7.64
50	905	907	805	254	128	119	123	124	5.01
55	916	921	834	286	133	123	126	126	3.28
60	927	924	857	315	143	130	137	137	2.29
65	937	938	874	341	174	135	138	139	1.79
70	946	944	889	370	179	141	144	145	1.52
75	955	954	902	396	178	148	150	150	0.98
80	963	961	913	425	198	153	152	155	0.30
85	971	955	916	452	215	154	152	162	-0.58
90	978	979	931	480	229	154	152	173	-1.29
95	985	980	940	461	247	155	151	189	-2.25
100	991	986	948	496	261	155	169	178	-3.30
105	996	994	958	528	263	163	161	199	-4.54
110	1001	998	965	583	***	158	157	221	-6.02
115	1006	1005	971	606	***	155	156	239	-7.72
120	1010	1011	976	***	***	150	153	***	-9.79
125		1013	979	***	***	161	150	***	-12.11
130	1017	1019	984	***	***	188	164	***	-14.82
135		1026	990	***	***	211	205	***	-17.89
140	1024	1032	997	***	***	233	228	***	-21.58
145		1038	1005	***	***	251	247	***	-26.14
150	1031	1038	1008	***	***	267	265	***	-31.84
155		1042	1013	***	***	282	281	***	-39.11
160	1038	1050	1020	***	***	298	298	***	-50.09
165		1049	1025	***	***	312	314	***	-71.49
170	1045	1055	1030	***	***	326	328	***	-74.12

*** Measurements not reliable



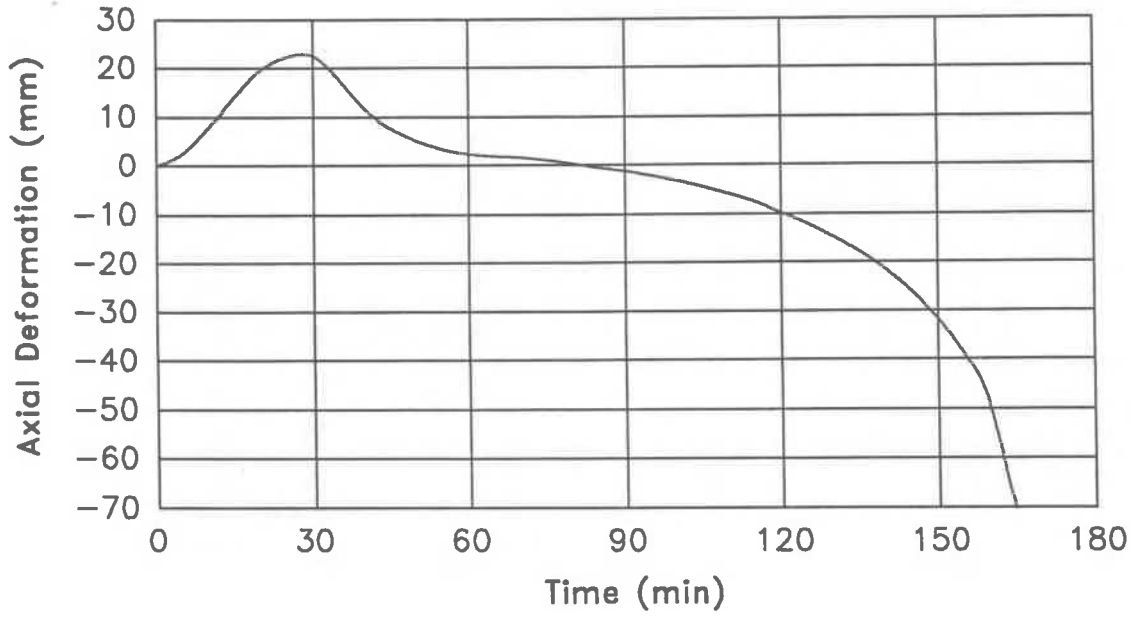


Figure A19. Temperatures and axial deformation of Column No. C-29

Table A20. Temperatures and axial deformation of Column No. C-30

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	73	32	21	21	21	21	21	0.00
5	538	571	183	24	21	21	21	21	1.49
10	704	669	298	41	23	***	21	22	6.70
15	760	730	414	89	100	***	112	51	12.85
20	795	771	510	102	107	***	109	73	17.80
25	821	833	593	114	110	***	76	80	19.74
30	843	827	625	118	87	***	47	82	6.27
35	862	854	641	107	75	***	46	84	3.77
40	878	871	672	122	77	***	60	92	2.34
45	892	881	682	91	73	***	77	105	0.99
50	905	896	688	92	88	***	126	127	-0.97
55	916	909	***	130	126	***	131	130	-4.58
60	927	918	705	140	132	***	140	139	-8.37
65	937	926	749	148	141	***	149	147	-12.53
70	946	936	786	154	147	***	152	152	-28.19

*** Measurements not reliable

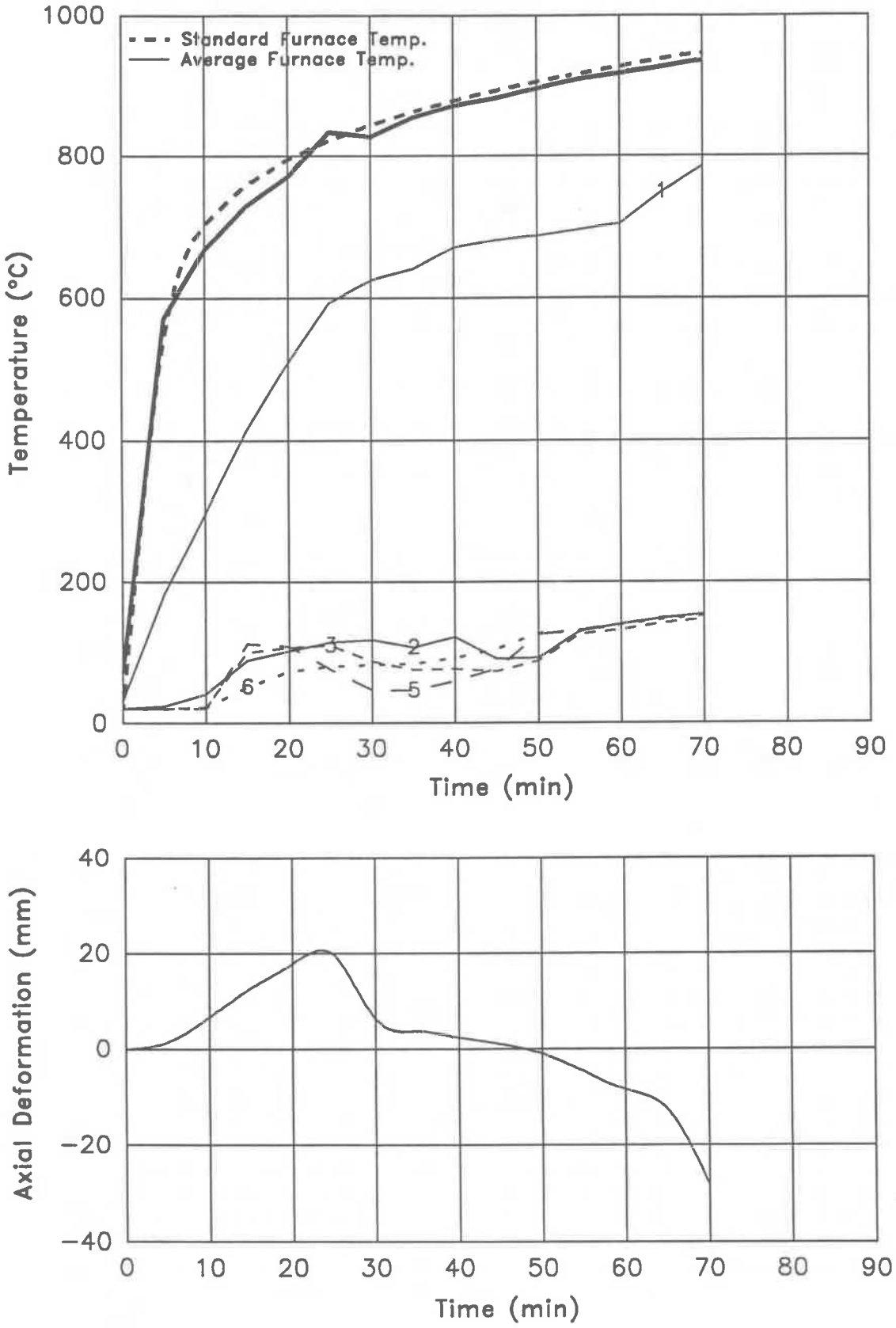


Figure A20. Temperatures and axial deformation of Column No. C-30

Table A21. Temperatures and axial deformation of Column No. C-31

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	Axial Def. (mm)
0	20	50	30	26	26	26	26	0.00
2		455	129	26	26	26	27	1.14
4		546	193	27	27	27	32	4.52
6		592	254	29	30	29	43	7.07
8		636	315	34	36	35	56	9.86
10	704	677	374	43	46	44	71	12.69
12		703	425	55	58	56	88	15.52
14		721	470	68	72	70	107	18.16
16		742	508	89	98	95	126	20.42
18		758	543	117	139	137	142	22.34
20	795	778	579	139	146	144	156	24.06
22		794	613	144	147	142	168	25.57
24		811	640	140	143	137	170	26.88
26		817	663	138	144	135	185	28.10
28		833	685	139	145	133	210	29.14
30	843	848	706	143	149	135	235	29.93
32		854	725	149	158	147	259	30.53
34		860	742	157	168	157	279	30.42
36		871	758	167	180	173	300	27.67
38		866	771	179	194	187	320	23.13
40	878	870	791	194	211	204	340	18.16
42		876	808	216	229	223	359	15.07
44		882	821	240	251	245	378	12.79
46		890	833	263	274	267	397	10.97
48		903	845	286	296	290	416	9.39
50	905	907	852	308	318	312	434	8.03
52		901	856	329	338	333	452	6.83
54		906	864	348	358	352	470	5.67
56		905	868	368	377	372	488	4.61
58		911	877	388	397	391	506	3.61
60	927	916	885	407	415	410	523	2.63
62		924	893	425	433	428	540	1.61
64		939	901	442	451	445	554	0.48
66		944	907	458	467	461	568	-0.68
68		944	910	475	483	479	582	-2.05
70	946	940	912	490	499	497	599	-3.67
72		940	916	505	514	512	614	-5.66
74		939	920	520	529	526	630	-8.13
76		942	925	534	543	540	644	-11.31
78		961	937	549	558	554	657	-15.64
80	963	948	936	564	573	567	671	-21.95
82		958	944	577	587	580	685	-32.62

*** Measurements not reliable

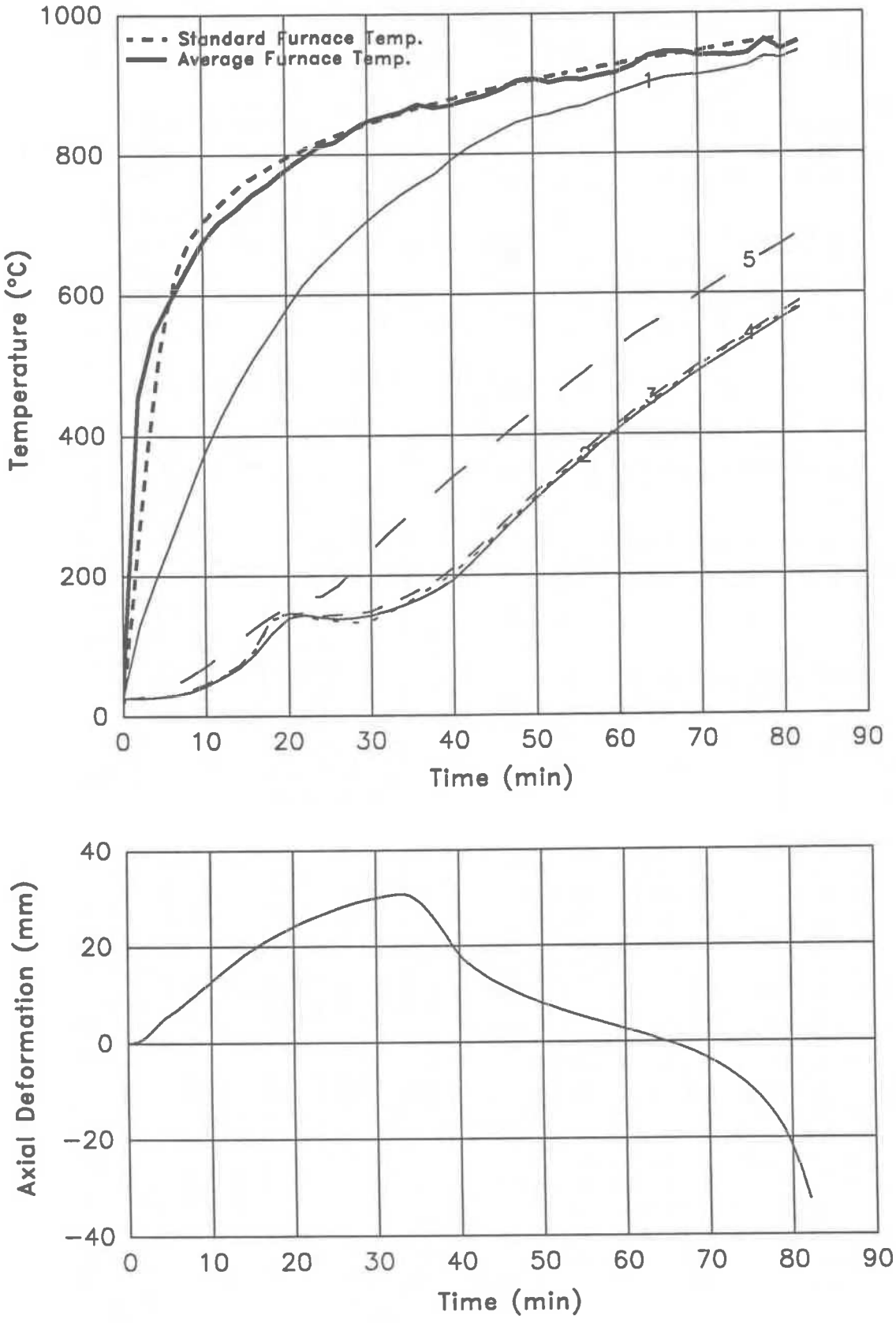
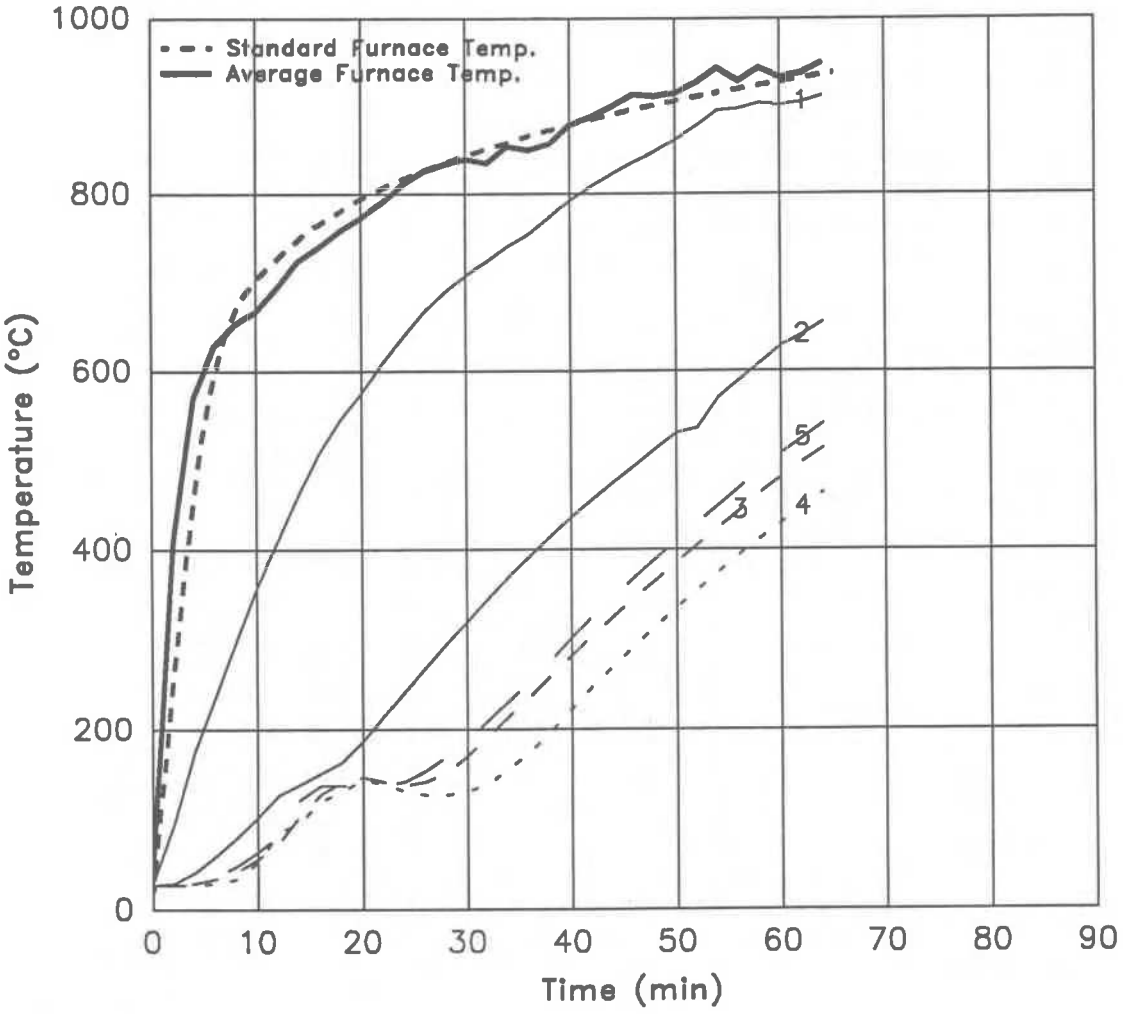


Figure A21. Temperatures and axial deformation of Column No. C-31

Table A22. Temperatures and axial deformation of Column No. C-32

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	Axial Def. (mm)
0	20	53	30	27	27	27	27	0.00
2		410	95	29	27	27	27	0.74
4		571	175	41	29	27	30	4.38
6		628	237	60	34	29	37	6.92
8		653	299	80	43	34	49	9.66
10	704	668	358	102	56	53	64	12.62
12		695	410	127	74	85	82	15.29
14		725	462	139	104	97	122	17.74
16		741	508	151	128	120	138	19.95
18		759	546	164	142	131	138	21.70
20	795	774	576	187	147	145	139	23.20
22		790	608	214	142	139	138	24.45
24		810	638	241	138	131	142	25.51
26		825	666	268	142	127	154	26.44
28		833	688	294	152	127	170	27.35
30	843	840	708	320	171	131	189	28.10
32		835	724	346	193	140	211	28.50
34		854	741	370	215	157	232	28.26
36		850	755	393	237	176	254	23.84
38		857	774	415	260	199	277	15.84
40	878	878	793	436	282	223	302	11.77
42		887	808	456	305	248	326	9.35
44		899	822	475	326	271	348	7.60
46		912	835	493	347	293	369	5.92
48		910	847	512	366	315	390	4.25
50	905	914	861	530	386	336	410	2.50
52		926	876	535	405	355	430	0.93
54		943	894	569	424	375	449	-0.50
56		928	896	589	443	394	469	-2.14
58		943	902	608	463	412	488	-4.13
60	927	933	901	628	481	430	507	-6.61
62		937	904	640	498	447	524	-10.19
64		949	911	654	513	464	540	-16.81

*** Measurements not reliable



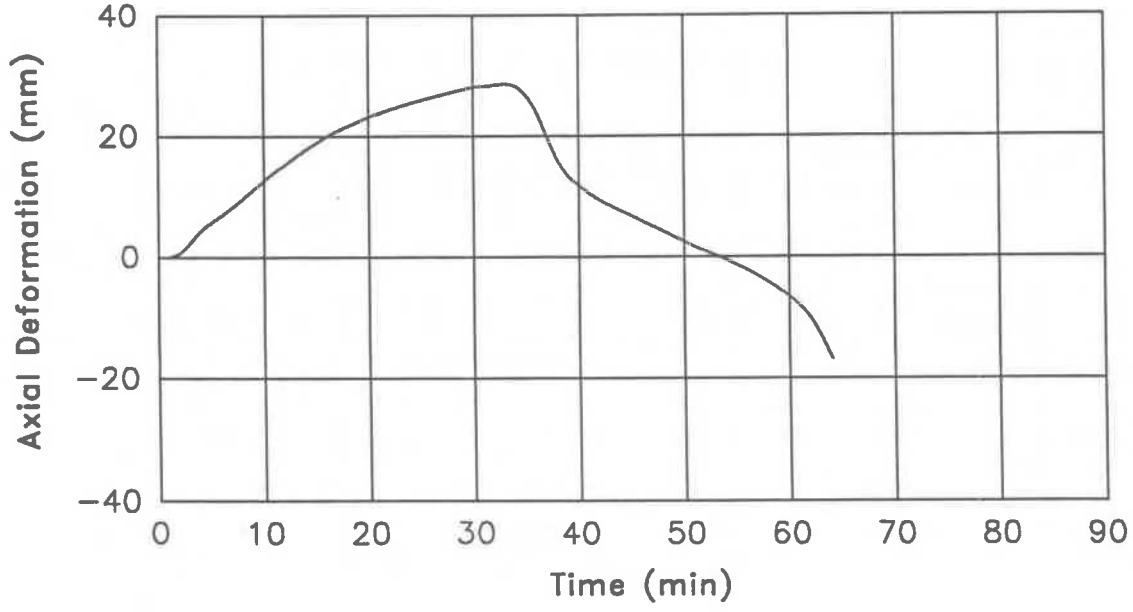
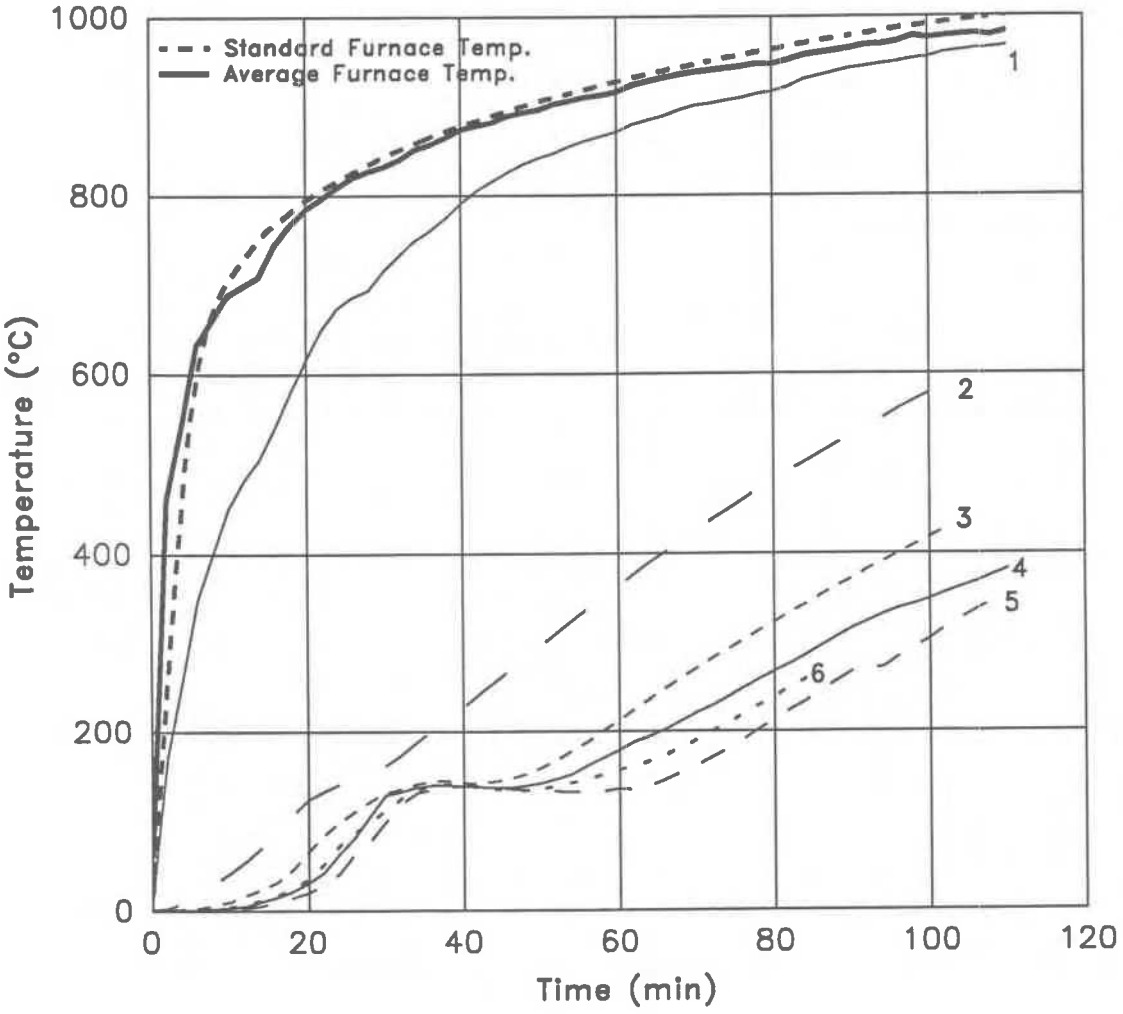


Figure A22. Temperatures and axial deformation of Column No. C-32

Table A23. Temperatures and axial deformation of Column No. C-34

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	62	15	1	1	1	1	1	0.00
2		460	171	3	1	1	1	1	2.54
4		545	261	9	2	1	1	1	5.73
6		632	349	20	3	1	1	1	8.90
10	704	688	451	43	11	4	2	5	14.49
12		699	483	56	18	6	4	8	16.70
14		709	505	70	24	11	6	12	18.17
16		744	541	86	33	16	10	18	19.54
18		766	579	107	46	22	15	25	20.09
20	795	785	616	124	67	32	21	36	20.04
22		796	649	133	84	43	29	52	17.28
24		809	673	141	99	64	42	73	11.26
26		820	686	148	111	82	64	87	9.01
28		827	694	154	123	107	79	100	8.01
30	843	832	715	162	131	129	99	112	7.31
32		840	733	174	136	133	120	126	6.73
34		851	749	188	141	138	131	135	6.10
36		857	761	202	145	140	135	139	5.43
38		865	774	215	145	140	138	141	4.83
40	878	874	791	228	143	139	139	140	4.26
42		878	805	242	142	138	139	138	3.72
44		882	816	256	144	137	138	136	3.21
46		889	826	269	147	137	136	135	2.73
48		893	835	283	152	139	134	134	2.26
50	905	896	842	297	159	142	133	136	1.78
52		902	848	311	168	147	133	139	1.34
54		906	855	325	178	152	132	143	0.90
56		910	861	338	189	162	132	146	0.49
58		912	866	351	201	170	133	152	0.07
60	927	916	871	364	213	179	136	157	-0.34
62		923	879	377	225	189	134	161	-0.74
64		927	884	390	237	195	139	167	-1.14
66		931	889	402	249	203	146	174	-1.53
68		935	895	414	260	212	154	182	-1.93
70	946	938	900	426	271	221	162	191	-2.34
72		940	902	438	282	229	171	200	-2.78
74		942	906	449	292	239	180	209	-3.20
76		944	909	460	303	249	191	220	-3.68
78		947	913	471	313	258	202	229	-4.17
80	963	947	916	482	323	267	213	239	-4.69
82		951	921	492	333	276	224	249	-5.23
84		957	929	502	343	286	234	259	-5.82
88		962	938	522	363	306	257	***	-7.16
90	978	965	942	531	372	316	267	***	-7.91
92		968	944	541	382	324	270	***	-8.75
94		969	947	550	391	332	272	***	-9.66
96		972	949	560	400	338	284	***	-10.68
98		978	953	569	409	343	294	***	-11.80
100	991	976	955	578	418	349	304	***	-13.08
102		978	960	586	427	356	317	***	-14.55
106		981	964	***	***	368	337	***	-18.32
108		979	965	***	***	375	345	***	-20.97
110	1001	983	967	***	***	382	355	***	-24.98

*** Measurements not reliable



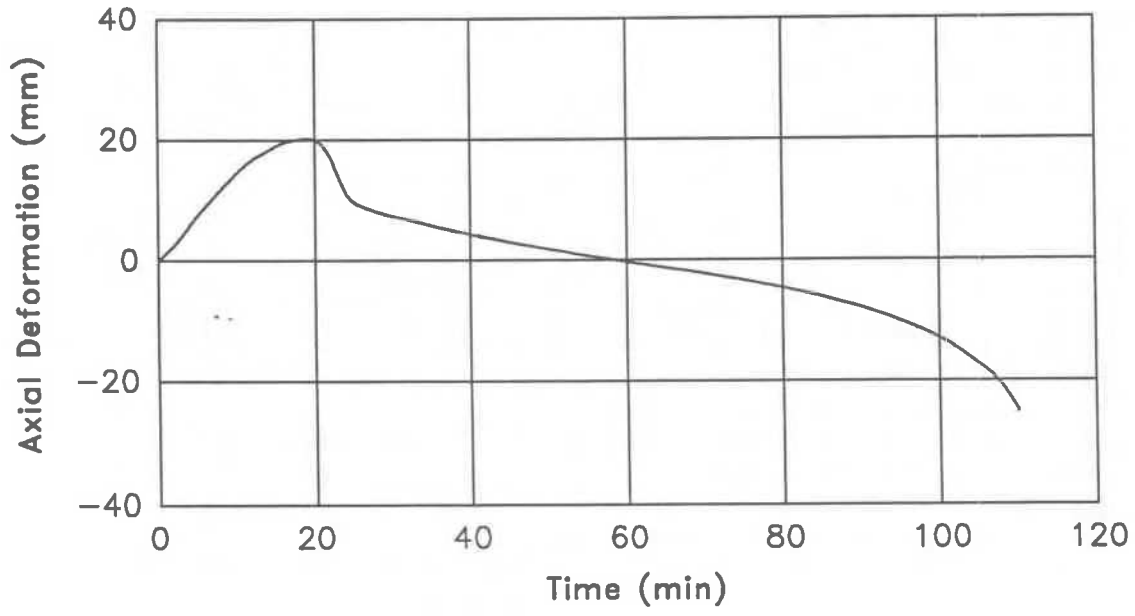
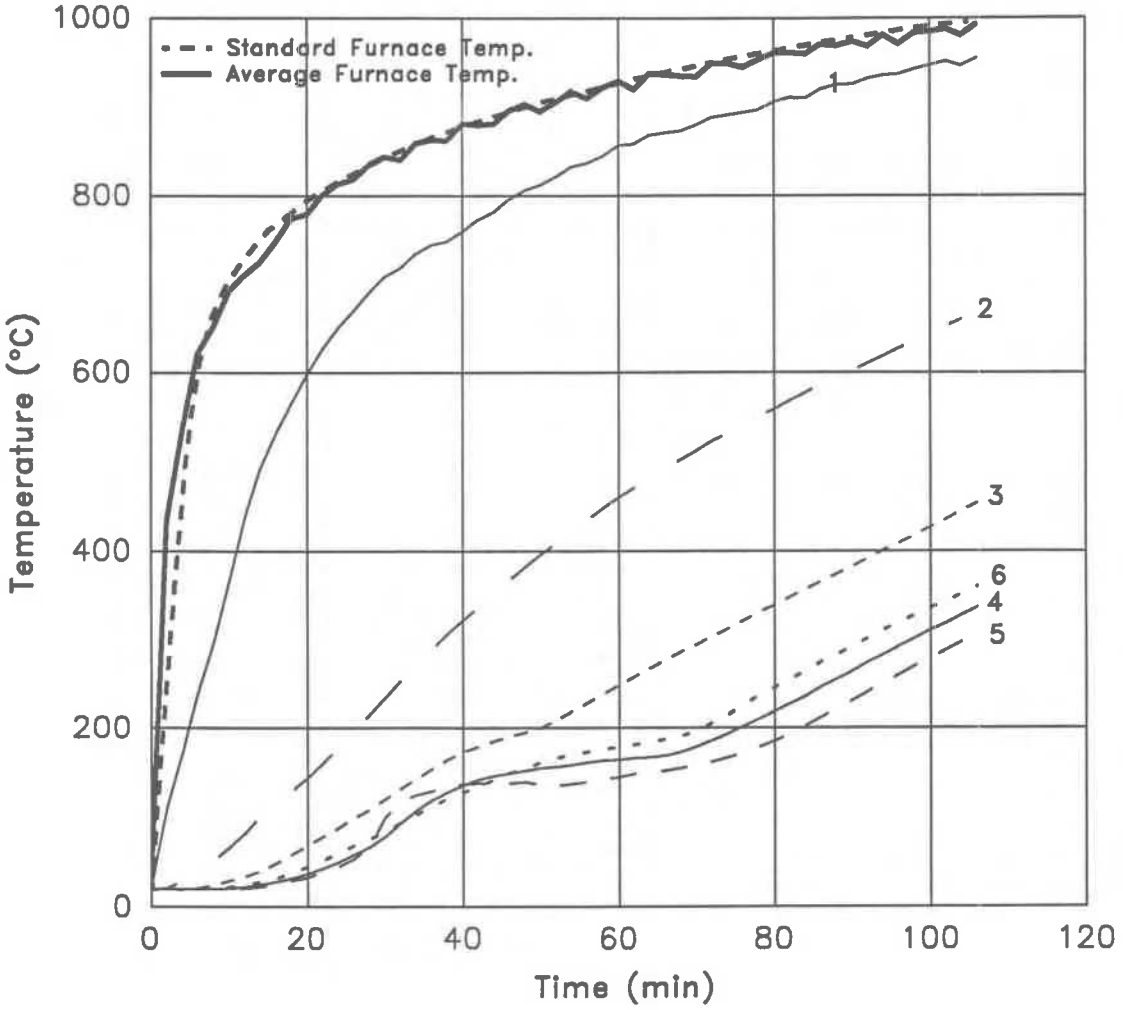


Figure A23. Temperatures and axial deformation of Column No. C-34

Table A24. Temperatures and axial deformation of Column No. C-35

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	51	23	20	20	20	20	20	0.00
2		434	110	21	20	20	20	20	0.88
4		538	173	29	20	20	20	20	3.52
6		621	239	40	21	20	20	20	6.96
8		652	297	52	24	20	20	21	10.19
10	704	692	365	66	29	21	20	22	12.78
12		710	439	82	34	22	21	25	14.66
14		724	491	101	40	25	22	28	15.59
16		747	532	114	48	28	25	32	14.69
18		774	565	129	58	32	29	38	7.10
20	795	780	598	144	68	37	33	45	5.08
22		801	626	160	78	43	39	52	4.39
24		814	651	178	88	50	45	60	3.90
26		819	670	197	99	58	53	68	3.48
28		836	691	216	109	67	68	76	3.18
30	843	844	708	234	120	78	99	84	2.89
32		841	718	254	132	94	118	94	2.55
34		859	734	272	143	107	125	103	2.25
36		863	744	289	154	119	129	113	1.64
38		862	748	306	164	128	135	121	1.11
40	878	881	760	322	173	136	137	128	0.77
42		880	773	337	179	142	138	135	0.22
44		881	782	352	185	146	137	142	-0.26
46		896	796	367	190	149	138	149	-0.69
48		903	807	382	195	152	139	155	-1.17
50	905	895	812	396	200	155	136	161	-1.59
52		906	822	409	209	156	135	166	-2.03
54		918	833	423	219	158	137	170	-2.42
56		910	837	435	229	161	139	173	-2.83
58		922	845	448	239	163	142	176	-3.23
60	927	929	857	460	249	164	145	178	-3.55
62		920	858	471	259	166	148	181	-3.92
64		938	868	482	268	167	150	184	-4.26
66		937	871	493	278	169	152	187	-4.67
68		935	873	503	287	173	155	191	-5.09
70	946	934	880	513	295	179	158	197	-5.40
72		949	888	523	304	186	162	206	-5.86
74		949	891	532	313	194	167	216	-6.35
76		945	894	541	322	202	172	227	-6.80
78		953	897	551	331	210	178	237	-7.33
80	963	961	906	559	339	219	185	246	-7.77
82		961	911	568	348	228	193	256	-8.33
84		960	910	577	357	237	203	265	-8.99
86		970	920	586	365	247	212	275	-9.54
88		969	925	594	374	256	222	284	-10.15
90	978	974	926	602	383	265	232	293	-10.95
92		968	932	610	392	275	242	302	-11.74
94		981	936	619	401	284	252	311	-12.96
96		971	937	627	409	293	261	319	-14.36
98		984	943	636	418	302	271	328	-15.85
100	991	985	947	644	427	311	280	336	-17.53
102		988	951	653	436	319	289	344	-19.33
104		981	946	660	445	328	298	352	-21.45
106		994	955	***	454	337	307	360	-24.20

*** Measurements not reliable



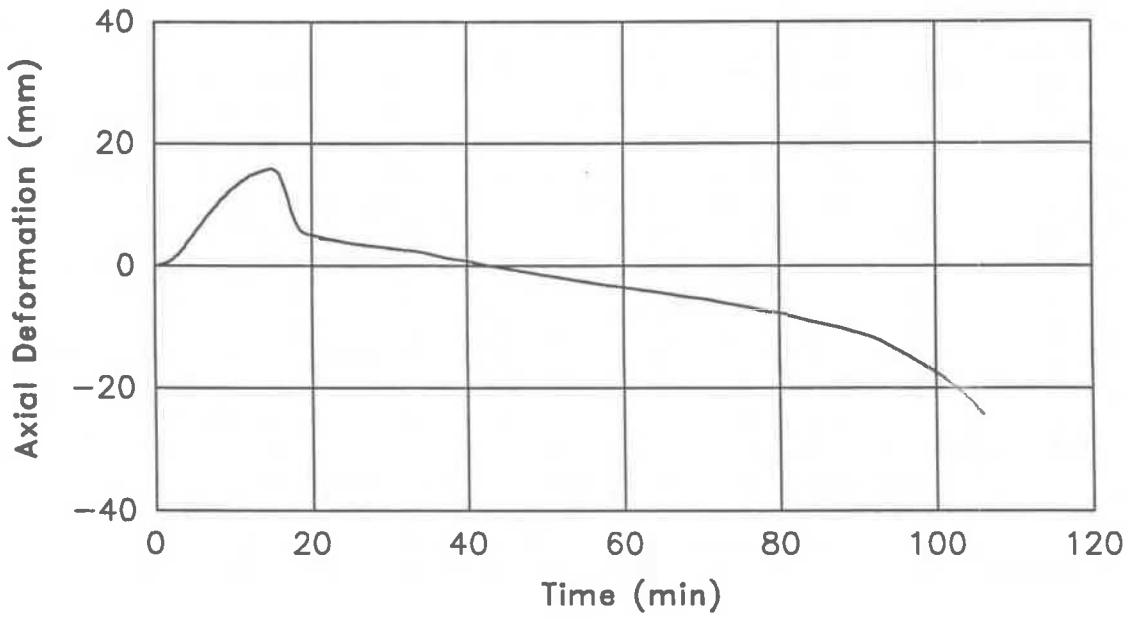


Figure A24. Temperatures and axial deformation of Column No. C-35

Table A25. Temperatures and axial deformation of Column No. C-37

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	50	25	22	22	22	22	22	0.00
2		440	78	22	22	22	22	22	0.84
4		517	127	24	22	22	22	22	2.69
6		603	190	29	22	23	22	22	5.34
8		646	247	36	24	25	22	22	8.18
10	704	675	295	45	26	37	23	23	10.96
12		702	346	56	30	24	23	24	13.62
14		728	399	69	34	27	25	25	16.01
16		750	448	84	40	30	27	28	18.00
18		767	494	102	47	34	31	32	19.45
20	795	782	539	117	56	39	36	37	20.16
22		797	578	131	67	46	43	43	20.20
24		809	610	136	80	57	62	59	19.49
26		820	640	152	94	72	85	80	16.16
28		830	668	154	108	88	104	95	9.15
30	843	837	689	160	121	105	122	114	6.53
32		846	707	171	133	122	127	123	5.33
34		855	722	183	143	133	140	133	4.42
36		863	736	199	151	144	150	143	3.38
38		869	744	217	158	152	154	150	2.29
40	878	875	756	234	163	157	157	155	1.30
42		880	768	249	164	159	157	157	0.42
44		887	782	263	164	159	155	156	-0.34
46		894	795	276	162	157	152	154	-1.06
48		898	806	289	163	155	148	151	-1.76
50	905	902	815	301	166	153	146	148	-2.41
52		907	823	314	171	152	143	146	-3.00
54		911	836	326	177	151	142	145	-3.57
56		917	845	338	185	151	142	144	-4.07
58		920	853	351	194	152	142	144	-4.55
60	927	924	861	362	203	153	143	145	-4.98
62		927	868	374	212	156	144	146	-5.44
64		931	874	386	222	160	147	149	-5.93
66		935	880	397	232	164	150	152	-6.44
68		939	887	408	241	169	155	157	-6.99
70	946	942	892	419	251	176	162	164	-7.59
72		944	897	429	260	186	170	174	-8.24
74		948	901	440	270	196	180	186	-9.01
76		950	906	450	280	207	190	197	-10.02
78		955	911	460	290	218	200	208	-11.24
80	963	957	915	***	300	230	210	218	-12.43
82		959	919	479	***	241	221	228	-13.71
84		963	922	489	321	252	232	239	-15.03
86		967	927	498	***	262	242	249	-16.47
88		968	930	508	***	***	253	251	-18.05
90	978	970	933	***	***	283	254	254	-19.80
92		974	937	***	***	293	268	264	-21.77
94		978	940	***	***	302	277	273	-24.05
96		978	944	***	***	***	285	287	-26.77
98		982	947	***	***	***	293	294	-29.96
100	991	983	951	***	***	***	302	303	-34.50

*** Measurements not reliable

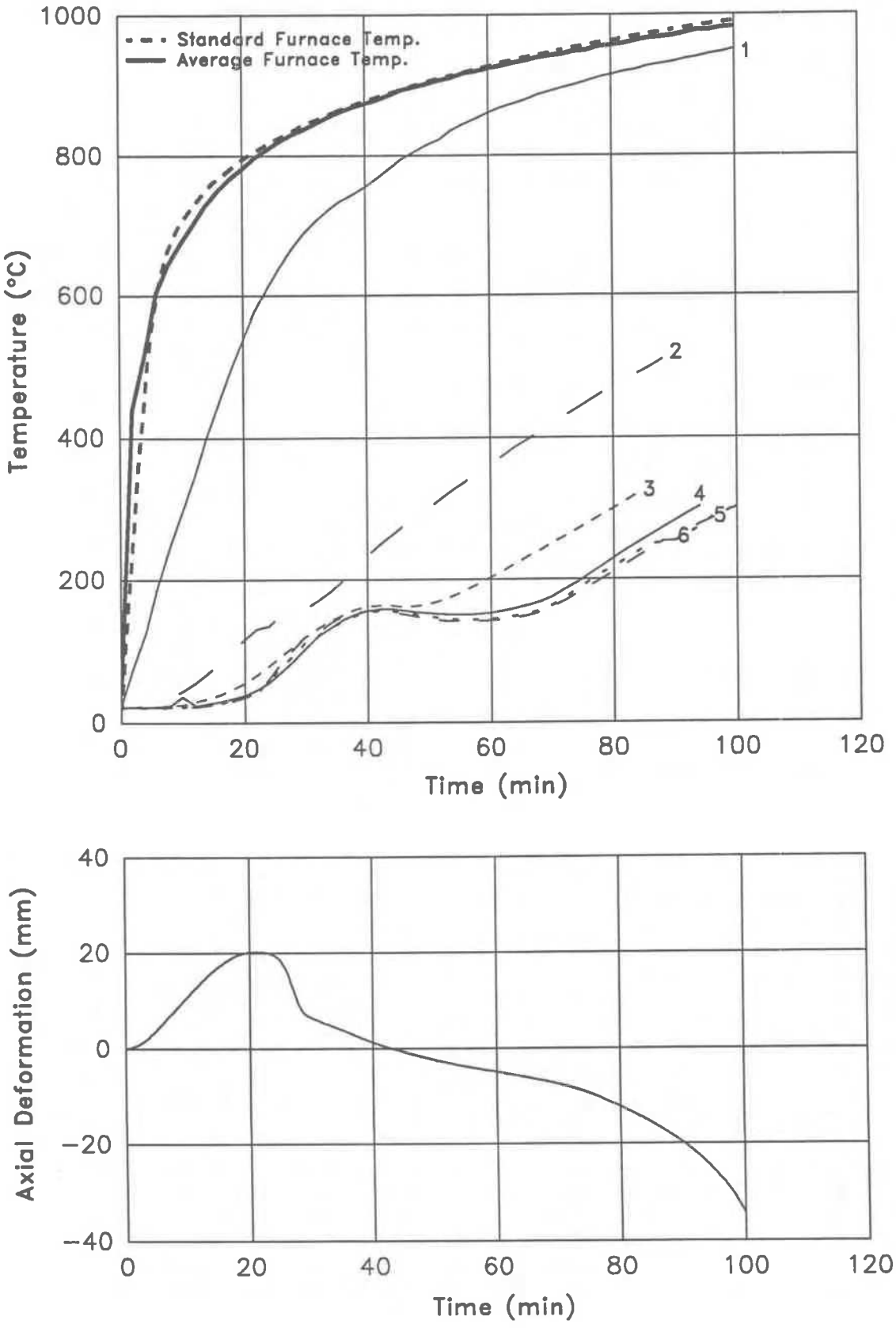
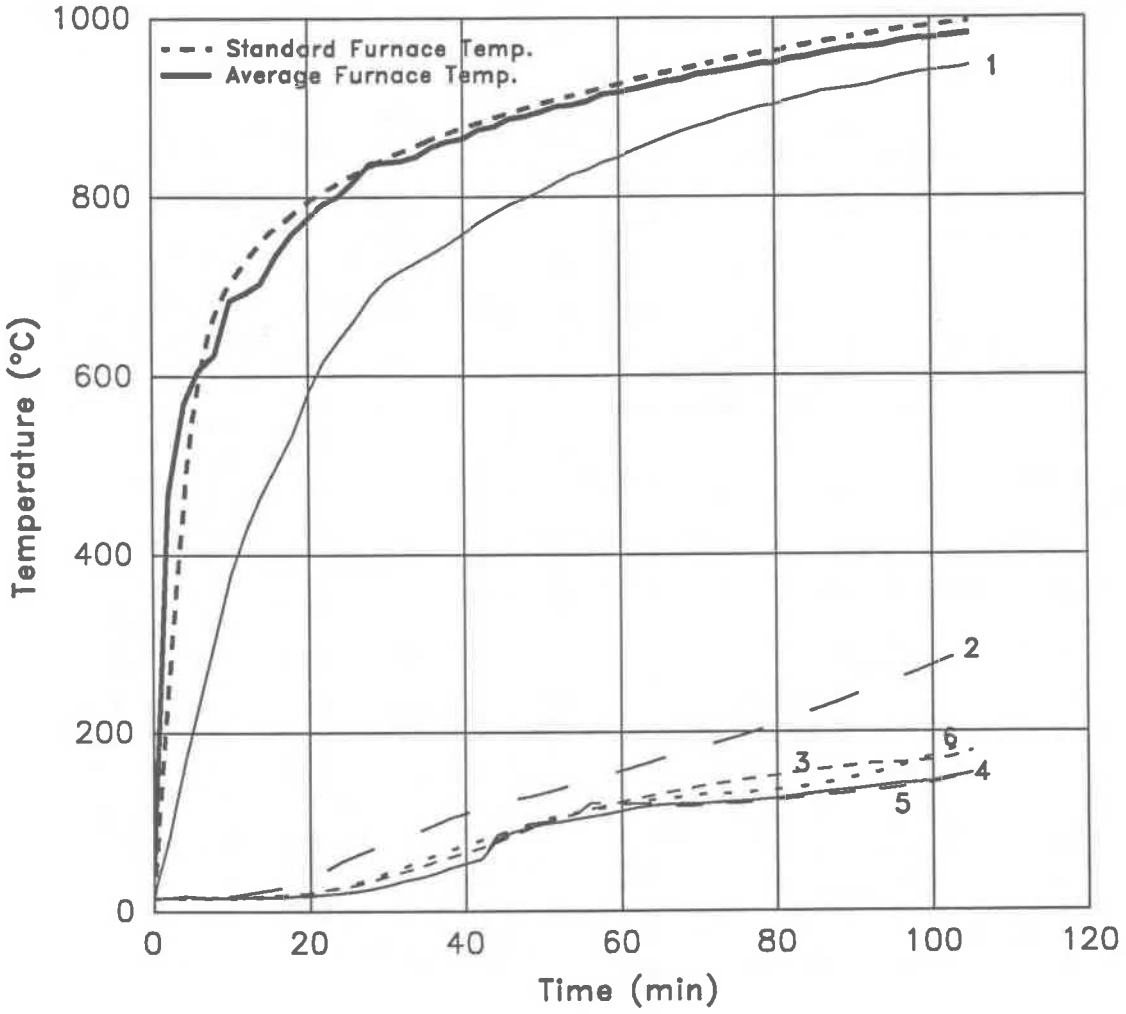


Figure A25. Temperatures and axial deformation of Column No. C-37

Table A26. Temperatures and axial deformation of Column No. C-40

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	53	20	15	15	15	16	15	0.00
2		468	84	15	15	15	15	15	0.61
4		569	167	15	15	17	16	15	3.36
6		607	234	15	15	16	15	15	6.34
8		624	307	16	15	15	16	15	9.46
10	704	685	378	17	15	16	15	15	12.10
12		693	429	20	16	16	16	16	14.03
14		704	467	23	17	16	16	16	15.05
16		736	501	26	18	16	16	17	15.22
18		759	534	30	19	17	17	19	10.82
20	795	777	581	37	21	18	18	21	4.96
22		792	615	46	24	19	19	24	3.58
24		802	640	56	27	21	21	27	2.70
26		818	662	64	30	23	23	32	2.05
28		838	689	71	35	26	26	38	1.48
30	843	839	707	78	40	29	29	44	1.00
32		841	718	84	45	34	34	50	0.58
34		846	727	90	50	38	38	57	0.16
36		857	737	97	56	43	43	63	-0.33
38		863	747	104	61	49	49	69	-0.83
40	878	866	759	110	67	54	54	75	-1.25
42		876	771	116	72	59	59	80	-1.68
44		880	782	121	78	81	86	86	-2.09
46		888	791	125	85	89	93	91	-2.49
48		891	799	128	92	94	98	97	-2.88
50	905	896	807	132	98	98	100	102	-3.27
52		902	817	137	104	100	102	107	-3.65
54		904	825	142	109	103	107	110	-4.02
56		908	831	147	114	106	121	114	-4.39
58		916	839	152	118	109	121	116	-4.71
60	927	918	845	157	122	112	120	119	-5.05
62		921	853	162	126	116	120	121	-5.40
64		925	860	167	129	118	120	124	-5.76
66		929	867	173	133	119	118	126	-6.10
68		931	873	178	136	120	117	128	-6.47
70	946	937	879	182	139	120	118	130	-6.85
72		939	884	187	142	121	119	131	-7.27
74		942	890	192	144	122	120	131	-7.67
76		945	895	197	147	123	121	132	-8.09
78		948	900	203	149	124	122	134	-8.55
80	963	950	904	209	151	126	124	136	-8.99
82		954	909	215	154	128	125	137	-9.48
84		956	913	222	156	130	127	139	-9.99
86		960	918	228	158	132	129	142	-10.59
88		963	920	234	160	134	130	145	-11.21
90	978	966	922	241	162	136	132	149	-11.89
92		967	925	248	164	138	134	152	-12.65
94		969	930	254	165	140	136	157	-13.48
96		973	934	261	165	142	138	162	-14.39
98		976	938	268	167	143	141	167	-15.48
100	991	977	941	275	168	145	143	173	-16.74
102		979	942	282	170	148	147	179	-18.13
104		981	944	288	175	151	150	185	-20.00
105		982	946	292	178	153	153	189	-24.44

*** Measurements not reliable



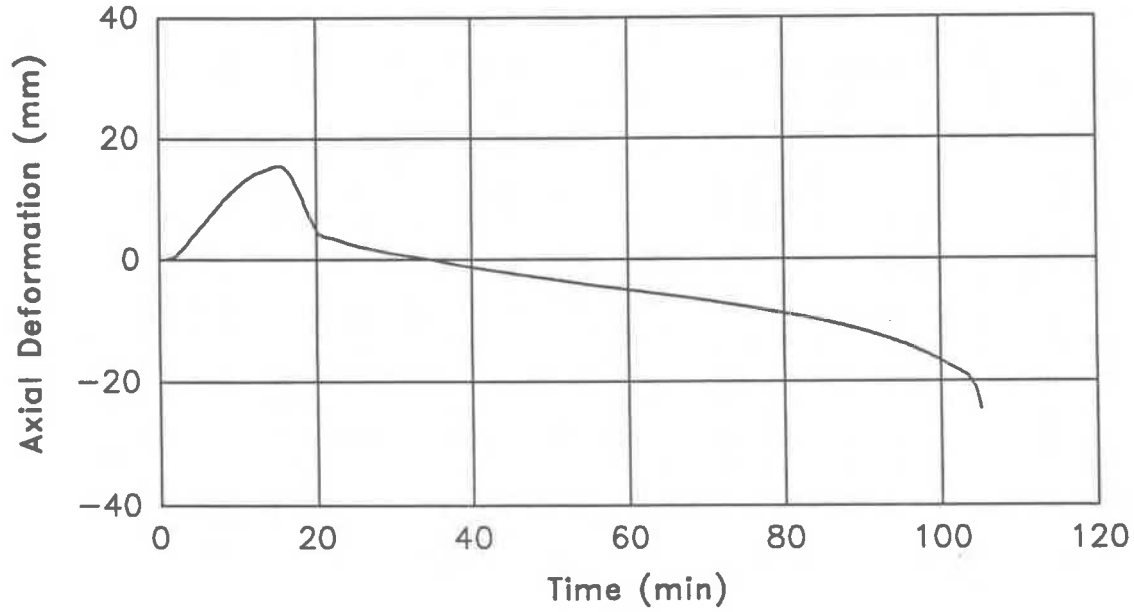
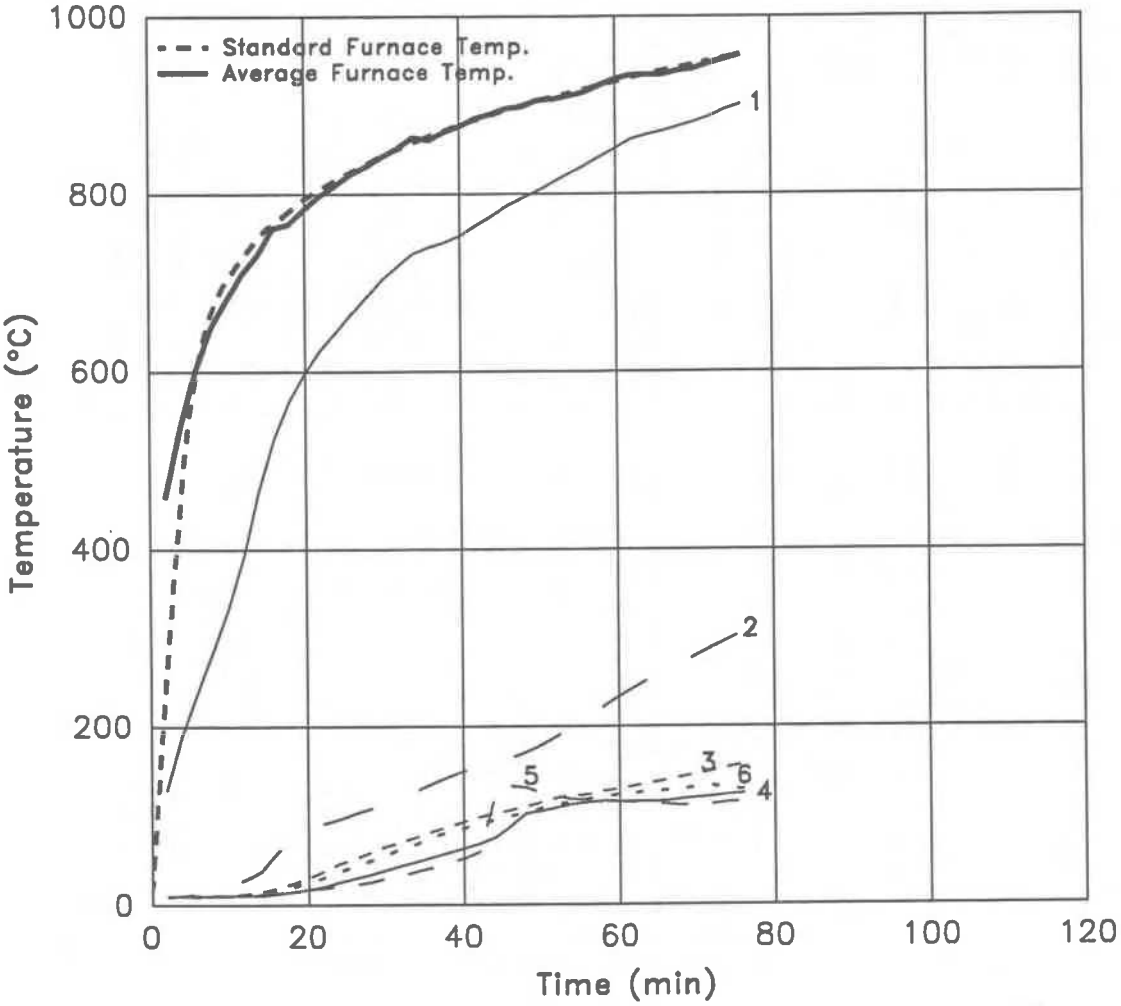


Figure A26. Temperatures and axial deformation of Column No. C-40

Table A27. Temperatures and axial deformation of Column No. C-41

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	***	***	***	***	***	***	***	0.00
2		458	129	10	10	10	10	10	0.90
4		540	193	11	10	10	10	10	2.44
6		602	238	13	11	10	10	10	5.25
8		651	286	16	11	10	10	11	8.63
10	704	681	333	22	11	11	10	11	11.61
12		711	394	29	13	11	11	12	14.01
14		731	465	38	15	11	12	14	15.55
16		762	525	58	19	13	14	17	16.05
18		766	567	76	24	15	16	21	1.35
20	795	784	599	84	31	18	18	26	7.79
22		798	624	91	38	21	19	31	5.07
24		810	644	96	46	26	21	38	3.84
26		823	665	102	52	30	23	44	2.95
28		832	685	108	59	34	26	50	2.32
30	843	842	703	114	65	39	30	56	1.78
32		852	719	121	70	44	33	63	1.24
34		864	733	128	76	48	38	68	0.65
36		861	740	136	82	53	42	77	0.02
38		870	745	143	87	58	47	81	-0.57
40	878	877	753	150	93	63	52	86	-1.13
42		885	764	154	98	68	59	90	-1.69
44		890	775	158	102	75	122	95	-2.25
46		897	786	164	106	87	133	99	-2.78
48		899	795	171	110	102	131	103	-3.30
50	905	906	804	179	114	105	125	108	-3.82
52		907	814	189	119	109	121	112	-4.30
54		911	823	199	122	112	118	115	-4.78
56		915	832	211	123	114	117	118	-5.25
58		923	842	222	127	116	117	121	-5.70
60	927	930	852	233	129	115	115	123	-6.17
62		934	862	243	133	115	114	125	-6.61
64		935	867	253	136	115	113	126	-7.18
66		935	871	262	139	116	112	128	-7.73
68		939	876	271	143	118	111	129	-8.32
70	946	941	881	280	146	119	111	131	-8.88
72		947	887	289	150	121	112	133	-9.64
74		952	895	298	154	123	114	129	-11.02
76		957	901	306	157	124	115	129	-12.67

*** Measurements not reliable



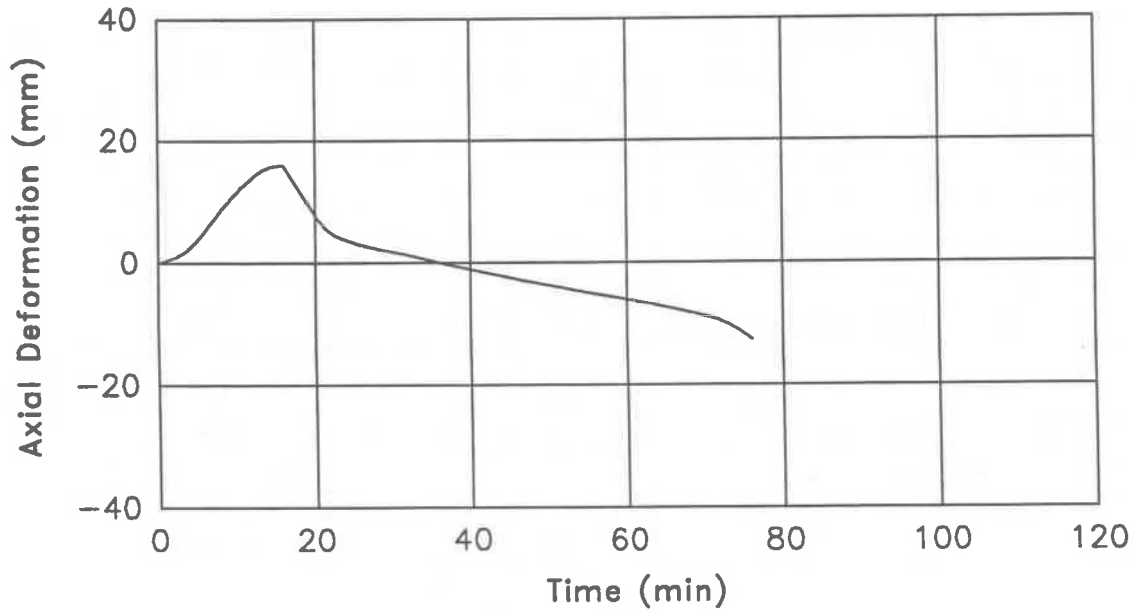
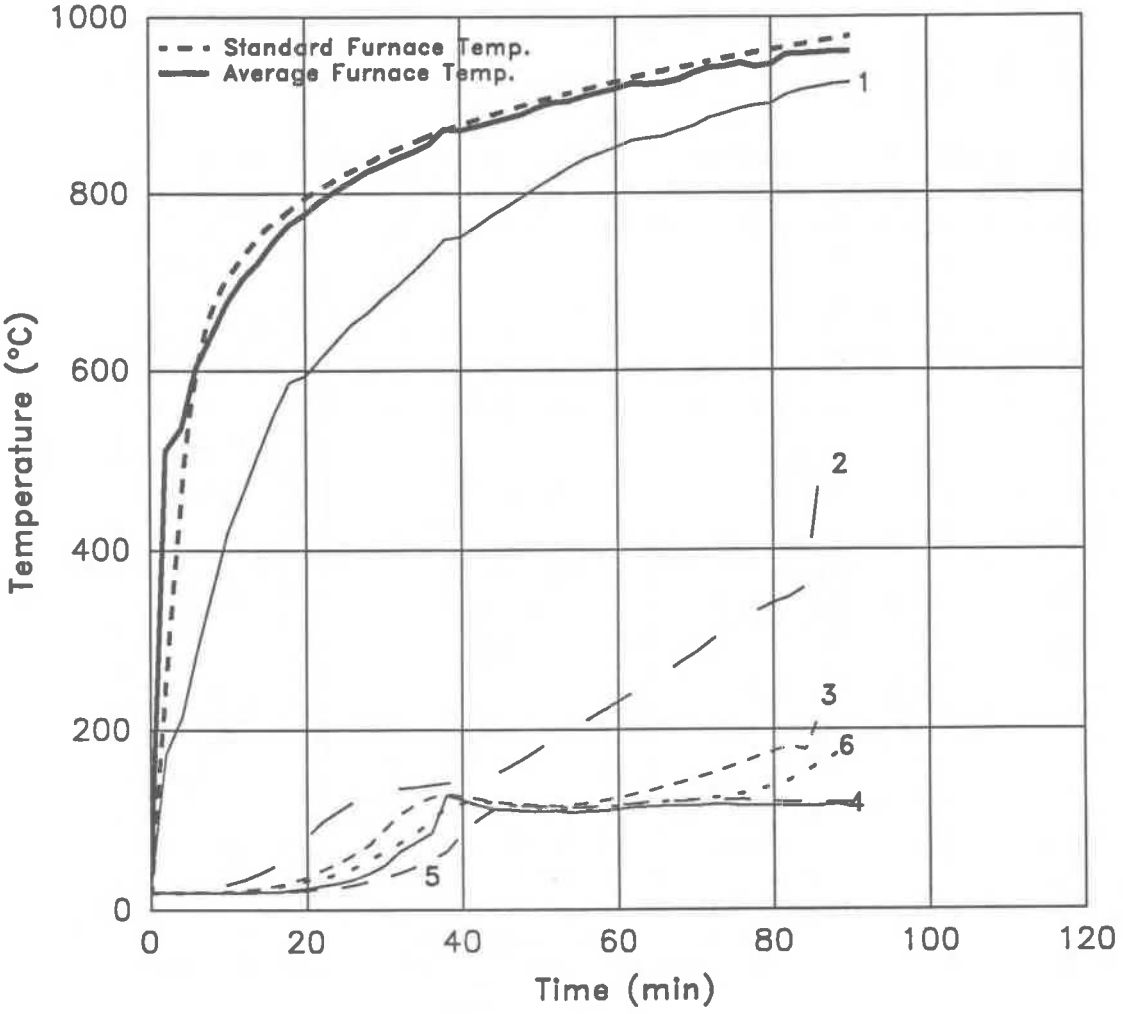


Figure A27. Temperatures and axial deformation of Column No. C-41

Table A28. Temperatures and axial deformation of Column No. C-42

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	51	29	19	20	19	20	19	0.00
2		511	174	19	20	19	20	19	0.82
4		536	214	20	20	19	19	19	2.59
6		603	286	21	20	19	20	19	5.42
8		641	355	24	20	19	19	20	8.52
10	704	677	421	29	21	19	19	20	11.03
12		704	465	34	22	20	19	21	13.11
14		721	508	41	24	20	20	23	14.12
16		746	552	50	27	20	20	26	14.16
18		765	587	60	31	22	21	29	9.32
20	795	777	594	82	37	24	22	33	5.53
22		791	613	98	45	27	24	35	4.12
24		804	633	110	52	30	25	41	3.17
26		814	652	121	62	34	28	47	2.42
28		825	665	131	73	41	32	56	1.82
30	843	832	681	135	90	50	36	65	1.26
32		841	696	136	107	66	42	75	0.73
34		847	712	137	118	75	48	86	0.20
36		856	729	139	126	86	56	100	-0.41
38		873	748	141	129	128	65	115	-1.10
40	878	872	751	143	127	123	86	119	-1.85
42		876	762	145	124	117	101	122	-2.51
44		881	775	151	121	113	113	120	-3.13
46		885	785	159	119	112	116	117	-3.75
48		890	797	169	118	111	116	116	-4.36
50	905	898	808	180	117	110	116	115	-4.93
52		904	819	191	116	111	115	114	-5.53
54		905	829	202	117	109	114	114	-6.14
56		911	839	211	119	110	115	114	-6.75
58		915	846	221	122	111	115	115	-7.42
60	927	919	853	231	125	112	117	116	-8.15
62		925	860	241	129	114	118	118	-8.93
64		924	863	252	133	115	120	119	-9.77
66		926	865	263	138	116	121	121	-10.69
68		929	871	275	142	116	121	122	-11.62
70	946	937	877	286	147	116	122	122	-12.59
72		943	886	299	152	117	122	124	-13.56
74		944	891	311	158	117	122	127	-14.63
76		948	897	322	164	116	123	130	-15.70
78		944	900	332	170	116	121	134	-16.83
80	963	947	902	341	176	116	121	138	-17.95
82		958	912	347	182	116	120	144	-19.27
84		959	918	358	178	116	120	154	-20.88
86		960	921	486	217	116	119	163	-22.94
88		961	924	***	***	118	119	173	-26.00
90	978	961	926	***	***	114	119	***	-32.66

*** Measurements not reliable



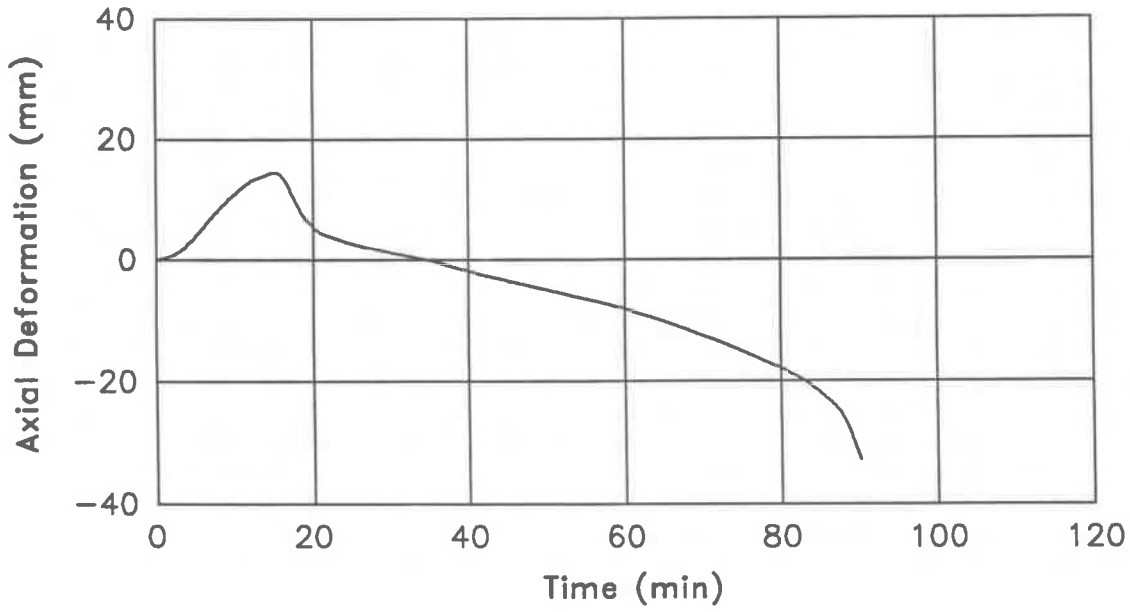
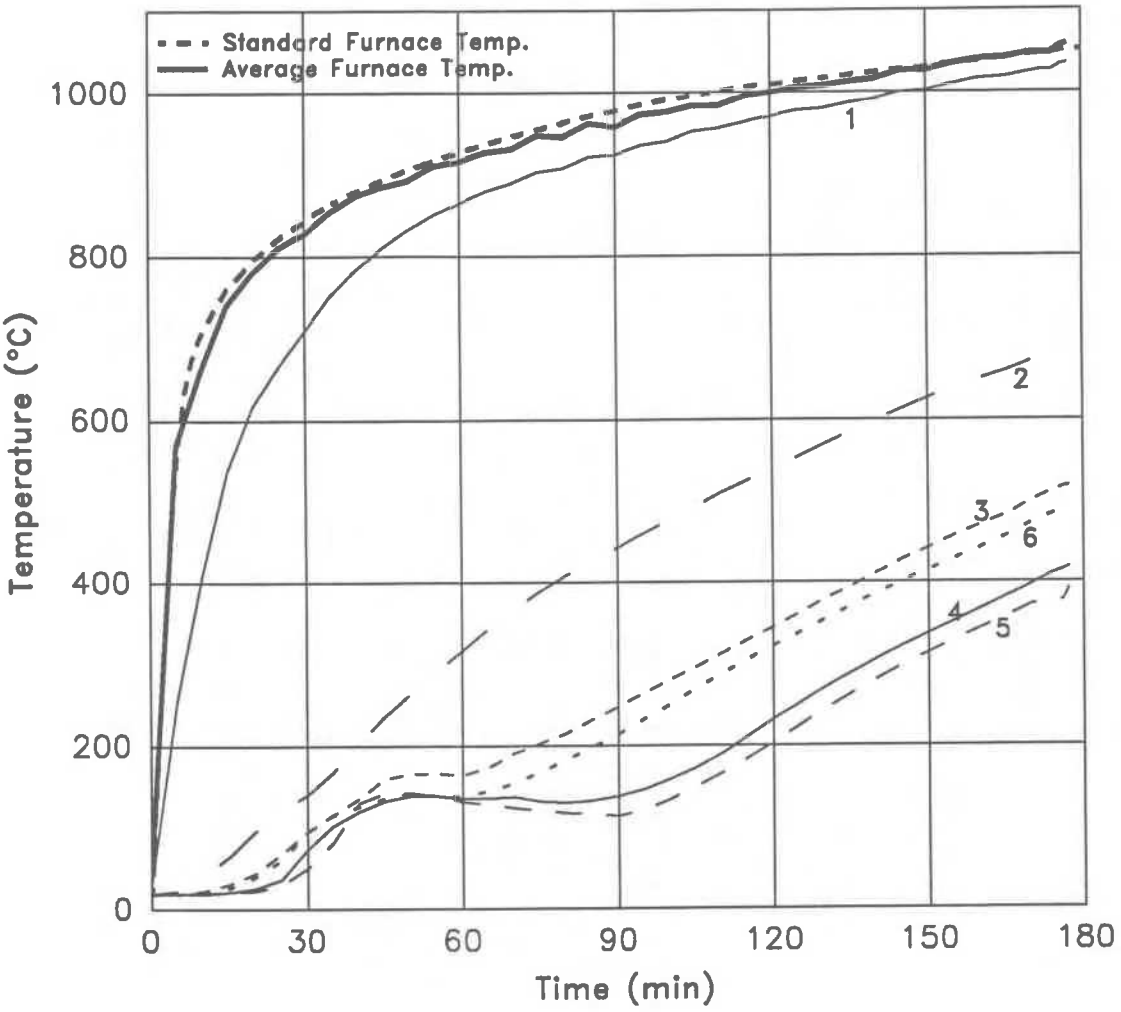


Figure A28. Temperatures and axial deformation of Column No. C-42

Table A29. Temperatures and axial deformation of Column No. C-44

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	54	32	19	19	19	20	19	0.00
5	538	569	255	23	19	19	20	19	4.21
10	704	662	409	41	23	19	20	22	11.41
15	760	740	538	65	31	21	21	27	17.77
20	795	780	617	96	44	26	23	39	20.36
25	821	810	666	123	68	36	29	60	14.22
30	843	828	710	141	96	74	51	96	5.83
35	862	853	751	168	116	103	82	116	3.85
40	878	873	784	204	137	121	131	127	2.39
45	892	884	809	235	160	134	143	137	1.31
50	905	892	832	262	166	140	144	143	0.41
55	916	910	850	290	167	140	139	140	-0.26
60	927	916	865	316	165	137	133	139	-0.86
65	937	927	879	343	174	137	129	145	-1.43
70	946	931	889	367	191	138	125	155	-1.82
75	955	948	902	389	203	133	122	169	-2.45
80	963	946	907	408	215	131	119	183	-3.16
85	971	963	921	426	231	134	117	198	-3.72
90	978	959	924	443	247	139	115	214	-4.47
95	985	973	936	460	263	147	122	232	-5.13
100	991	976	940	477	279	159	135	250	-5.96
105	996	984	953	493	295	173	150	268	-6.64
110	1001	984	957	509	311	190	166	286	-7.38
115	1006	996	964	524	328	211	184	304	-8.19
120	1010	1000	971	539	345	232	204	321	-9.41
125		1006	978	554	362	251	224	338	-10.47
130	1017	1008	980	569	379	270	244	354	-11.90
135		1013	987	584	395	288	262	371	-13.44
140	1024	1016	992	598	411	305	280	386	-15.19
145		1026	1000	612	427	321	297	401	-17.18
150	1031	1027	1003	625	442	337	313	415	-19.25
155		1035	1010	637	456	352	328	***	-21.75
160	1038	1040	1016	648	470	367	343	442	-24.64
165		1042	1018	658	483	382	358	456	-28.32
170	1045	1047	1024	670	499	397	373	473	-33.02
172		1047	1026	675	505	404	374	479	-35.51
174		1047	1026	679	511	410	374	484	-38.40
176		1056	1033	678	516	415	378	490	-43.66
177		1058	1035	678	518	418	392	492	-67.89

*** Measurements not reliable



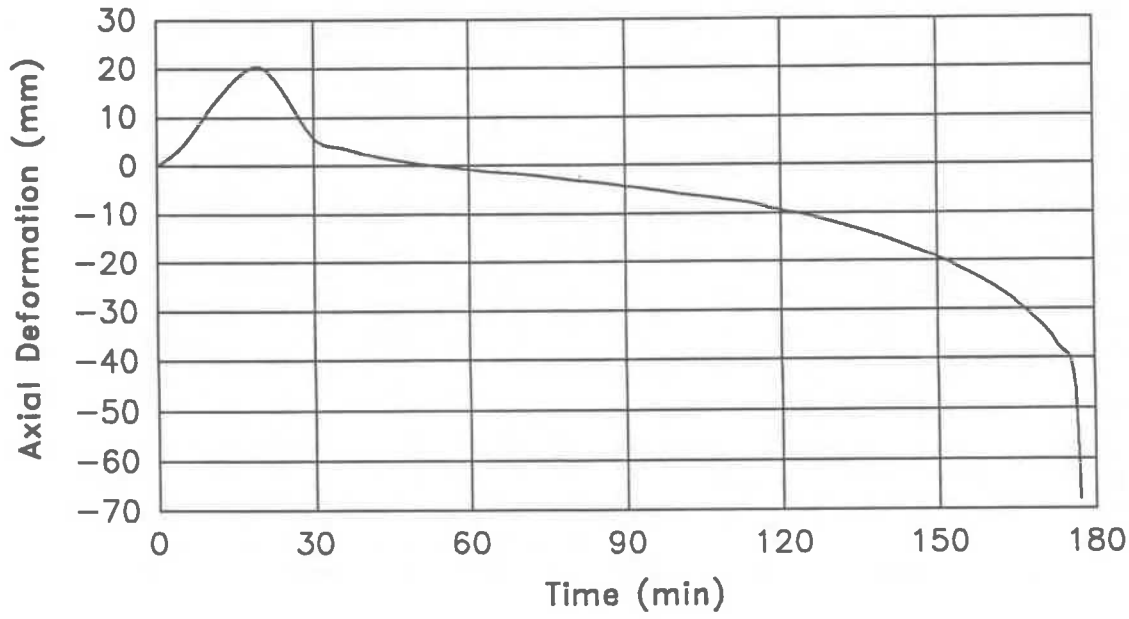
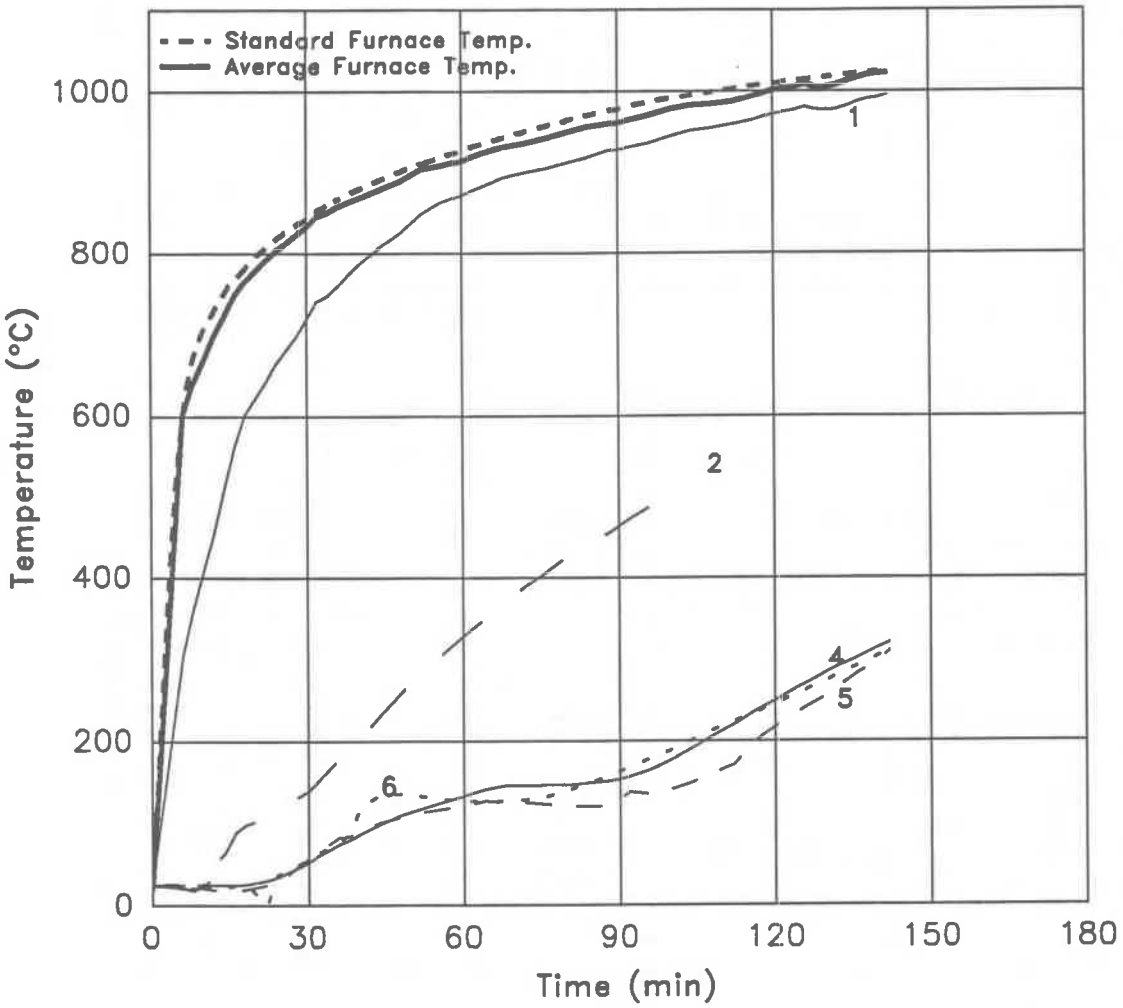


Figure A29. Temperatures and axial deformation of Column No. C-44

Table A30. Temperatures and axial deformation of Column No. C-45

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	***	***	***	***	***	***	***	0.00
2		***	***	***	***	***	***	***	***
4		***	***	***	***	***	***	***	3.69
6		602	306	27	25	21	21	21	6.77
8		638	358	33	25	18	21	21	9.54
10	704	667	407	41	26	25	21	22	12.37
12		697	453	51	33	25	19	22	14.75
14		721	508	64	***	25	19	23	16.68
16		748	563	89	***	25	18	24	18.51
18		765	602	98	***	26	20	26	19.22
22		791	640	107	***	30	25	0	7.62
24		802	663	116	***	34	27	36	5.43
26		811	680	125	***	39	36	42	4.70
28		823	698	132	***	45	48	49	4.20
30	843	834	720	140	***	52	57	56	3.82
32		845	739	151	***	60	65	63	3.47
34		849	746	165	***	67	74	70	3.15
36		856	758	178	***	74	83	78	2.60
38		862	772	190	***	80	84	86	2.19
40	878	867	785	203	***	87	91	120	1.79
44		877	806	231	***	99	101	135	1.11
48		888	824	259	***	110	108	136	0.51
52		903	847	284	***	118	113	133	-0.11
56		908	862	306	***	126	117	130	-0.64
60	927	915	872	328	***	134	121	128	-1.09
64		924	882	349	***	141	127	126	-1.51
68		931	893	369	***	145	126	127	-1.90
72		936	899	389	***	145	125	129	-2.30
76		942	904	407	***	146	123	133	-2.79
80	963	949	911	425	***	146	121	140	-3.24
84		956	918	442	***	148	120	148	-3.76
88		960	926	455	***	151	120	158	-4.31
92		964	930	473	***	156	138	168	-5.00
96		970	936	488	***	165	135	179	-5.56
100	991	978	944	502	***	177	141	189	-6.16
104		982	951	515	***	191	149	201	-6.92
108		984	954	***	***	206	160	213	-7.67
112		987	959	***	***	220	171	224	-8.81
116		994	964	***	***	236	200	234	-10.06
120	1010	1002	972	***	***	250	217	246	-11.74
122		1004	974	***	***	257	226	251	-12.65
124		1005	976	***	***	264	234	***	-13.61
126		1010	980	***	***	270	242	262	-14.61
128		1005	977	***	***	277	249	268	-15.84
130	1017	1005	976	***	***	284	256	274	-17.05
132		1007	977	***	***	290	265	280	-18.42
134		1012	981	***	***	296	274	286	-19.93
136		1016	986	***	***	302	283	292	-21.64
138		1020	990	***	***	308	290	298	-23.66
140	1024	1021	992	***	***	314	299	304	-26.58
142		1022	996	***	***	320	310	308	-43.24

*** Measurements not reliable



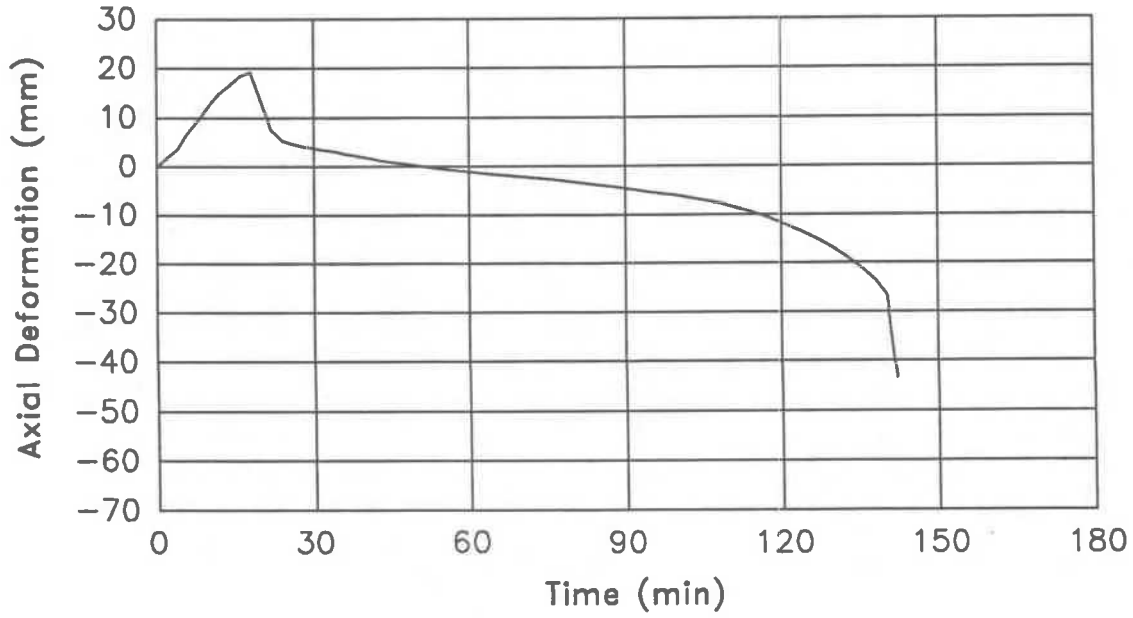


Figure A30. Temperatures and axial deformation of Column No. C-45

Table A31. Temperatures and axial deformation of Column No. C-46

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	50	22	15	16	15	16	***	0.00
2		419	125	15	16	15	16	***	0.78
4		588	220	17	16	15	15	***	2.72
6		604	271	22	16	15	15	***	5.88
8		645	300	28	17	15	15	***	8.40
10	704	670	357	35	18	15	16	***	10.64
12		692	343	47	24	17	17	***	12.26
14		704	443	62	32	23	25	***	12.86
16		747	490	80	42	30	34	***	12.66
18		767	506	93	53	39	41	***	7.63
20	795	783	537	95	60	43	42	***	5.51
22		791	585	96	64	48	44	***	4.40
24		800	618	99	67	49	46	***	3.77
26		813	650	108	71	52	48	***	3.34
28		824	672	113	81	55	51	***	2.96
30	843	834	692	116	103	60	55	***	2.63
32		845	710	116	112	72	69	***	2.28
34		852	726	130	115	103	101	***	1.92
36		853	734	142	117	115	113	***	1.31
38		860	746	154	113	112	110	***	-3.81
40	878	868	764	164	112	111	110	***	-5.91
42		876	779	173	113	112	110	***	-8.07
44		883	793	184	114	113	112	***	-10.38
46		890	805	195	116	114	113	***	-14.13
48		***	***	207	123	116	115	***	-23.61

*** Measurements not reliable

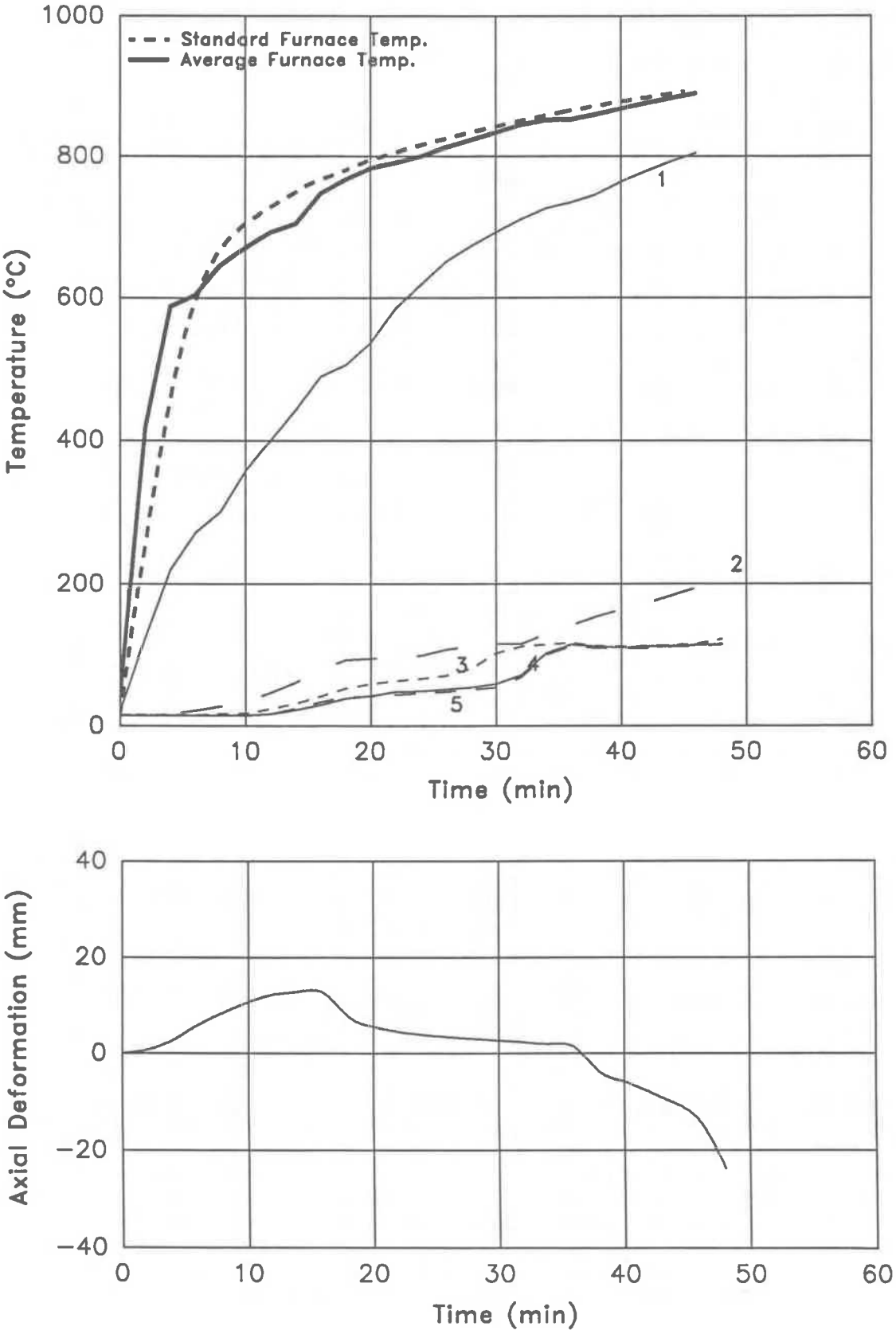


Figure A31. Temperatures and axial deformation of Column No. C-46

Table A32. Temperatures and axial deformation of Column No. C-50

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	49	29	23	23	23	23	23	0.00
2		178	61	23	23	23	23	23	0.13
4		347	113	23	23	23	23	23	0.79
6		632	239	23	23	23	23	23	4.80
8		677	352	23	23	23	23	23	9.40
10	704	681	420	23	23	26	31	23	12.48
12		704	466	24	26	67	93	24	14.99
14		728	505	24	31	72	95	28	17.08
16		749	533	26	35	75	96	31	18.73
18		764	550	28	38	77	96	33	19.32
20	795	782	570	32	40	78	96	36	18.83
22		798	595	35	42	59	55	37	13.33
24		809	619	39	42	50	49	38	6.03
26		822	650	43	41	46	46	38	4.90
28		833	678	47	41	44	43	38	4.26
30	843	838	696	51	42	43	44	39	3.79
32		846	714	56	43	44	45	40	3.42
34		853	730	60	45	45	46	42	3.04
36		859	738	64	47	48	51	44	2.62
38		869	757	68	49	50	53	46	2.30
40	878	874	770	72	52	54	57	49	2.03
50	905	902	835	95	80	112	131	75	1.11
60	927	925	870	126	100	107	113	96	0.55
70	946	944	892	142	119	125	132	116	-0.02
80	963	953	905	156	132	128	128	127	-0.76
90	978	972	926	172	136	127	124	134	-1.52
100	991	981	941	190	145	131	128	141	-2.33
110	1001	995	956	212	155	139	135	150	-3.15
120	1010	1008	972	236	167	148	145	159	-4.01
130	1017	1017	981	261	179	158	156	169	-4.91
140	1024	1027	997	285	191	172	171	180	-5.85
150	1031	1037	***	310	210	190	189	193	-6.97
160	1038	1045	***	336	240	215	213	216	-8.23
170	1045	1054	***	363	271	245	240	248	-9.77
180	1052	1058	***	391	299	273	267	280	-11.62
190	1059	1063	***	417	325	299	294	309	-13.60
200	1066	1076	***	443	350	324	319	336	-15.80
210	1072	1090	***	468	374	348	343	362	-18.38
220	1079	1100	***	491	398	371	367	389	-21.34
230	1086	1098	***	514	422	396	392	415	-26.03
232	***	1100	***	518	426	401	398	421	-28.38

*** Measurements not reliable

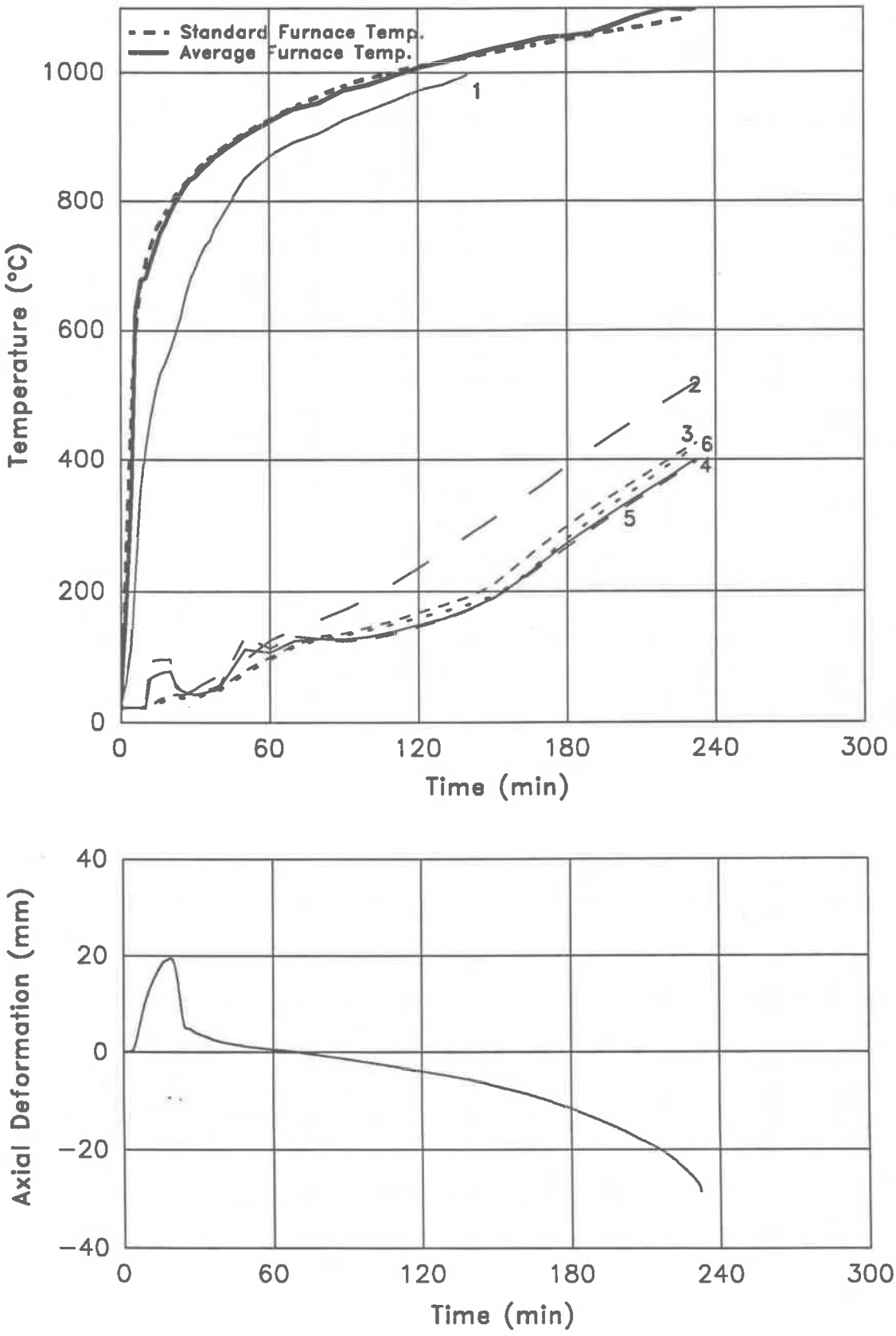


Figure A32. Temperatures and axial deformation of Column No. C-50

Table A33. Temperatures and axial deformation of Column No. C-51

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	57	25	20	21	21	21	21	0.00
2		448	111	20	21	21	21	21	0.45
4		539	202	20	21	21	21	21	2.43
6		604	227	21	21	21	21	21	5.46
8		637	272	21	21	21	21	21	8.34
10	704	672	329	23	21	20	21	20	10.99
12		696	390	25	21	21	21	20	13.18
14		719	466	27	21	21	21	21	14.76
16		752	529	31	22	21	21	21	15.39
18		767	568	35	23	21	22	21	13.85
20	795	778	591	40	25	22	22	21	6.48
22		789	609	46	27	22	23	22	4.84
24		798	627	52	30	23	24	23	4.01
26		814	650	59	33	24	25	25	3.51
28		821	672	67	37	26	28	27	3.05
30	843	831	694	74	41	28	28	29	2.65
32		840	712	82	47	31	30	32	2.29
34		848	727	90	53	37	34	35	1.90
36		854	740	98	59	46	40	39	1.42
38		860	745	106	66	59	50	43	1.00
40	878	865	753	113	73	107	64	48	0.62
42		880	768	120	81	133	87	53	0.27
44		896	791	125	91	136	105	58	-0.09
46		890	803	131	104	136	113	66	-0.41
48		896	814	136	115	135	125	76	-0.71
50	905	892	819	141	123	132	127	86	-0.99
52		898	826	147	128	129	127	94	-1.25
54		903	834	153	130	126	124	101	-1.52
56		910	845	158	130	124	122	106	-1.78
58		916	854	162	129	121	120	109	-2.04
60	927	920	864	166	128	118	120	111	-2.29
62		917	868	170	127	116	117	113	-2.55
64		922	874	173	127	114	115	114	-2.79
66		925	880	177	127	111	114	114	-3.02
68		930	887	181	128	110	111	113	-3.24
70	946	936	894	185	128	108	109	113	-3.46
72		943	902	189	129	106	107	112	-3.72
74		939	904	193	130	105	106	112	-4.12
76		942	905	196	132	105	104	112	-4.56
78		947	911	199	134	105	104	111	-4.96
80	963	936	906	202	136	105	104	111	-5.45
82		938	906	204	138	107	105	112	-5.84
84		956	916	206	140	108	104	112	-6.19
86		962	925	208	142	109	104	113	-6.59
88		970	933	211	144	110	105	114	-7.05
90	978	974	940	215	146	112	105	115	-7.53
92		972	943	219	148	113	105	116	-8.08
96		968	943	228	153	117	105	118	-9.13
98		975	948	233	155	118	106	119	-9.64
100	991	978	952	237	158	120	107	120	-10.18
102		978	954	242	160	121	108	121	-10.80
106		983	959	252	166	125	110	124	-12.22
108		987	963	***	168	126	112	125	-13.15
110	1001	988	966	262	171	127	113	***	-14.46
112		991	970	***	***	***	116	127	-34.40

*** Measurements not reliable

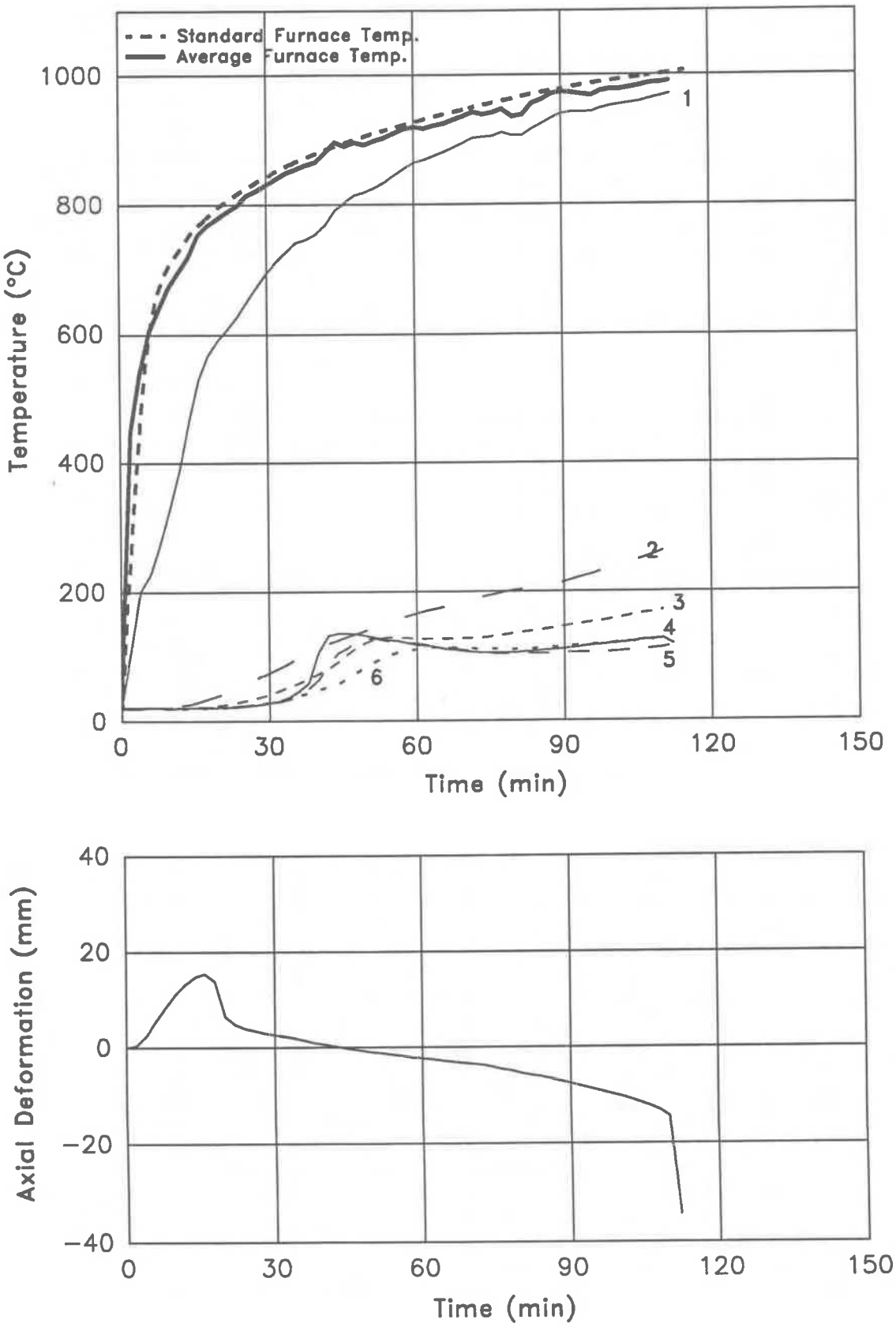


Figure A33. Temperatures and axial deformation of Column No. C-51

Table A34. Temperatures and axial deformation of Column No. C-53

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	54	21	15	15	15	16	16	0.00
2		463	124	15	15	15	16	15	0.90
4		488	181	15	15	15	15	15	***
6		614	282	17	15	15	16	15	***
8		643	355	19	15	15	15	15	8.47
10	704	671	413	23	15	16	64	15	11.13
12		698	459	29	17	21	86	21	13.47
14		729	495	35	20	30	73	16	15.37
16		743	521	43	25	38	62	21	***
18		759	552	50	29	43	63	29	***
20	795	776	580	58	34	46	67	30	***
22		791	600	67	38	49	62	33	5.05
24		804	621	77	42	49	58	37	4.22
26		819	641	87	46	48	55	40	***
28		829	665	98	51	48	48	44	2.76
30	843	837	690	104	56	49	43	49	2.20
32		840	706	119	62	51	40	53	1.80
34		848	719	129	69	56	45	58	1.47
36		857	732	139	75	61	48	59	1.16
38		864	741	149	83	66	52	61	0.82
40	878	871	748	156	91	73	56	62	0.53
44		884	774	162	108	86	63	67	-0.08
48		891	794	172	128	128	82	77	-0.55
52		902	809	190	133	131	122	88	-0.99
56		911	825	210	131	129	124	88	-1.46
60	927	919	840	230	130	127	135	90	-1.87
64		927	855	248	131	125	133	94	-2.23
68		933	866	266	132	122	131	96	-2.67
72		940	878	282	135	119	128	96	-3.07
76		946	890	298	138	116	128	94	-3.50
80	963	951	899	313	143	115	***	94	-3.93
84		958	909	328	148	114	***	92	-4.41
88		963	917	342	154	114	***	91	-4.89
92		968	924	356	160	114	***	92	-5.40
96		972	931	369	168	114	***	91	***
100	991	980	939	382	177	116	***	91	-6.48
104		980	943	395	186	119	***	119	-7.12
108		989	952	407	196	122	***	125	-7.77
112		990	958	419	206	127	***	126	-8.53
116		999	969	431	216	132	***	130	-9.45
120	1010	1000	970	443	226	137	***	127	-10.55
124		1006	975	454	236	142	***	130	-11.80
128		1010	979	466	246	148	***	130	-13.29
132		1015	984	477	255	154	***	***	-14.94
136		1020	990	488	265	161	***	***	***
140	1024	1023	995	499	274	170	***	***	-19.59
142		1023	995	506	279	***	***	***	-21.20
144		1024	995	511	284	***	***	***	-23.34
146		1026	998	515	288	***	***	***	***
148		1029	1001	***	294	***	***	***	-33.38
149		***	***	***	***	***	***	***	-42.75

*** Measurements not reliable

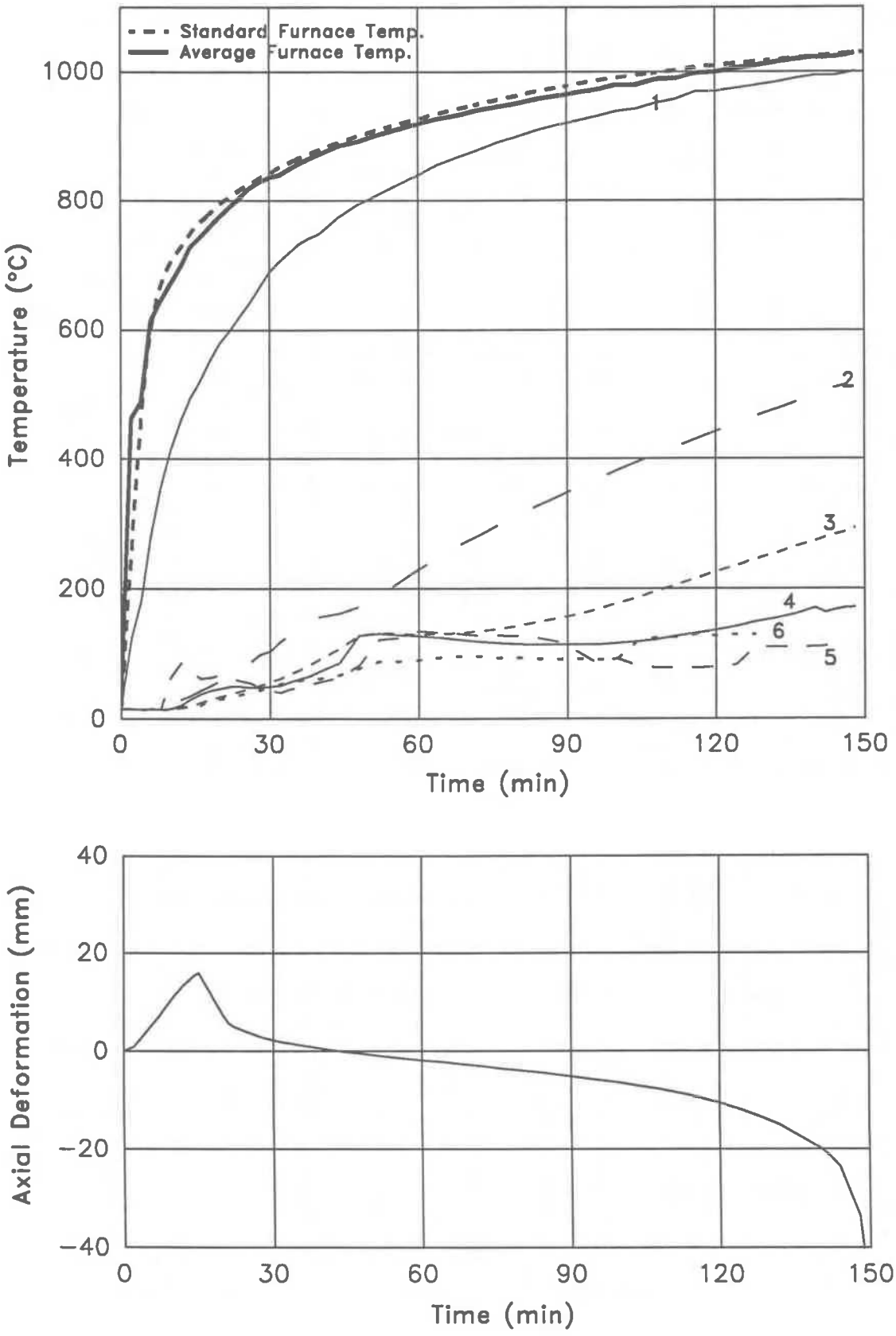


Figure A34. Temperatures and axial deformation of Column No. C-53

Table A35. Temperatures and axial deformation of Column No. C-55

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	49	22	19	19	19	19	19	0.00
2		412	72	19	19	19	19	19	0.50
4		568	133	20	19	19	19	19	2.62
6		608	186	23	19	19	19	19	4.78
8		671	250	28	19	19	19	19	7.53
10	704	682	302	34	19	19	19	19	10.10
12		715	357	40	20	19	19	20	12.79
14		732	406	45	21	19	21	20	15.17
16		745	452	51	22	20	23	21	17.46
18		771	495	62	23	20	24	22	19.38
20	795	781	529	75	25	21	25	23	20.85
22		798	563	83	27	21	26	25	22.02
24		811	594	89	30	22	28	27	22.55
26		822	622	95	33	23	34	30	22.47
28		822	641	103	37	24	37	33	20.87
30	843	837	661	111	41	25	29	38	17.10
32		849	679	122	45	25	27	43	8.96
34		859	697	132	51	26	27	49	5.40
36		851	712	143	57	27	28	56	4.27
38		870	728	153	64	28	30	63	3.52
40	878	880	739	162	70	30	32	69	2.88
50	905	904	785	205	91	43	48	102	1.03
60	927	917	840	252	114	59	68	124	0.48
70	946	950	879	297	140	81	95	143	0.13
80	963	954	904	337	149	108	126	152	-0.56
90	978	962	923	372	163	121	127	160	-1.27
100	991	992	942	405	179	126	125	173	-1.99
110	1001	988	949	435	199	127	123	192	-2.74
120	1010	998	962	464	222	129	125	214	-3.53
130	1017	1010	975	491	245	133	129	236	-4.35
140	1024	1036	986	516	267	138	136	***	-5.19
150	1031	1042	996	538	289	142	144	***	-6.07
160	1038	1049	1006	559	310	149	153	***	-7.02
170	1045	1061	1018	578	330	162	164	***	-8.02
180	1052	1067	1026	596	349	179	177	***	-9.16
190	1059	1068	1036	614	***	198	191	***	-10.42
200	1066	1085	1044	633	***	219	218	***	-11.98
210	1072	1091	1053	653	***	241	236	***	-13.71
220	1079	1100	1068	671	***	262	260	***	-15.65
230	1086	1103	1072	688	***	282	283	***	-17.85
240	1093	1113	1076	***	***	303	306	***	-20.36
250	1100	1123	1080	***	***	322	327	***	-23.20
260	1107	1123	1083	***	***	339	342	***	-26.52
270	1114	1135	1093	***	***	358	360	***	-30.82
272	1121	1133	1094	***	***	362	364	***	-32.34
274	1128	1130	1094	***	***	366	368	***	-37.25

*** Measurements not reliable

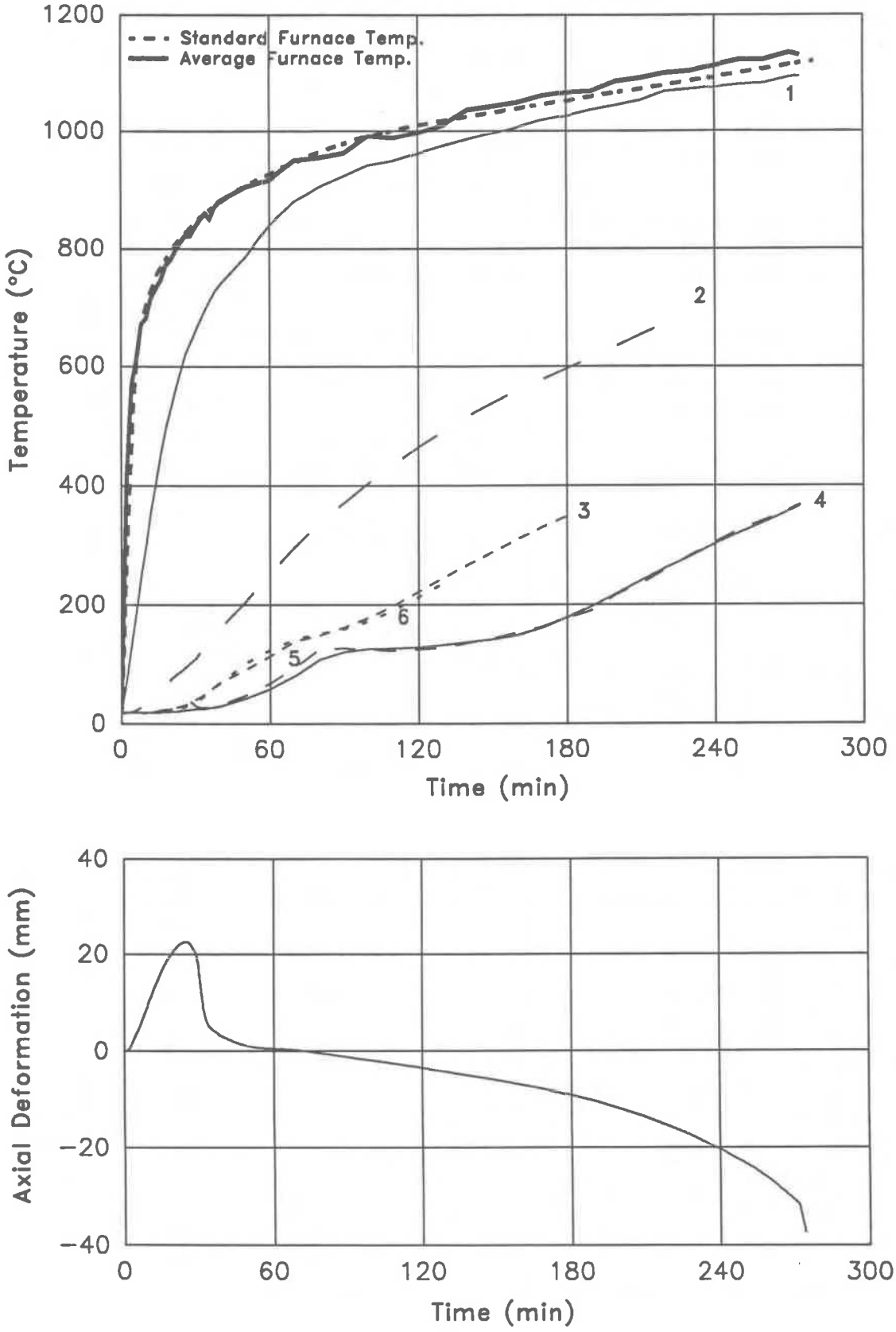


Figure A35. Temperatures and axial deformation of Column No. C-55

Table A36. Temperatures and axial deformation of Column No. C-57

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	54	27	18	18	18	18	17	0.00
2		509	135	18	18	17	18	17	0.41
4		525	205	18	18	18	18	17	2.06
6		591	284	18	18	18	18	17	4.34
8		643	356	18	19	18	17	17	7.37
10	704	672	415	18	19	19	18	17	10.07
12		702	464	19	23	19	18	18	12.34
14		720	501	19	19	20	18	18	13.81
16		747	537	20	22	21	18	18	14.21
18		766	562	21	20	20	18	18	11.71
20	795	777	590	22	24	20	18	18	5.53
22		789	621	24	25	19	18	18	4.38
24		800	642	26	24	18	18	18	3.72
26		816	664	29	21	18	18	18	3.28
28		829	687	32	21	18	18	18	2.85
30	843	837	703	36	21	18	18	19	2.53
32		842	716	40	20	18	18	19	2.20
34		850	727	45	20	18	18	20	2.03
36		854	737	49	19	19	19	21	1.75
38		859	746	54	19	19	19	22	1.42
40	878	865	750	59	19	19	20	23	1.17
50	905	896	810	80	24	24	24	30	0.37
60	927	920	854	94	34	33	35	55	-0.02
70	946	937	882	108	50	49	53	77	-0.36
80	963	950	905	125	110	90	74	91	-0.76
90	978	966	924	144	109	99	90	102	-1.25
100	991	975	938	161	112	106	100	108	-1.76
110	1001	990	954	178	109	109	106	111	-2.28
120	1010	1000	967	194	110	110	109	113	-2.81
130	1017	1010	981	207	113	113	112	117	-3.39
140	1024	1022	994	217	112	113	115	121	-3.93
150	1031	1031	1004	232	111	114	119	127	-4.50
160	1038	1040	1015	251	111	115	123	134	-5.06
170	1045	1047	1025	268	124	124	129	140	-5.64
180	1052	1057	1037	286	133	131	135	148	-6.25
190	1059	1067	1044	304	140	138	142	155	-6.86
200	1066	1074	1050	321	146	143	148	162	-7.48
210	1072	1078	1055	338	149	147	153	168	-8.10
220	1079	1088	1068	354	153	151	157	174	-8.74
230	1086	1095	1072	370	159	157	162	180	-9.39
240	1093	1105	***	387	169	166	168	191	-10.12
250	1100	1114	***	403	180	176	176	204	-10.90
260	1107	1118	***	419	194	190	186	219	-11.81
270	1114	1123	***	435	209	204	198	236	-12.92
280	1121	1135	***	450	226	220	215	254	-14.20
290	1128	1139	***	465	243	237	236	272	-16.06
292		1141	***	468	247	241	240	275	-16.78
293		***	***	***	***	***	***	***	-20.94

*** Measurements not reliable

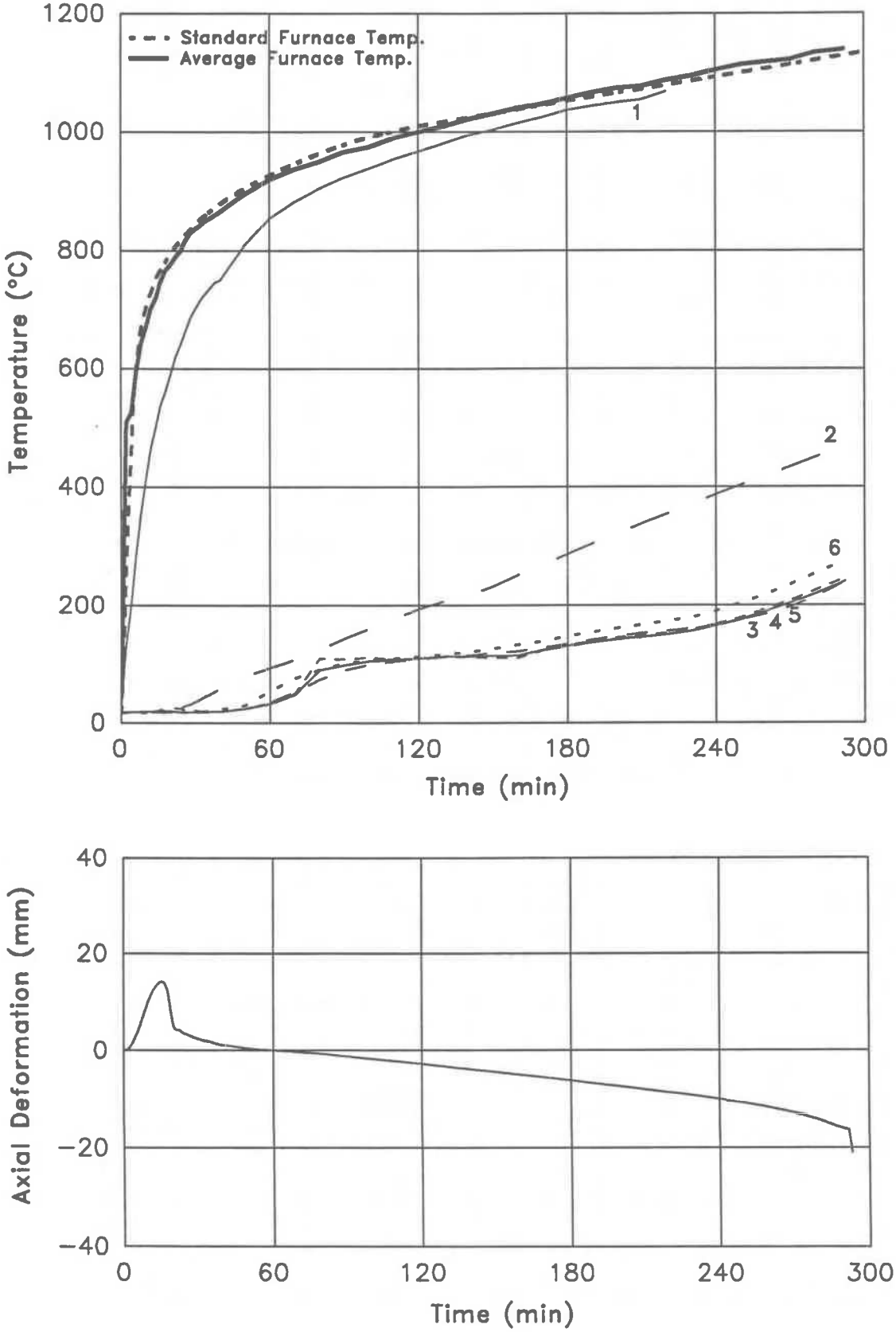
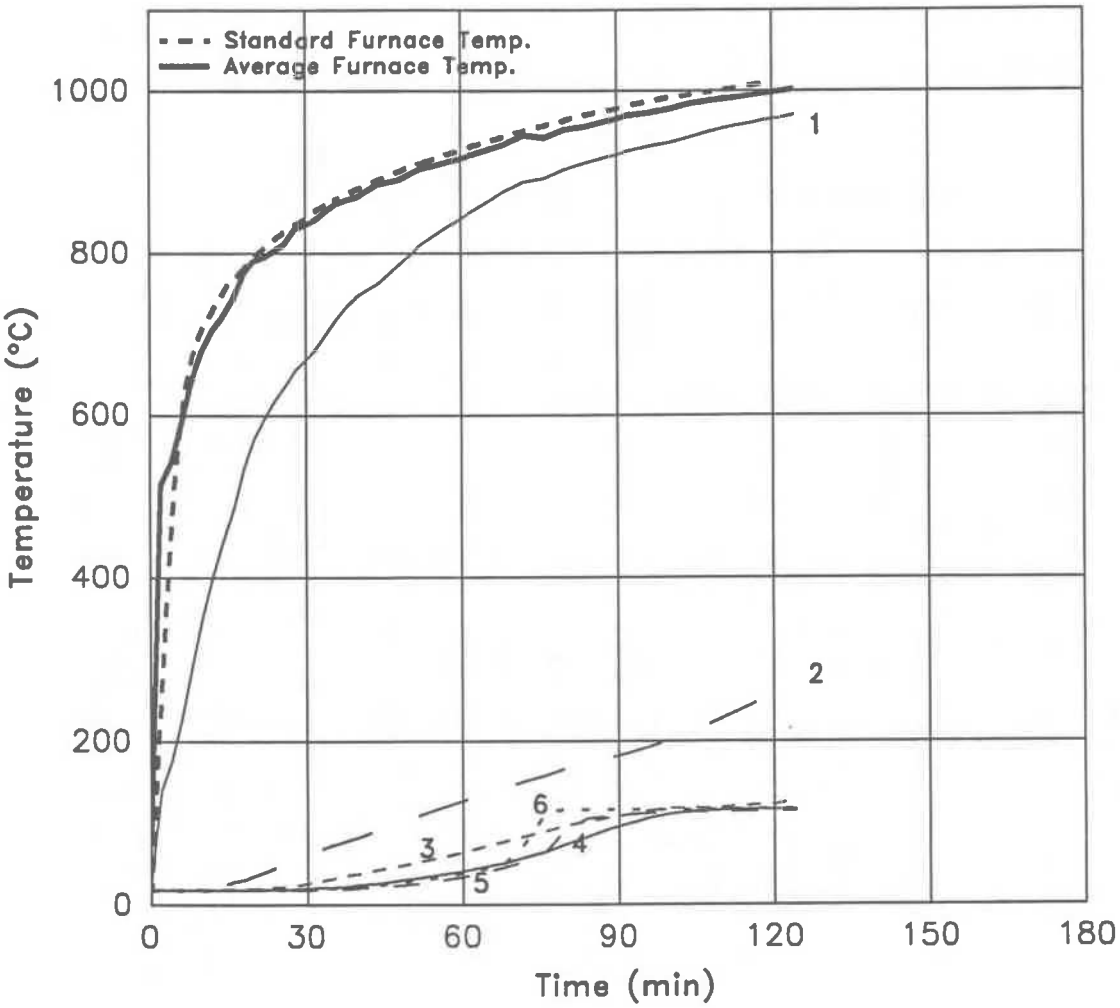


Figure A36. Temperatures and axial deformation of Column No. C-57

Table A37. Temperatures and axial deformation of Column No. C-59

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	91	30	18	19	18	19	18	0.00
2		514	140	18	19	18	19	18	0.05
4		542	177	18	19	18	18	18	0.85
6		592	229	19	19	18	19	18	2.17
8		640	289	20	19	18	18	18	4.17
10	704	679	352	21	19	18	18	18	6.69
12		704	401	23	19	18	18	18	9.42
14		721	444	25	19	18	18	19	11.89
16		744	485	28	20	18	18	19	14.12
18		775	534	31	20	18	18	19	16.09
20	795	791	569	35	20	19	18	19	17.73
22		795	596	40	21	19	18	19	18.32
24		803	617	45	22	19	18	19	18.27
26		811	635	50	23	19	18	19	15.66
28		830	656	56	24	20	18	19	7.51
30	843	***	***	***	***	***	***	***	***
32		841	681	66	28	21	19	20	3.78
34		851	700	71	31	21	19	21	3.10
36		860	719	75	33	22	20	21	2.59
38		865	734	79	36	23	20	22	2.12
40	878	869	747	83	38	25	21	23	1.65
44		884	762	92	43	27	22	25	0.63
48		890	785	100	48	30	24	28	-0.19
52		903	809	110	53	33	27	31	-0.91
56		909	826	119	58	37	30	34	-1.51
60	927	917	843	127	64	41	34	39	-2.07
64		925	858	135	71	46	39	44	-2.52
68		933	873	143	77	51	45	49	-2.87
72		945	887	151	84	58	53	76	-3.12
76		942	891	158	90	65	66	114	-3.47
80	963	952	902	166	97	74	93	116	-3.71
84		956	911	173	102	83	105	116	-3.99
88		963	918	179	106	92	108	116	-4.34
92		969	925	185	110	99	110	116	-4.71
96		972	931	193	115	106	112	116	-5.13
100	991	977	936	202	118	111	112	116	-5.61
104		984	943	212	119	114	113	116	-6.14
108		988	950	222	118	115	113	116	-6.92
112		991	956	234	120	116	114	117	-8.44
116		995	961	246	122	116	114	116	-11.58
120	1010	999	966	259	123	116	115	117	-15.63
122		1000	967	265	125	116	115	117	-18.59
124		1003	970	271	126	116	115	117	-23.76

*** Measurements not reliable



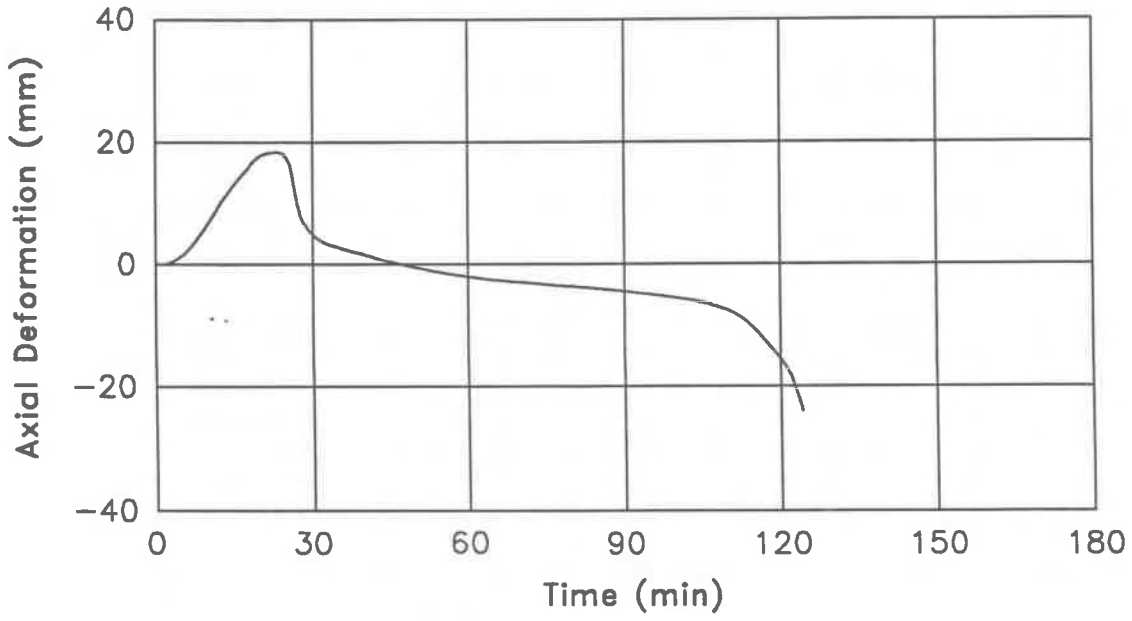
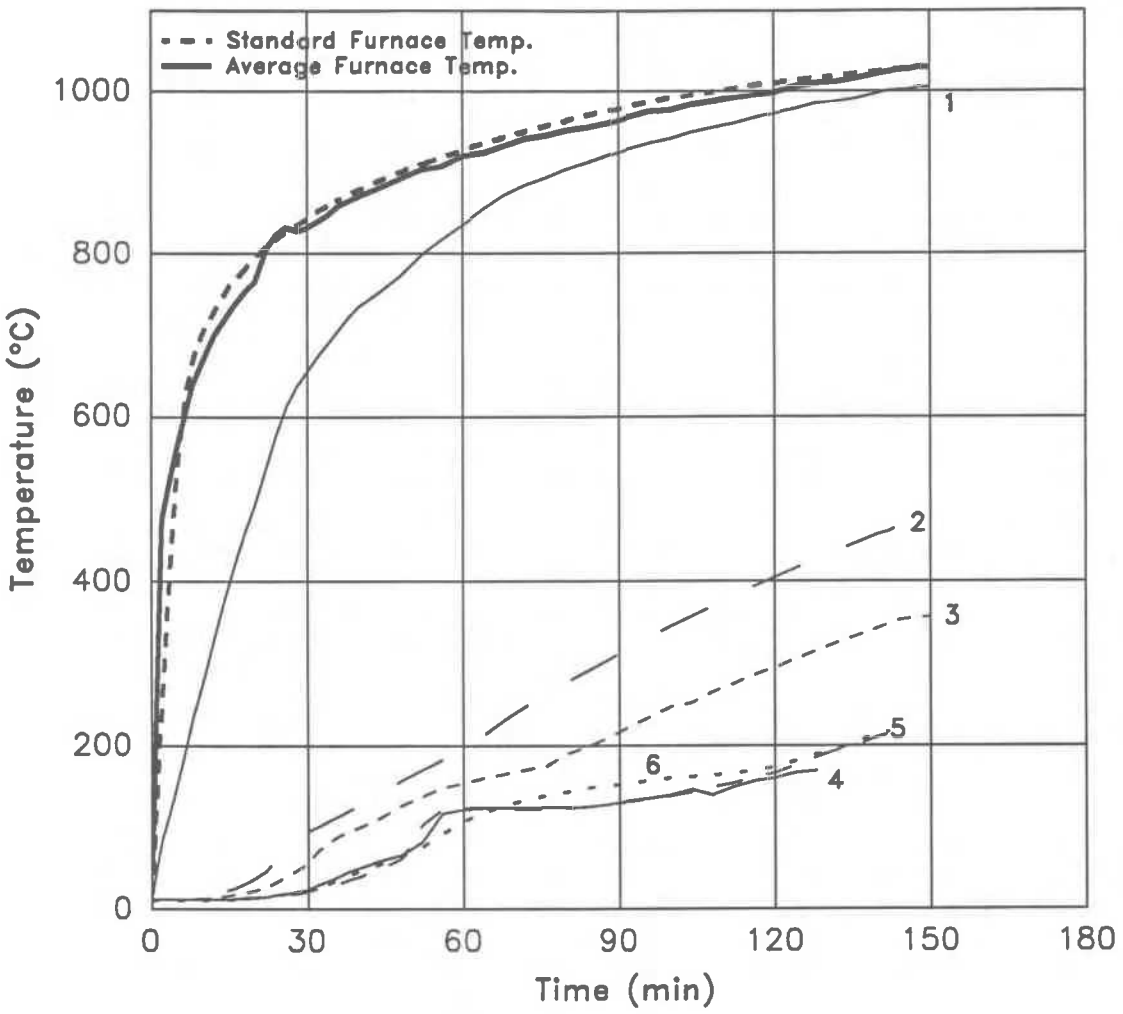


Figure A37. Temperatures and axial deformation of Column No. C-59

Table A38. Temperatures and axial deformation of Column No. C-60

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	51	16	12	12	12	12	11	0.00
2		476	84	12	12	12	12	11	0.33
4		540	132	12	12	12	12	11	1.55
6		592	182	13	12	12	12	11	3.42
8		639	233	14	13	12	12	11	5.55
10	704	670	280	16	13	12	12	11	7.76
12		699	330	19	14	12	12	12	10.16
14		718	377	22	16	12	12	12	12.46
16		738	421	26	18	13	13	12	14.61
18		753	460	31	20	14	13	13	16.51
20	795	765	494	37	23	14	14	14	18.03
22		803	536	45	27	15	15	15	19.31
24		821	576	60	32	17	16	17	19.70
26		831	612	78	39	19	18	19	18.74
28		827	637	87	47	21	19	20	11.79
30	843	832	655	95	56	24	22	23	6.10
32		839	672	101	70	29	25	27	4.73
34		847	689	108	81	34	28	31	4.02
36		858	706	114	89	39	31	36	3.46
38		864	722	121	95	45	35	41	2.99
40	878	870	735	128	101	50	39	46	2.51
44		880	752	143	112	59	49	55	1.39
48		892	773	157	127	66	61	64	0.64
52		903	798	170	138	82	103	76	0.00
56		907	817	183	148	117	123	92	-0.52
60	927	920	835	196	154	123	124	108	-0.96
64		923	854	213	160	124	124	119	-1.32
68		932	870	231	165	124	123	128	-1.60
72		941	883	248	170	124	123	134	-1.80
76		945	892	263	175	125	123	140	-2.03
80	963	951	902	278	190	125	124	144	-2.21
84		955	911	292	199	126	126	148	-2.44
88		961	920	306	210	129	128	151	-2.70
92		968	928	320	223	133	132	154	-2.98
96		975	936	333	235	136	135	157	-3.30
100	991	976	941	346	248	140	139	160	-3.66
104		983	949	358	253	146	144	162	-3.96
108		987	954	370	265	140	149	163	-4.34
112		992	960	382	275	149	154	166	-4.71
116		995	966	394	286	156	161	169	-5.10
120	1010	999	972	405	296	160	166	174	-5.53
124		1006	978	416	306	166	176	181	-5.97
128		1010	985	427	316	169	186	189	-6.41
132		1011	988	437	326	***	194	196	-6.92
136		1016	992	447	335	***	201	205	-7.45
140	1024	1021	998	457	344	***	211	215	-8.02
142		1024	1001	460	349	***	214	217	-9.76
144		1026	1002	466	353	***	***	***	-16.14
146		1027	1003	***	355	***	***	***	-19.44
148		1030	1005	***	356	***	***	***	-22.60
150	1031	1031	1006	***	358	***	***	***	-27.07

*** Measurements not reliable



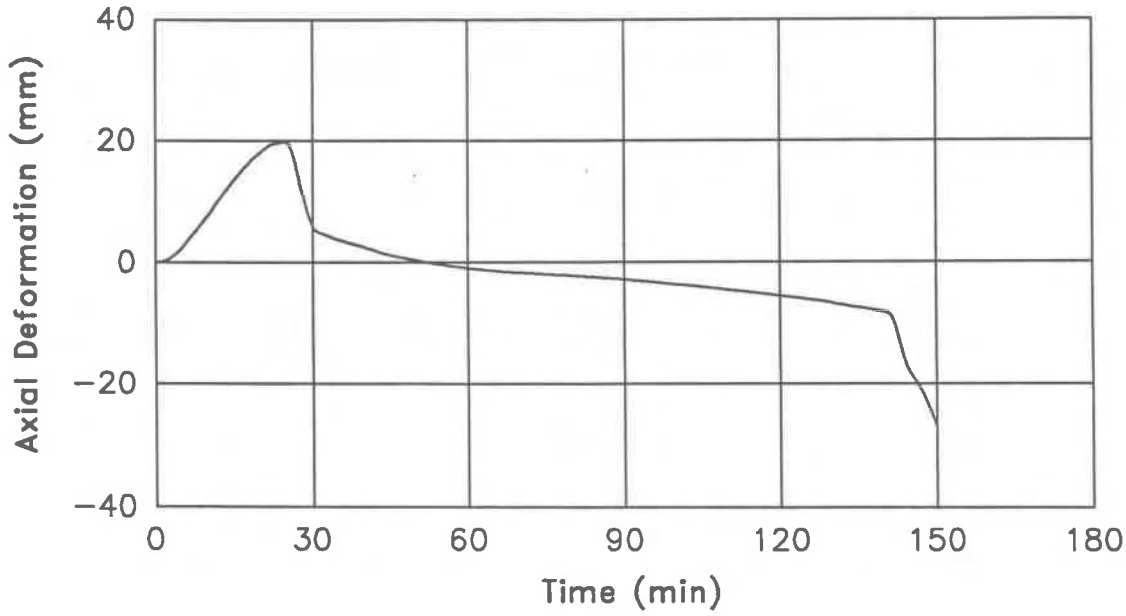
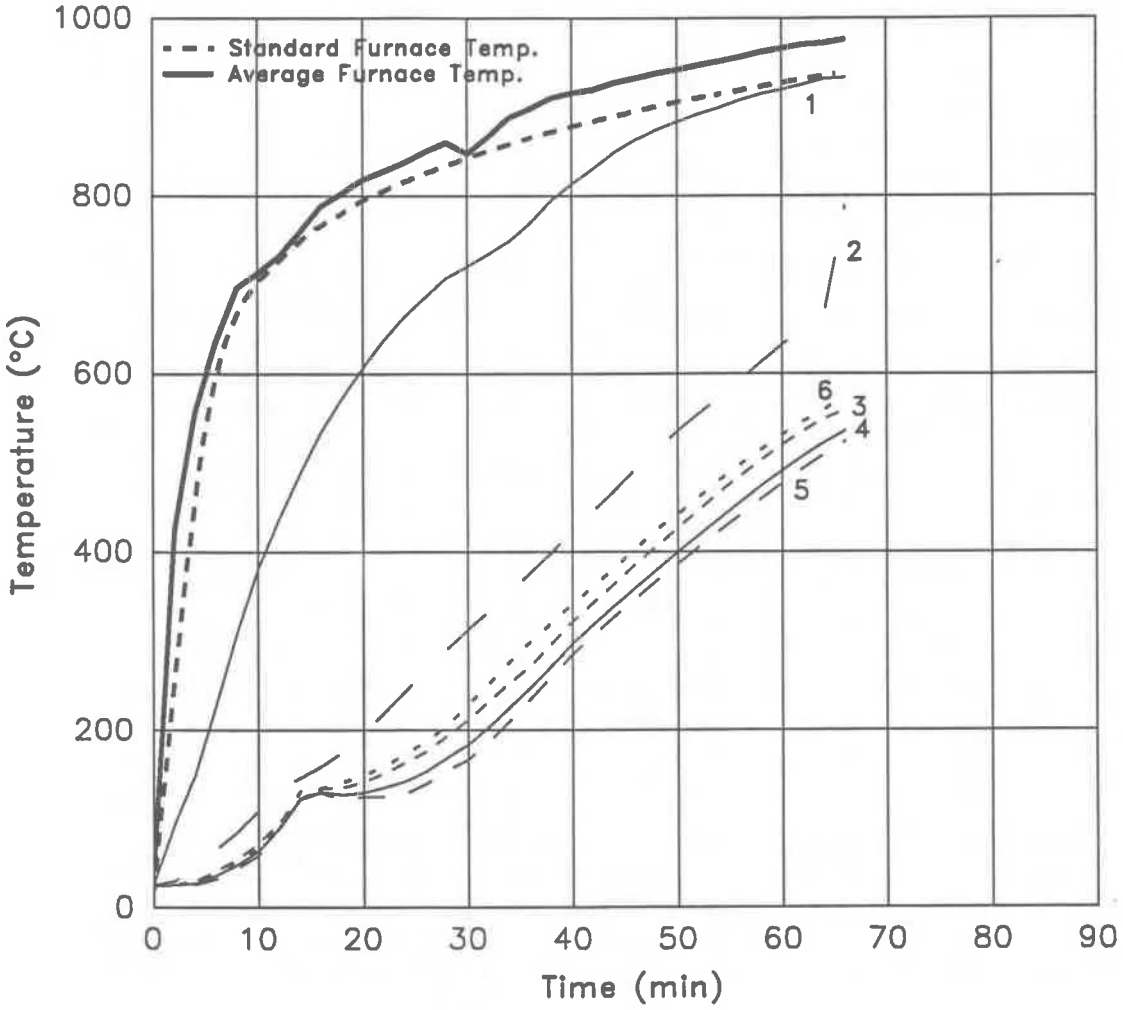


Figure A38. Temperatures and axial deformation of Column No. C-60

Table A39. Temperatures and axial deformation of Column No. SQ-01

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	46	27	25	24	24	24	25	0.00
2		424	94	30	25	25	25	25	0.86
4		556	150	46	30	27	26	30	3.03
6		636	230	65	41	36	32	40	6.03
8		697	311	85	55	48	44	53	9.43
10	704	714	381	109	72	63	58	66	12.72
12		732	437	133	96	89	90	94	15.14
14		760	487	146	123	122	125	131	17.18
16		788	534	159	134	130	129	134	18.92
18		803	572	175	135	127	122	141	19.52
20	795	819	607	197	141	129	124	149	19.55
22		828	638	220	151	135	124	159	19.54
24		838	665	244	163	142	128	173	19.07
26		850	687	268	176	153	139	187	18.19
28		860	708	291	194	169	154	206	16.82
30	843	848	721	313	212	184	167	229	15.24
32		867	735	334	233	204	187	253	14.09
34		888	749	356	254	226	211	277	12.64
36		898	770	377	273	249	236	300	11.32
38		910	795	400	298	273	262	321	10.41
40	878	916	814	423	322	297	285	342	9.76
42		919	831	446	344	319	307	362	9.30
44		927	849	469	365	340	328	383	8.87
46		932	863	492	386	360	348	403	8.33
48		938	874	514	406	380	368	425	7.63
50	905	942	883	535	427	400	386	442	6.75
52		947	892	554	446	418	405	460	5.68
54		951	899	572	466	437	423	479	4.38
56		956	907	593	484	455	441	497	2.85
58		962	914	613	502	473	459	514	0.95
60	927	966	919	633	520	490	476	531	-1.37
62		970	925	651	535	507	493	546	-4.40
64		972	931	669	549	522	508	559	-9.06
66		976	933	789	559	535	523	575	-33.40

*** Measurements not reliable



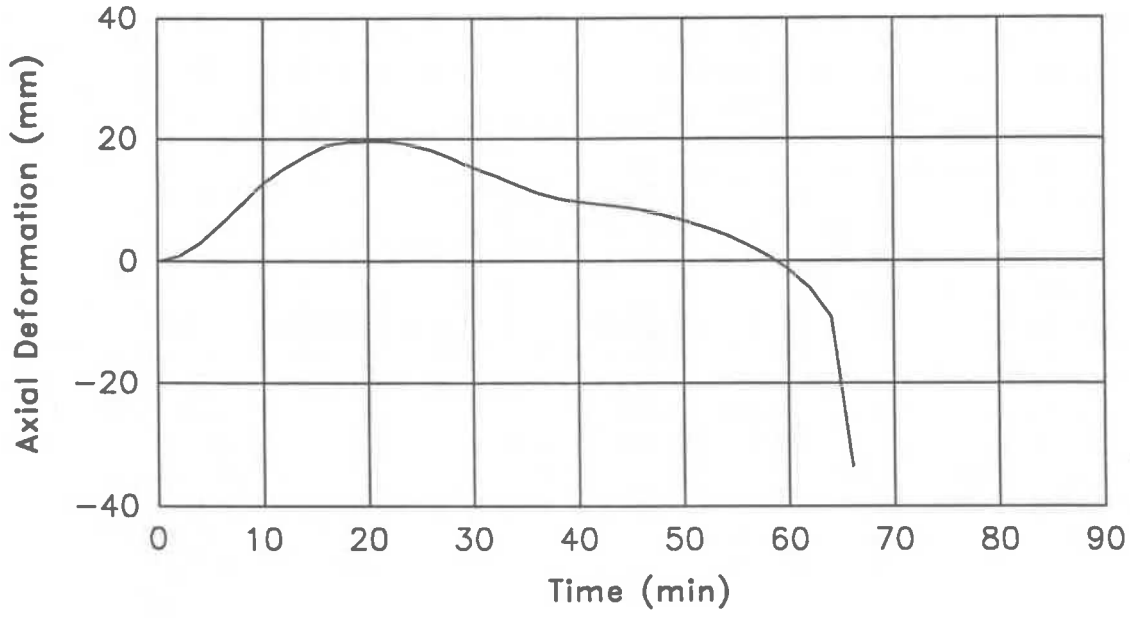


Figure A39. Temperatures and axial deformation of Column No. SQ-01

Table A40. Temperatures and axial deformation of Column No. SQ-02

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	49	21	18	12	11	11	11	0.00
2		445	166	18	12	11	11	12	2.36
4		550	207	19	17	12	12	12	5.43
6		618	273	26	26	14	13	16	8.32
8		655	333	68	37	19	16	22	11.10
10	704	724	404	115	50	28	21	30	14.04
12		701	428	136	64	37	29	39	16.23
14		731	473	156	82	48	44	51	17.89
16		751	512	171	105	62	62	65	19.70
18		759	538	184	115	115	90	92	20.99
20	795	774	567	198	129	131	114	128	21.96
22		802	603	225	141	139	133	150	22.27
24		806	622	240	152	141	138	160	22.32
26		804	645	250	163	140	138	157	22.22
28		814	669	267	171	139	135	151	20.81
30	843	827	693	***	180	141	131	151	17.83
32		845	714	***	187	145	133	156	13.23
34		860	737	***	199	152	138	164	9.80
36		870	752	***	215	157	143	171	7.43
38		865	751	***	231	163	150	179	5.75
40	878	859	764	***	244	162	149	188	4.51
42		873	785	***	254	144	145	199	3.55
44		889	798	***	255	140	139	212	2.83
46		894	812	***	254	135	139	223	2.12
48		888	818	***	239	133	142	234	1.49
50	905	889	825	***	254	133	149	246	0.99
52		895	832	***	282	161	158	263	0.54
54		900	839	***	306	184	181	277	0.09
56		903	847	***	328	209	200	292	-0.43
58		913	856	***	347	234	221	306	-0.96
60	927	923	865	***	365	259	243	322	-1.62
62		921	871	***	382	282	265	337	-2.39
64		924	877	***	399	303	284	352	-3.23
66		926	880	***	415	322	303	367	-4.16
68		935	884	***	430	340	320	382	-5.09
70	946	937	888	***	445	356	336	396	-6.23
72		950	896	***	456	371	352	411	-7.57
74		953	899	***	469	386	366	427	-9.04
76		952	903	***	481	400	379	441	-10.65
78		957	907	***	491	412	393	455	-12.53
80	963	963	911	***	498	418	407	469	-14.73
82		966	912	***	497	427	421	482	-17.49
84		963	907	***	499	440	435	495	-21.25
86		957	910	***	506	448	445	505	-28.73

*** Measurements not reliable

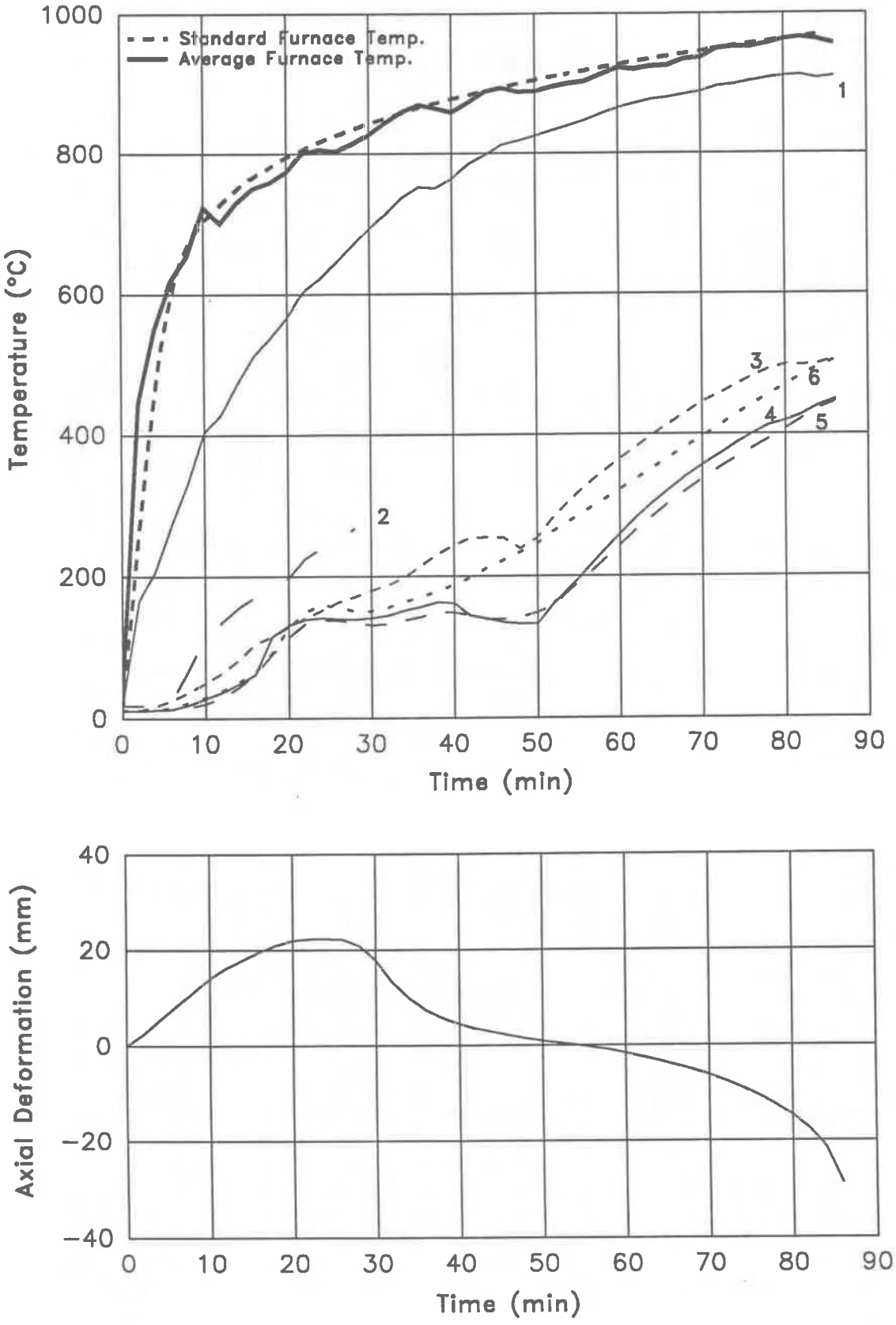


Figure A40. Temperatures and axial deformation of Column No. SQ-02

Table A41. Temperatures and axial deformation of Column No. SQ-07

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	44	26	17	17	17	17	17	0.00
2		352	109	17	17	17	17	17	***
4		603	193	19	18	17	17	20	***
6		638	234	24	20	19	19	27	7.18
8		674	296	32	25	24	23	37	10.31
10	704	698	352	41	33	31	31	48	13.10
12		717	408	53	43	40	41	62	15.44
14		746	462	69	56	53	56	87	17.16
16		735	495	93	78	78	88	114	17.84
18		743	522	110	98	104	109	121	18.28
20	795	732	539	122	112	115	116	125	18.33
22		750	559	132	123	123	118	132	18.31
24		755	575	138	129	125	117	138	17.61
26		759	586	145	131	127	120	146	16.62
28		765	600	151	134	130	123	154	15.59
30	843	760	612	159	138	133	125	162	14.67
32		765	625	164	143	138	129	171	13.88
34		756	634	173	149	142	133	180	13.30
36		779	651	181	154	146	135	189	12.85
38		781	662	192	158	148	135	199	12.43
40	878	772	668	202	165	152	142	210	12.10
42		776	677	213	173	159	153	222	11.86
44		795	689	226	182	169	166	235	11.64
46		798	697	240	194	181	178	249	11.40
48		788	702	255	209	194	192	263	11.18
50	905	812	714	270	225	210	207	278	10.98
52		795	716	284	242	226	224	293	10.67
54		813	726	298	257	243	241	308	10.39
56		824	732	312	272	259	257	323	10.06
58		805	729	325	287	274	273	337	9.71
60	927	806	732	338	301	289	287	350	***
62		799	737	351	314	302	301	363	9.02
64		869	759	363	327	315	314	376	8.84
66		934	804	375	339	328	327	388	8.30
68		979	863	387	351	340	339	401	8.24
70	946	984	897	398	362	352	351	412	7.52
72		990	919	410	374	363	362	424	6.50
74		995	929	422	385	374	373	435	5.04
76		996	932	434	395	384	383	447	3.14
78		1011	939	446	406	395	394	460	0.72
80	963	1021	950	459	418	405	404	471	-3.32

*** Measurements not reliable

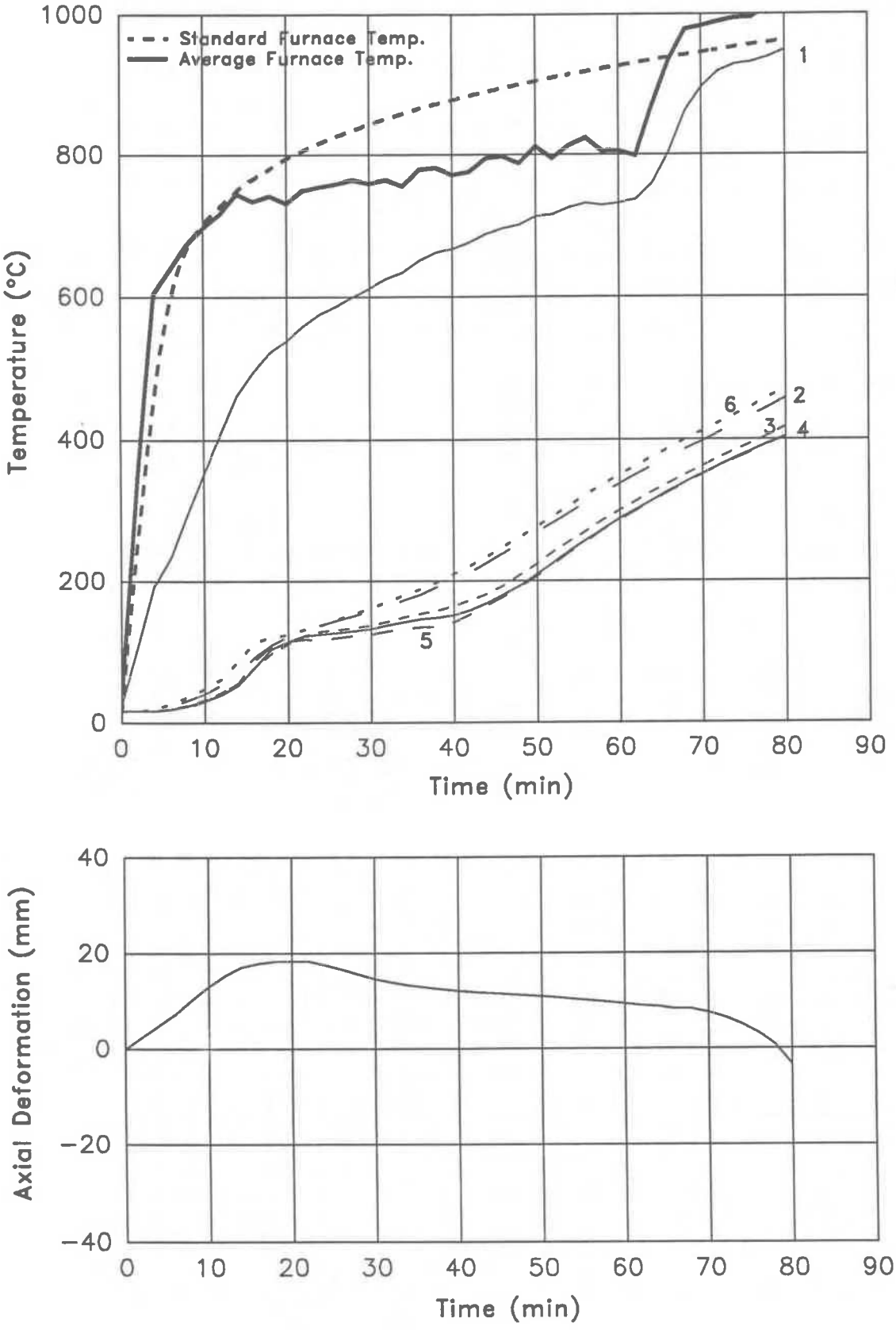
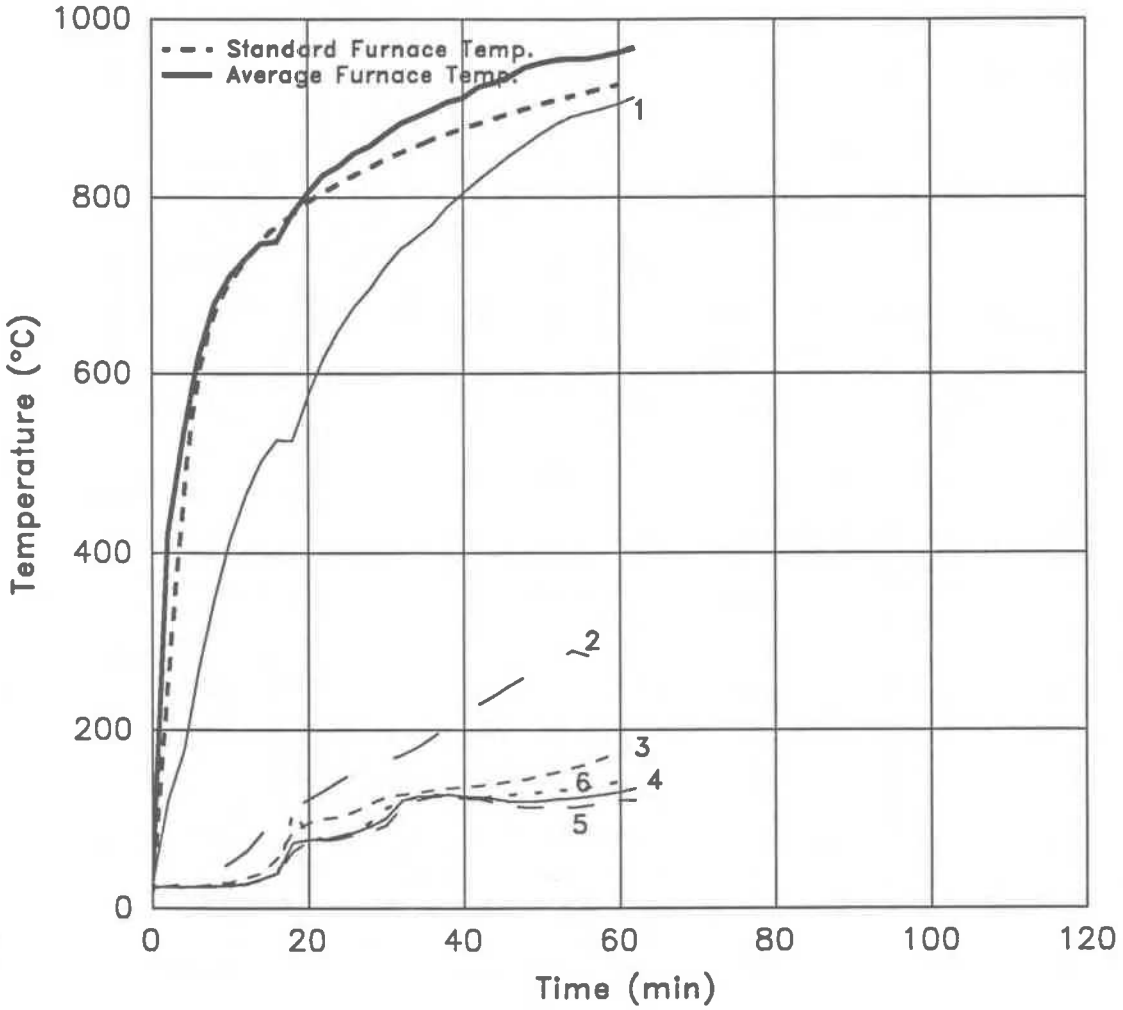


Figure A41. Temperatures and axial deformation of Column No. SQ-07

Table A42. Temperatures and axial deformation of Column No. SQ-17

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	47	29	24	24	24	24	24	0.00
2		421	121	25	24	24	24	24	0.67
4		533	176	28	24	24	24	24	3.16
6		619	268	34	25	24	24	24	6.30
8		680	349	41	27	25	24	25	9.66
10	704	710	415	51	29	26	24	26	12.67
12		731	466	64	34	28	27	28	14.69
14		748	502	83	39	33	33	32	15.57
16		750	526	102	56	39	40	38	15.51
18		781	525	112	86	73	63	108	10.99
20	795	806	576	122	96	77	76	82	6.58
22		825	617	131	100	77	75	77	5.60
24		836	650	143	102	81	78	81	5.00
26		850	676	152	109	85	82	85	4.62
28		858	697	158	118	92	86	97	4.24
30	843	871	721	165	124	101	93	112	3.82
32		884	742	172	127	121	113	120	3.45
34		891	755	180	129	125	121	125	3.07
36		899	770	192	132	126	125	127	2.70
38		907	790	206	134	127	126	126	2.39
40	878	912	805	217	136	125	123	123	2.12
42		924	820	229	137	124	122	123	1.87
44		929	834	239	139	122	118	126	1.61
46		936	847	250	142	119	115	127	1.35
48		946	860	260	144	119	113	128	1.07
50	905	951	872	269	148	120	113	130	0.75
52		955	883	279	152	122	113	131	0.39
54		956	891	289	157	123	113	133	0.01
56		956	896	***	162	125	115	135	-0.40
58		959	900	***	168	127	118	138	-0.83
60	927	963	906	***	175	130	121	142	-1.40
62		968	912	***	***	134	121	124	-40.17

*** Measurements not reliable



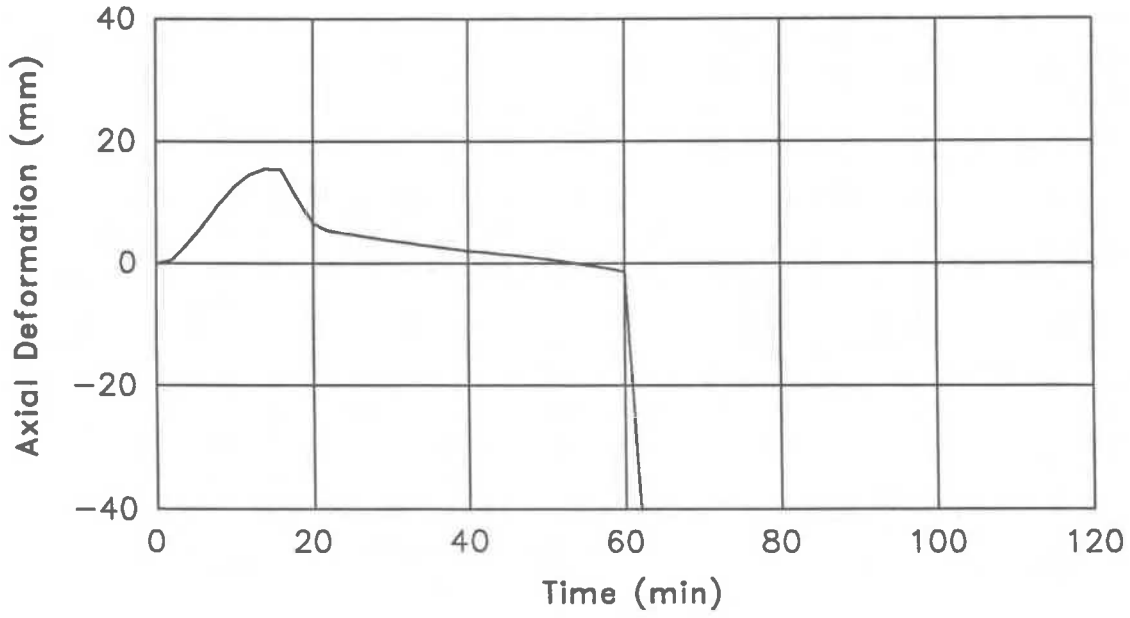


Figure A42. Temperatures and axial deformation of Column No. SQ-17

Table A43. Temperatures and axial deformation of Column No. SQ-20

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	52	22	17	18	18	18	18	0.00
2		460	105	17	18	18	18	18	0.77
4		554	174	18	18	18	18	17	3.59
6		607	236	19	18	18	18	17	6.25
8		641	301	22	18	18	19	17	9.33
10	704	663	348	26	18	18	20	18	11.99
12		696	397	30	19	18	20	18	14.05
14		727	441	36	20	19	21	19	15.61
16		740	482	42	22	20	22	19	16.43
18		781	524	49	24	21	23	20	16.44
20	795	788	552	56	26	22	27	22	11.19
22		782	550	63	29	24	26	23	3.70
24		803	579	71	33	26	27	25	2.73
26		805	603	80	36	28	29	27	2.02
28		814	***	90	40	31	31	30	1.47
30	843	825	***	100	45	34	34	33	1.10
32		835	***	109	49	37	37	36	0.75
34		850	***	118	54	41	41	40	0.36
36		859	***	128	59	45	45	44	-0.08
38		866	***	141	65	49	50	48	-0.53
40	878	873	***	142	71	54	54	53	-0.98
42		879	***	145	78	60	58	58	-1.40
44		886	***	150	85	65	66	64	-1.78
46		891	***	154	91	71	73	71	-2.13
48		897	***	157	96	77	85	79	-2.45
50	905	903	***	160	101	85	108	91	-2.74
52		908	***	164	108	94	115	99	-3.02
54		913	***	168	114	102	120	106	-3.28
56		920	***	172	118	109	126	114	-3.54
58		923	***	176	120	115	126	121	-3.81
60	927	925	***	184	122	119	126	124	-4.12
62		927	***	191	124	122	125	126	-4.43
64		929	***	199	125	124	124	127	-4.75
66		939	***	206	126	125	123	127	-5.06
68		943	***	213	127	125	122	127	-5.40
70	946	948	***	220	129	126	121	127	-5.76
72		948	***	226	129	126	120	127	-6.15
74		950	***	232	130	126	119	127	-6.52
76		950	***	237	130	126	118	128	-6.91
78		953	***	241	131	125	118	128	-7.30
80	963	961	***	246	132	125	120	128	-7.67
82		961	***	251	133	126	121	128	-8.07
84		962	***	256	134	126	120	126	-8.50
86		966	***	261	135	126	120	125	-8.91
88		970	***	265	136	127	121	125	-9.35
90	978	977	***	269	138	127	123	126	-9.79
92		981	***	273	139	128	124	127	-10.29
94		978	***	277	141	128	125	128	-10.86
96		985	***	283	142	128	126	130	-11.64
97		***	***	***	***	***	***	***	-20.88

*** Measurements not reliable

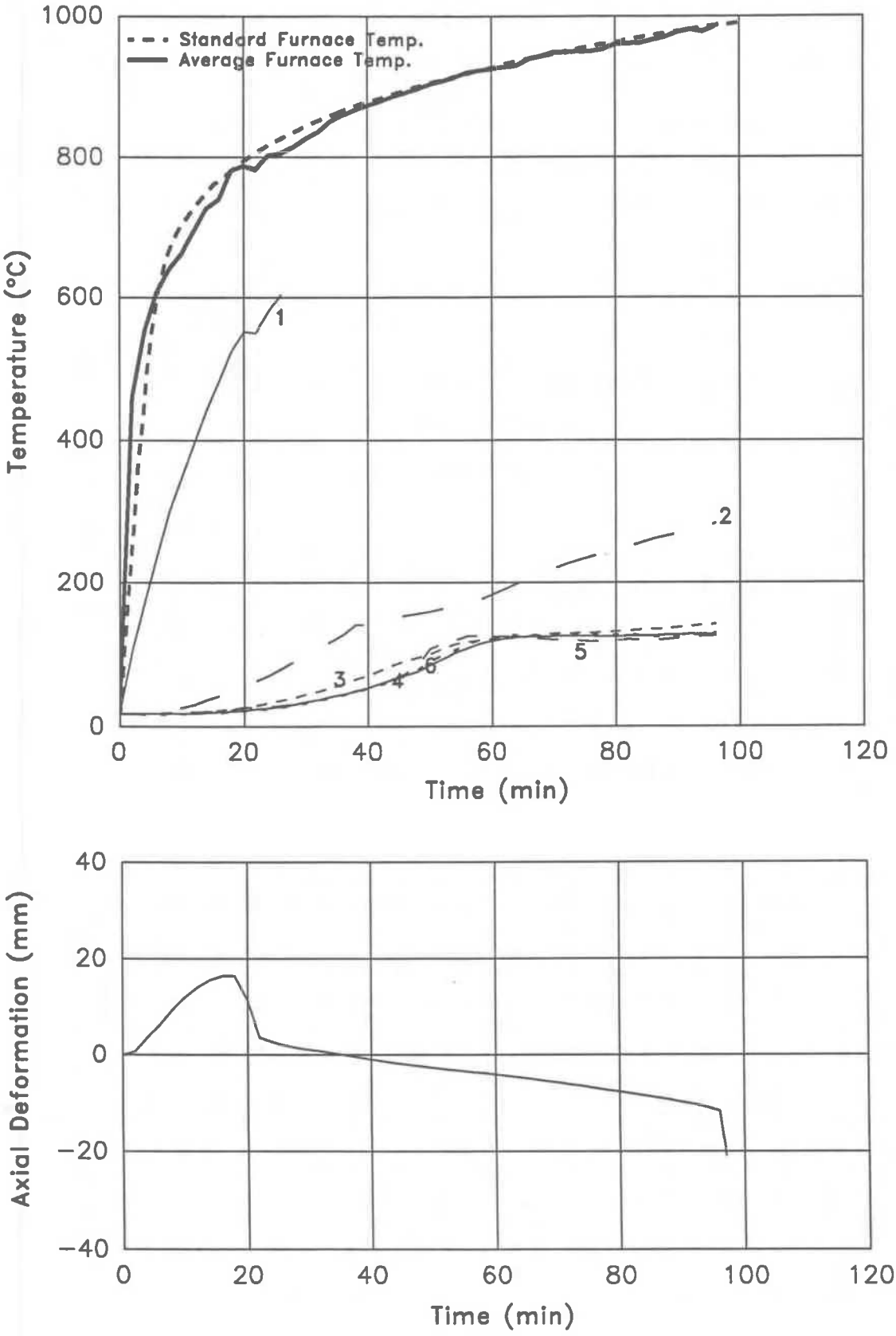


Figure A43. Temperatures and axial deformation of Column No. SQ-20

Table A44. Temperatures and axial deformation of Column No. SQ-24

Time (min)	Std. furn. temp. (°C)	Avg. furn. temp. (°C)	Column cross-section temperature (°C) measured at Thermocouple No. 1	2	3	4	5	6	Axial Def. (mm)
0	20	46	***	21	21	21	21	21	0.00
2		397	***	21	21	21	21	21	0.44
4		542	***	21	21	21	21	21	3.03
6		597	208	22	21	21	22	21	5.89
8		668	288	24	22	21	22	22	9.21
10	704	657	338	27	23	22	22	22	11.47
12		693	400	31	25	22	22	23	13.51
14		739	451	35	27	23	23	25	15.26
16		730	477	39	29	24	24	26	15.80
18		752	493	45	32	26	26	29	15.96
20	795	774	519	51	36	28	29	32	15.94
22		791	535	57	40	32	32	35	13.21
24		803	533	63	45	35	36	39	8.98
26		813	566	69	50	39	40	44	7.78
28		823	599	74	55	43	44	49	7.28
30	843	833	627	80	61	48	48	55	6.96
32		844	***	86	66	52	52	61	6.68
34		849	***	92	72	57	57	68	6.46
36		857	***	98	77	62	62	77	6.20
38		863	761	104	82	77	88	88	5.95
40	878	871	***	109	89	86	95	108	5.74
44		882	***	120	103	104	110	119	5.35
48		895	***	129	116	113	116	120	5.08
50	905	898	***	133	121	117	118	120	4.98
54		905	***	142	127	123	117	118	4.82
58		914	***	147	130	123	116	117	4.70
60	927	918	***	150	132	122	114	119	4.66
64		923	***	156	134	121	112	124	4.57
68		933	***	164	134	120	112	129	4.50
70	946	939	***	168	135	120	113	132	4.45
74		942	***	177	140	120	116	138	4.36
78		948	***	188	146	121	120	145	4.27
80	963	953	***	194	150	123	122	148	4.23
84		956	***	205	157	127	125	155	4.13
88		965	***	217	165	131	129	163	4.02
90	978	968	***	224	169	133	132	167	3.96
94		971	***	236	178	139	137	175	3.81
98		977	***	249	189	146	143	183	3.68
100	991	978	***	255	194	150	146	187	3.60
104		984	***	268	205	158	153	195	3.42
108		988	***	281	216	168	160	204	3.24
110	1001	991	***	287	222	172	163	208	3.12
112		993	***	294	228	177	167	212	2.98
114		995	***	300	234	182	171	216	2.84
116		997	***	307	240	187	175	221	2.67
118		999	***	313	246	193	179	225	2.45
120	1010	1004	***	320	252	198	184	230	2.06
122		1003	***	326	258	204	189	235	1.62
124		1007	***	333	264	210	195	241	1.14
126		1010	***	339	270	215	200	246	0.58
128		1012	***	345	276	221	206	252	-0.27
130	1017	1014	***	352	282	227	212	258	-1.69
131		***	***	***	***	***	***	***	-11.00

*** Measurements not reliable

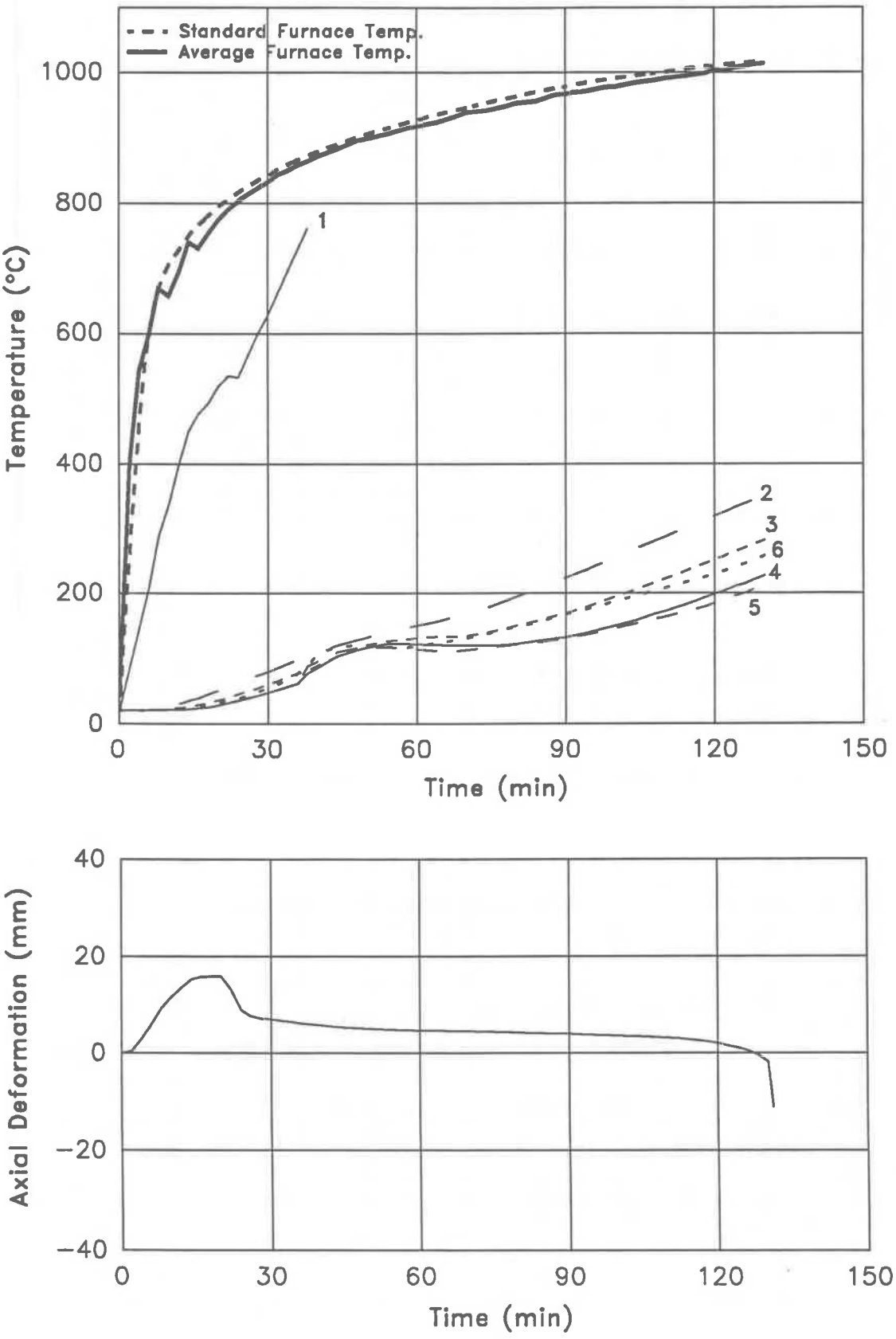


Figure A44. Temperatures and axial deformation of Column No. SQ-24

APPENDIX B

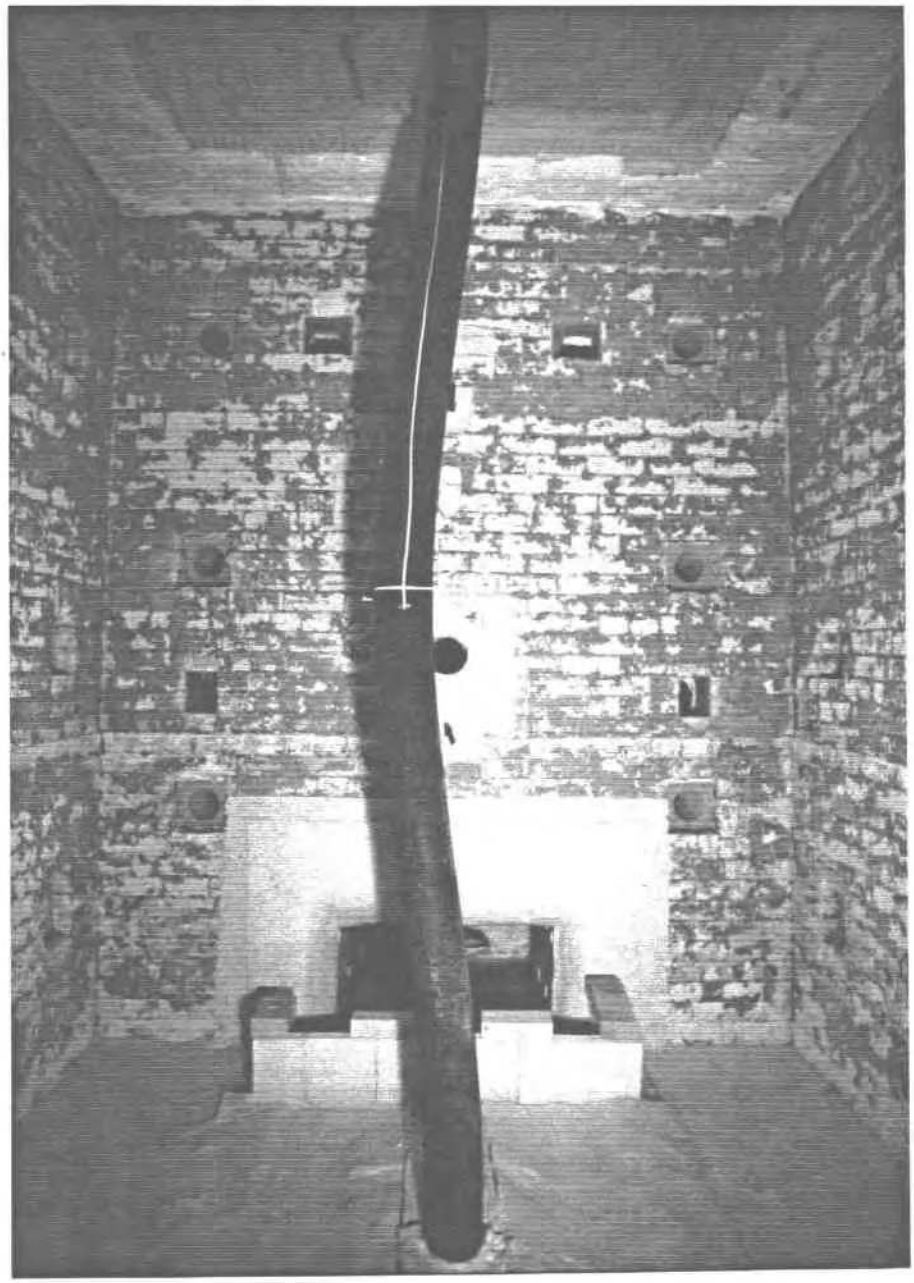


Figure B1. Column No. C-02 after test

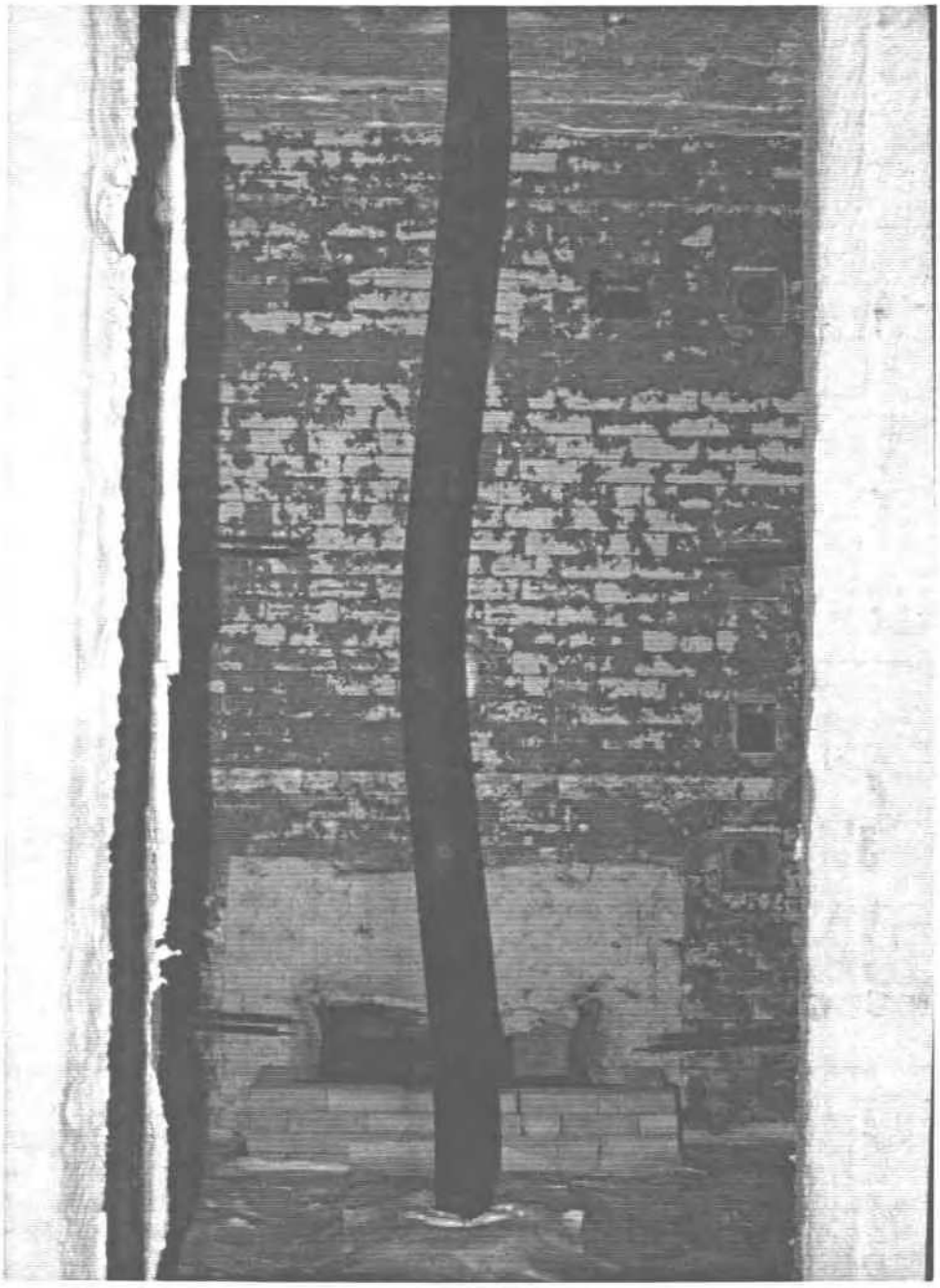


Figure B2. Column No. C-04 after test

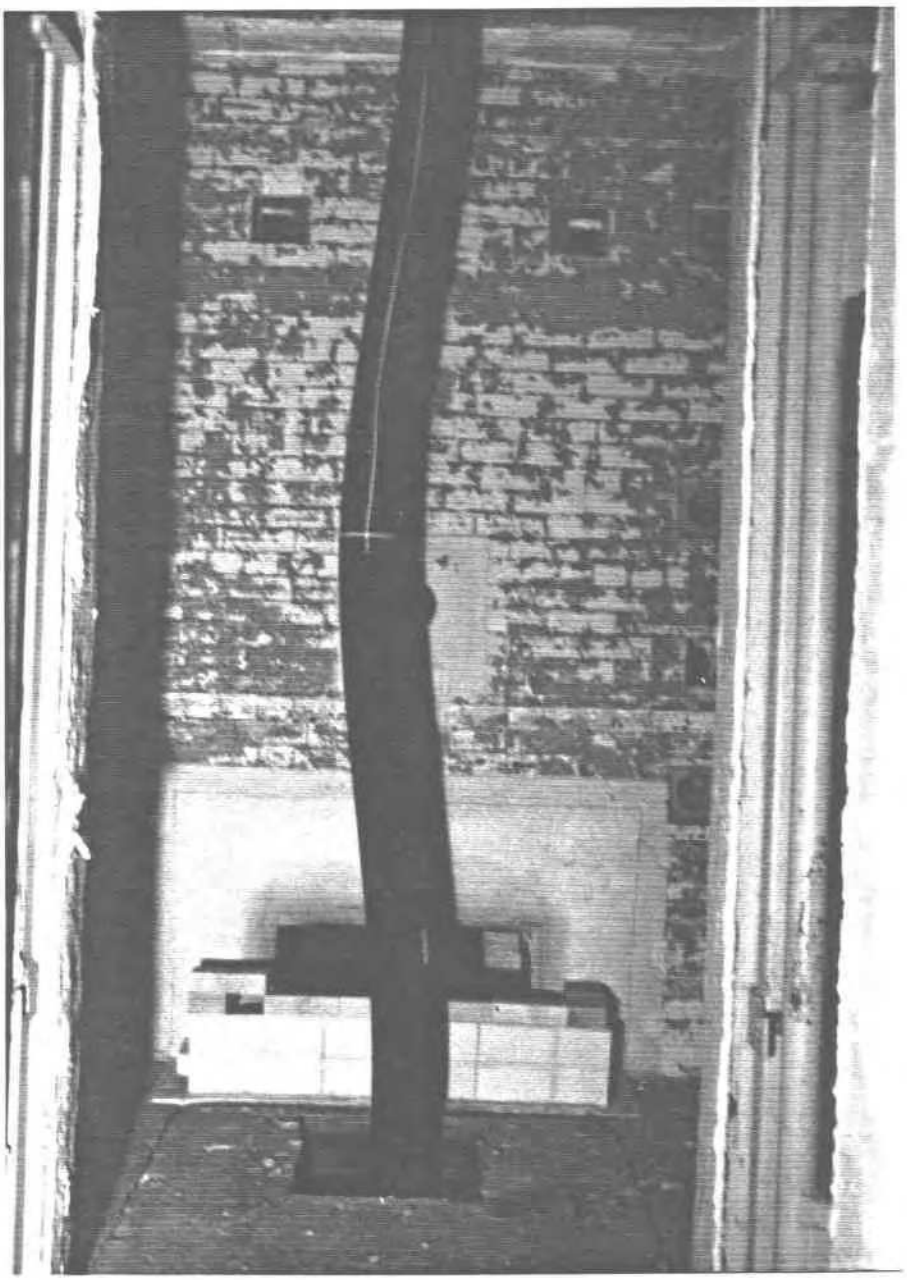


Figure B3. Column No. C-05 after test

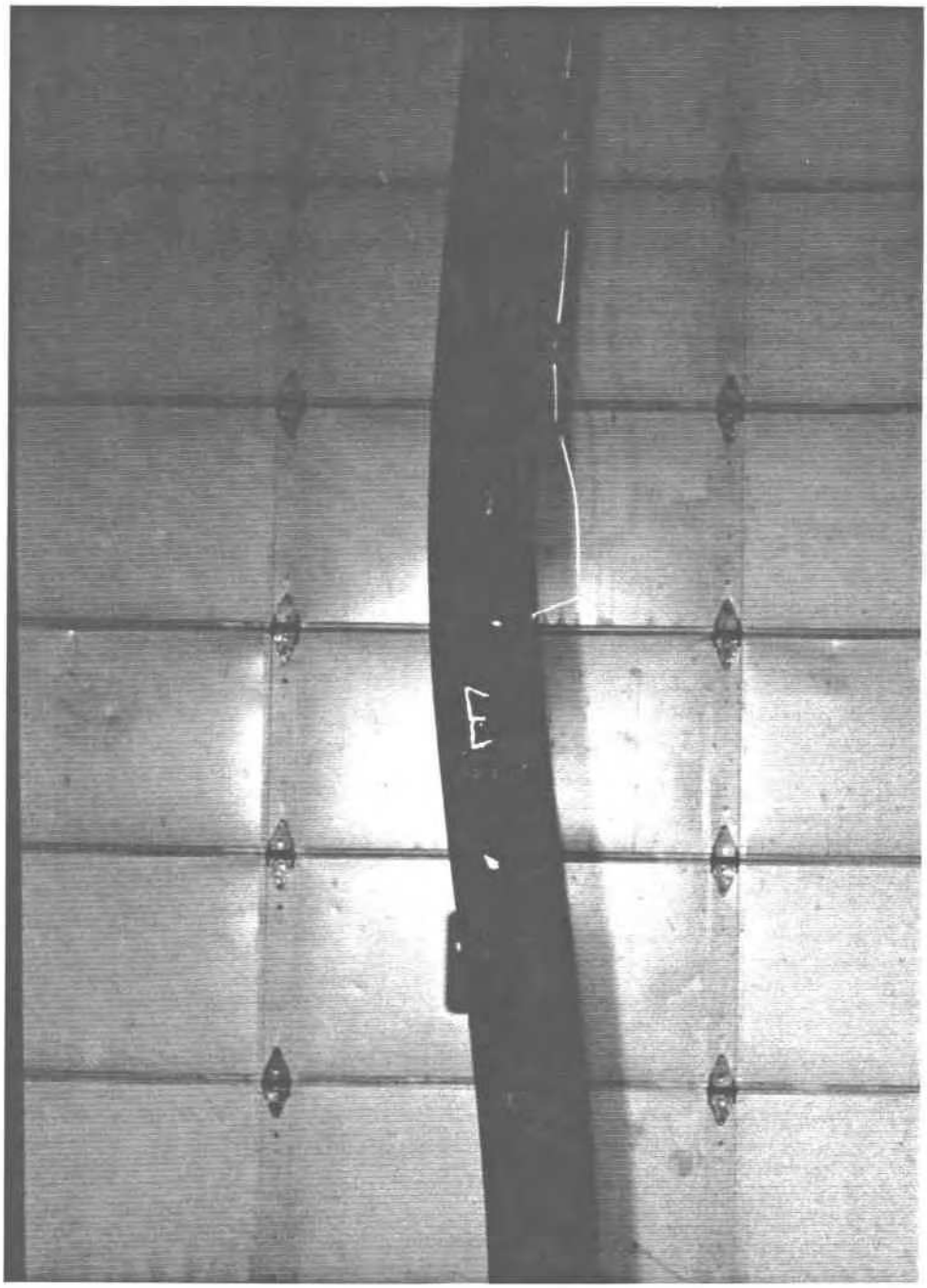


Figure B4. Column No. C-06 after test

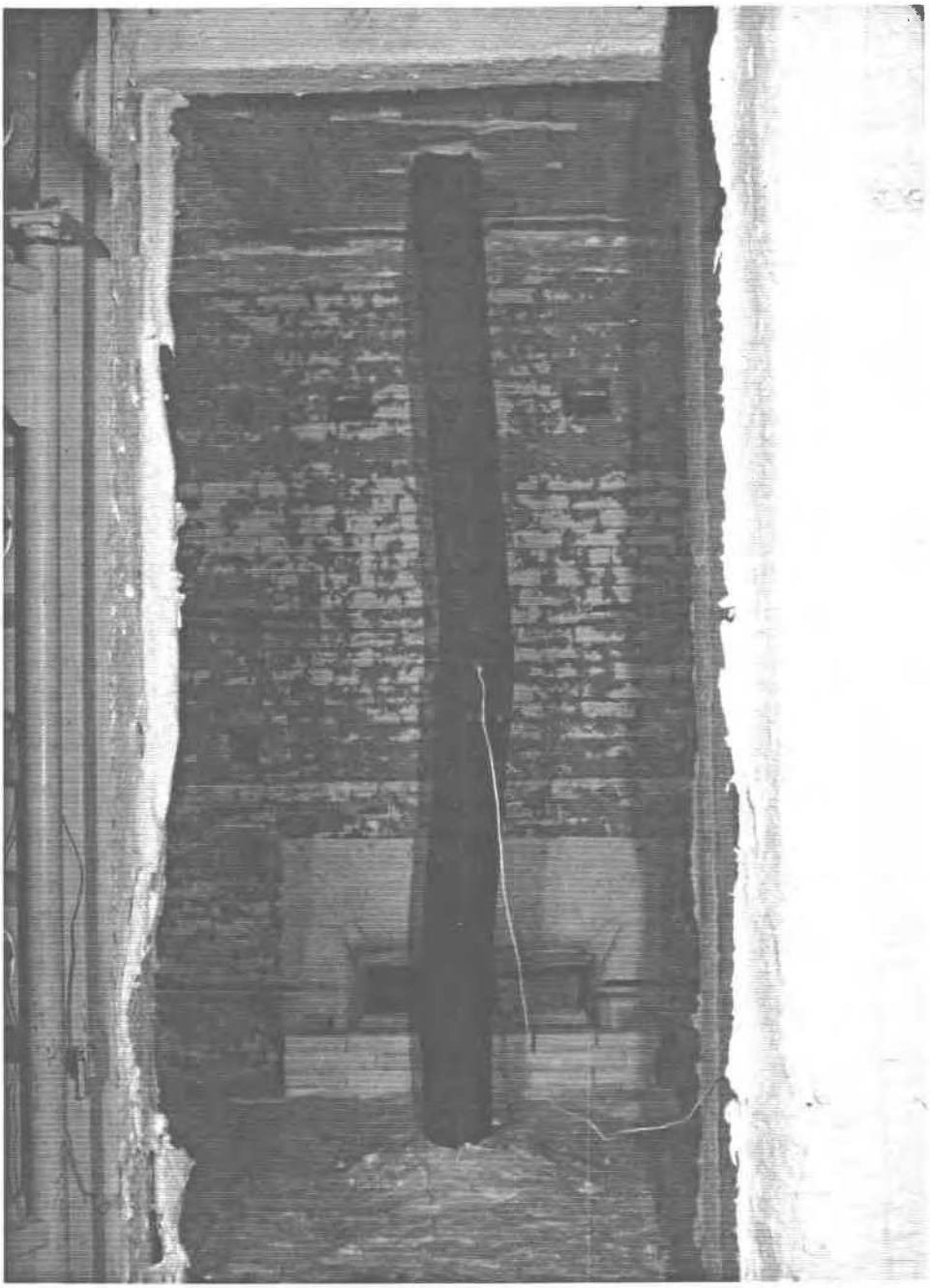


Figure B5. Column No. C-08 after test

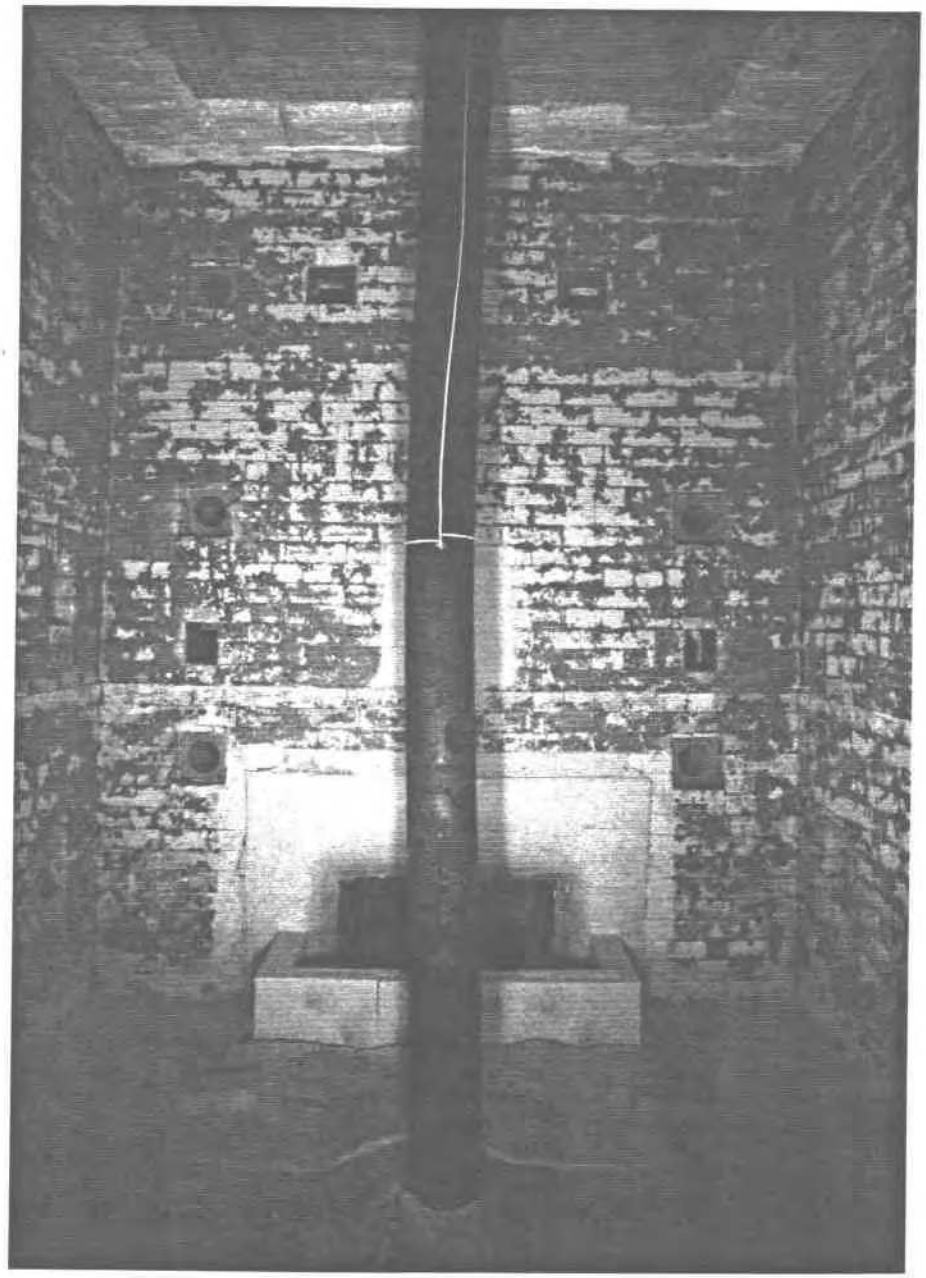


Figure B6. Column No. C-09 after test

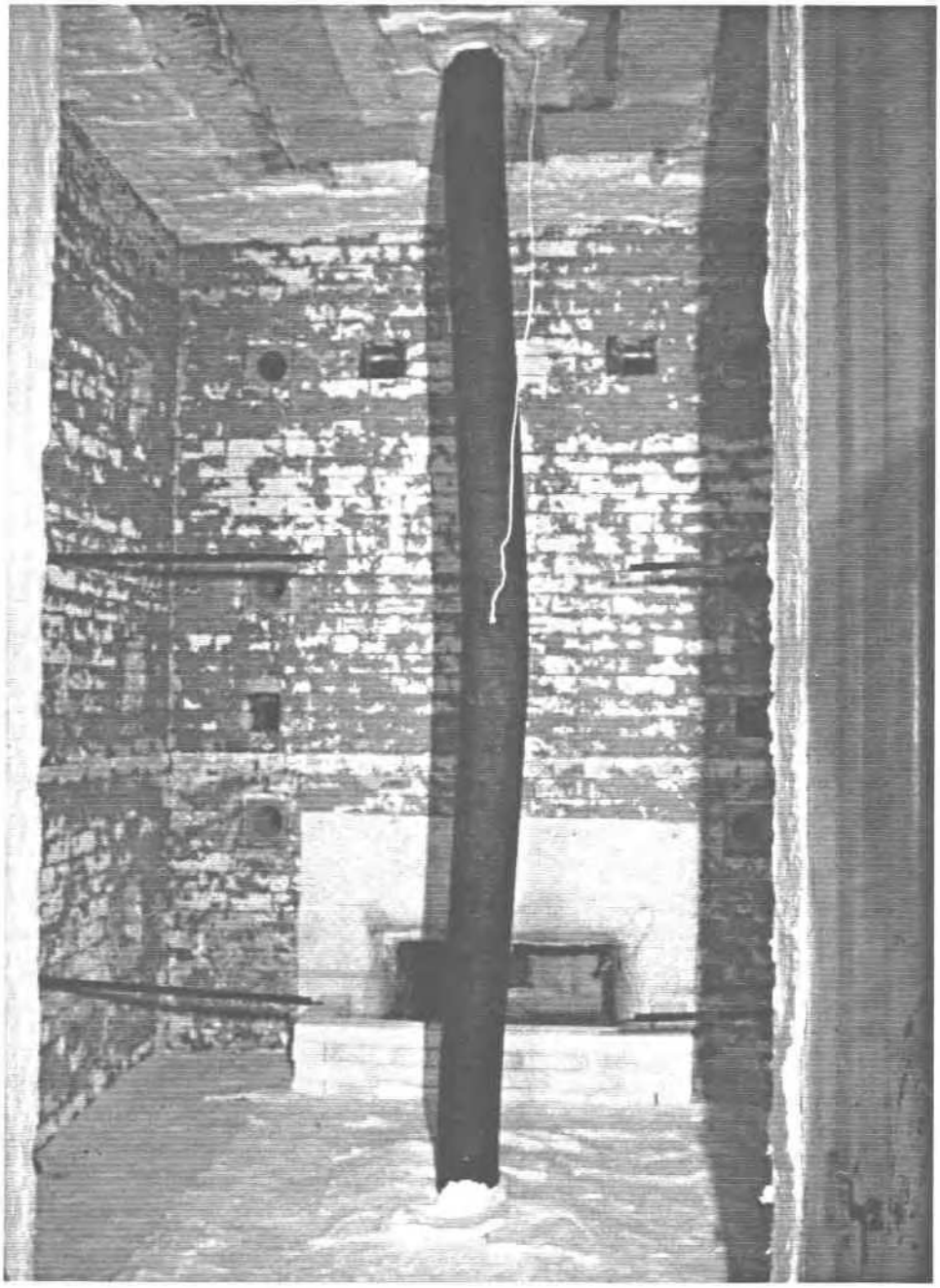


Figure B7. Column No. C-11 after test

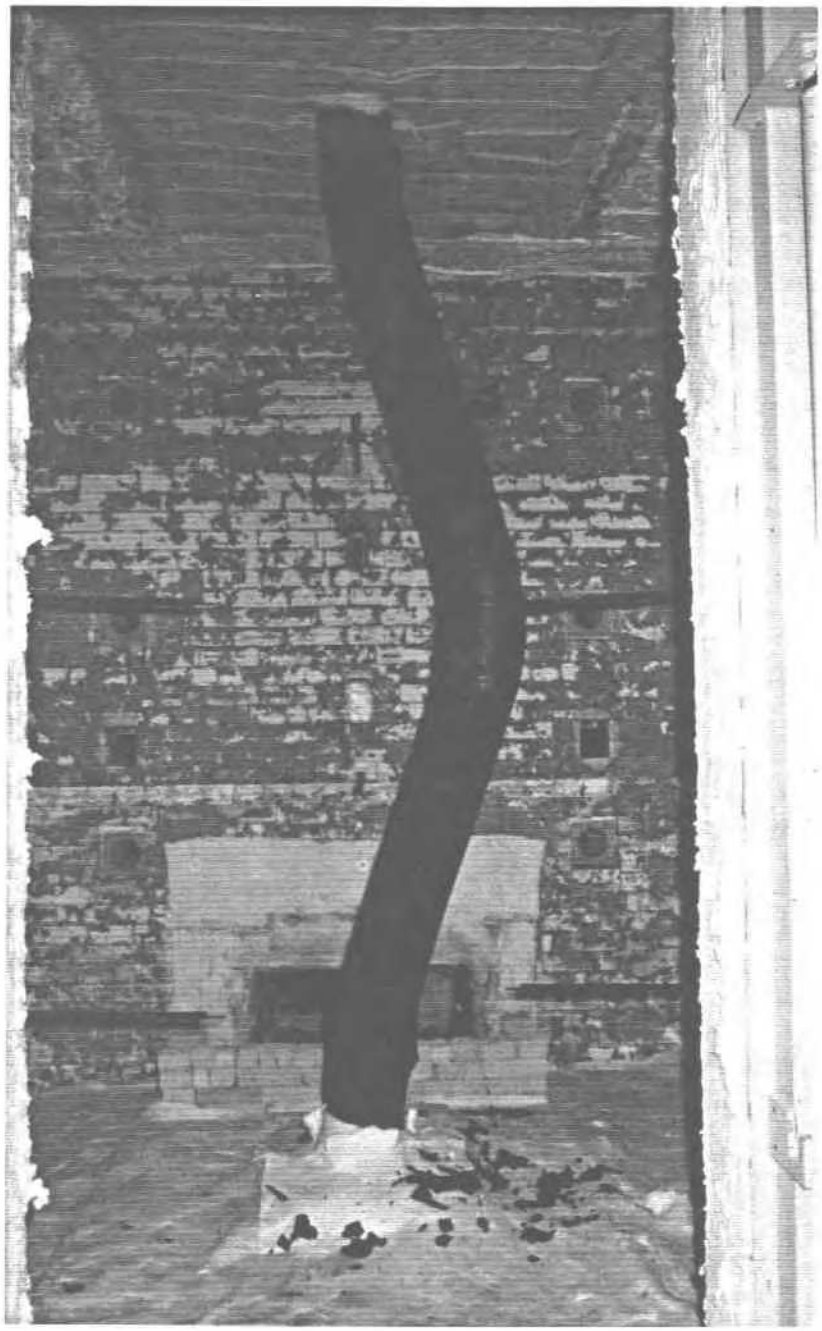


Figure B8. Column No. C-13 after test

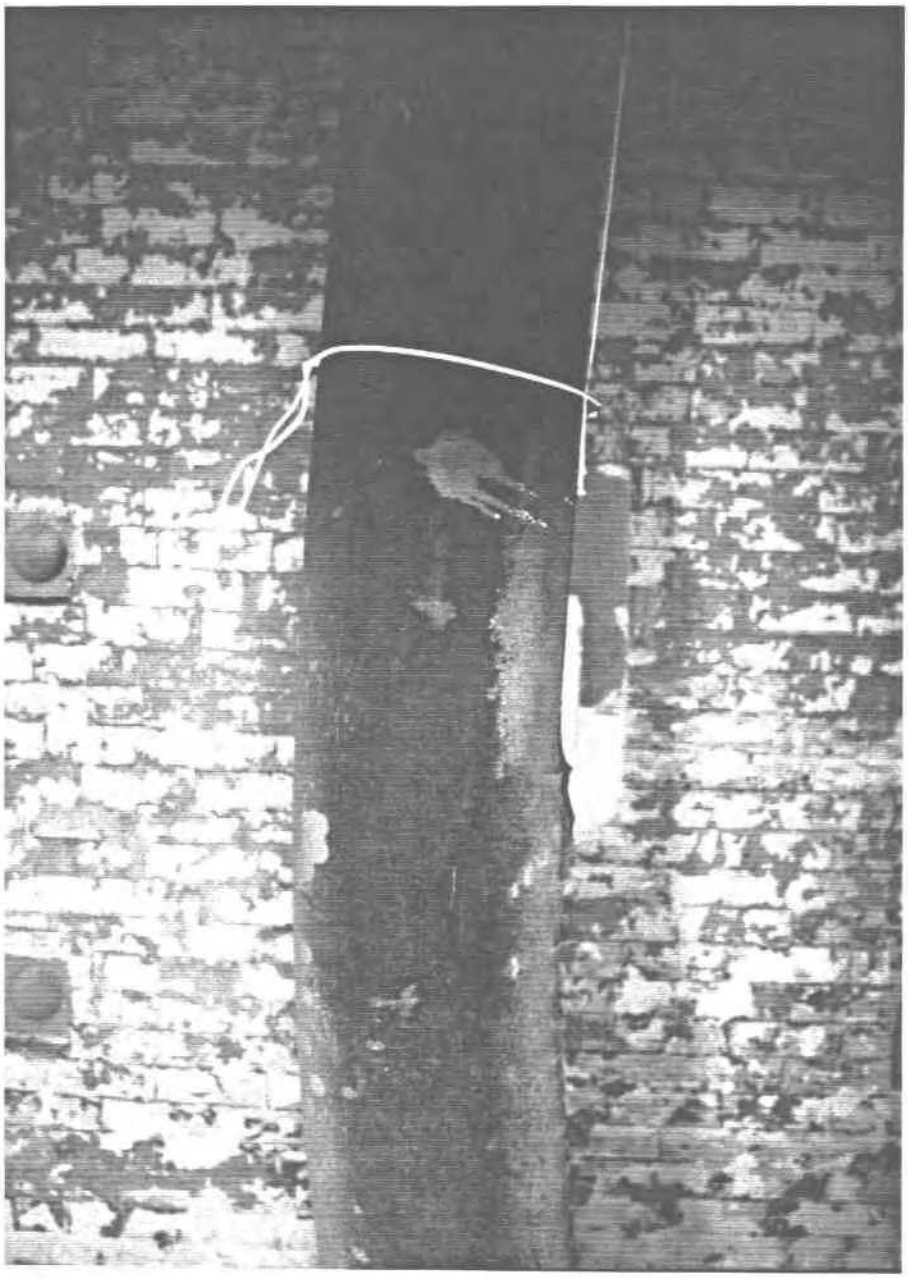


Figure B9. Column No. C-15 after test

Figure B10. Column No. C-16 after test

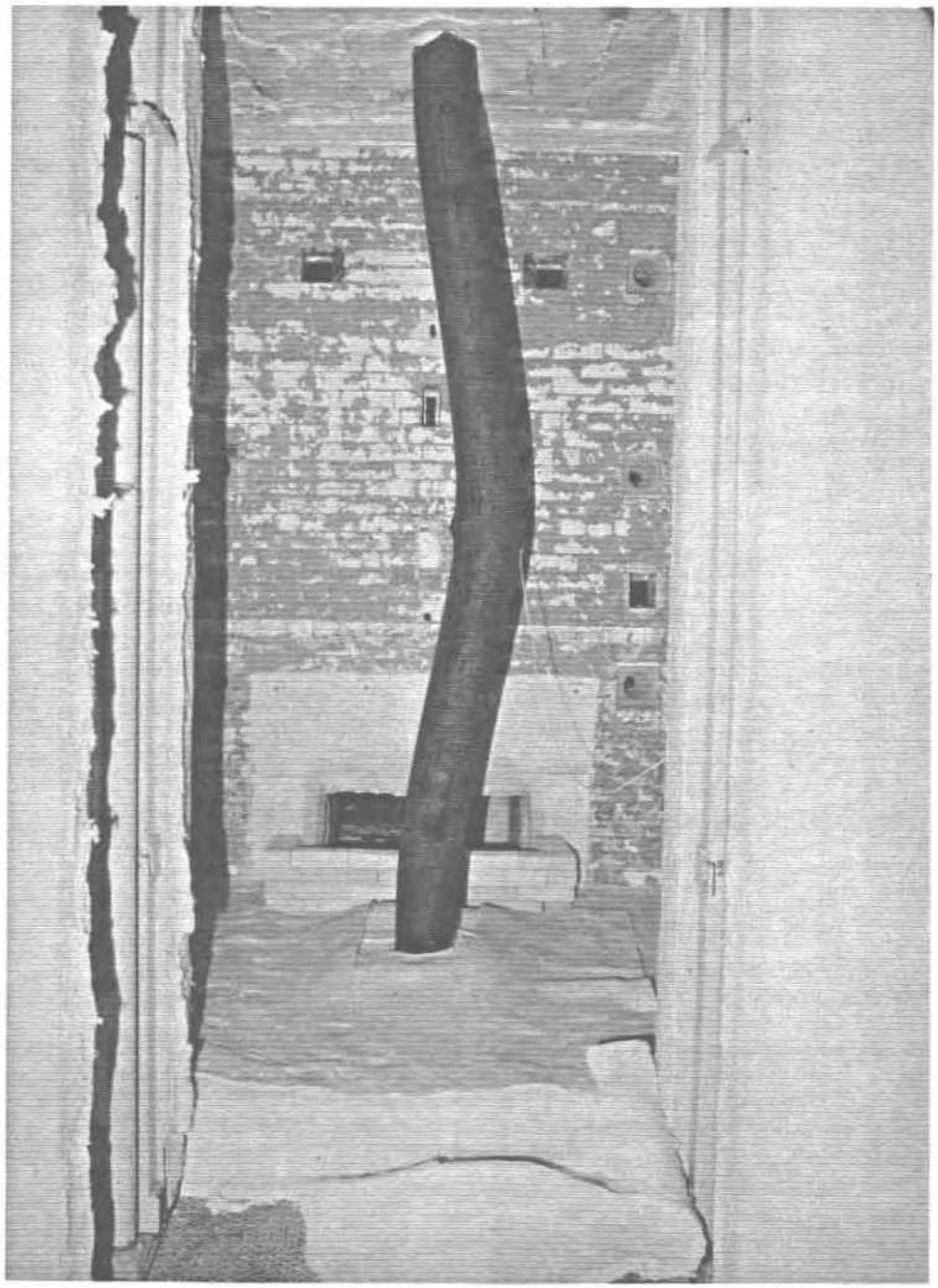


Figure B11. Column No. C-17 after test

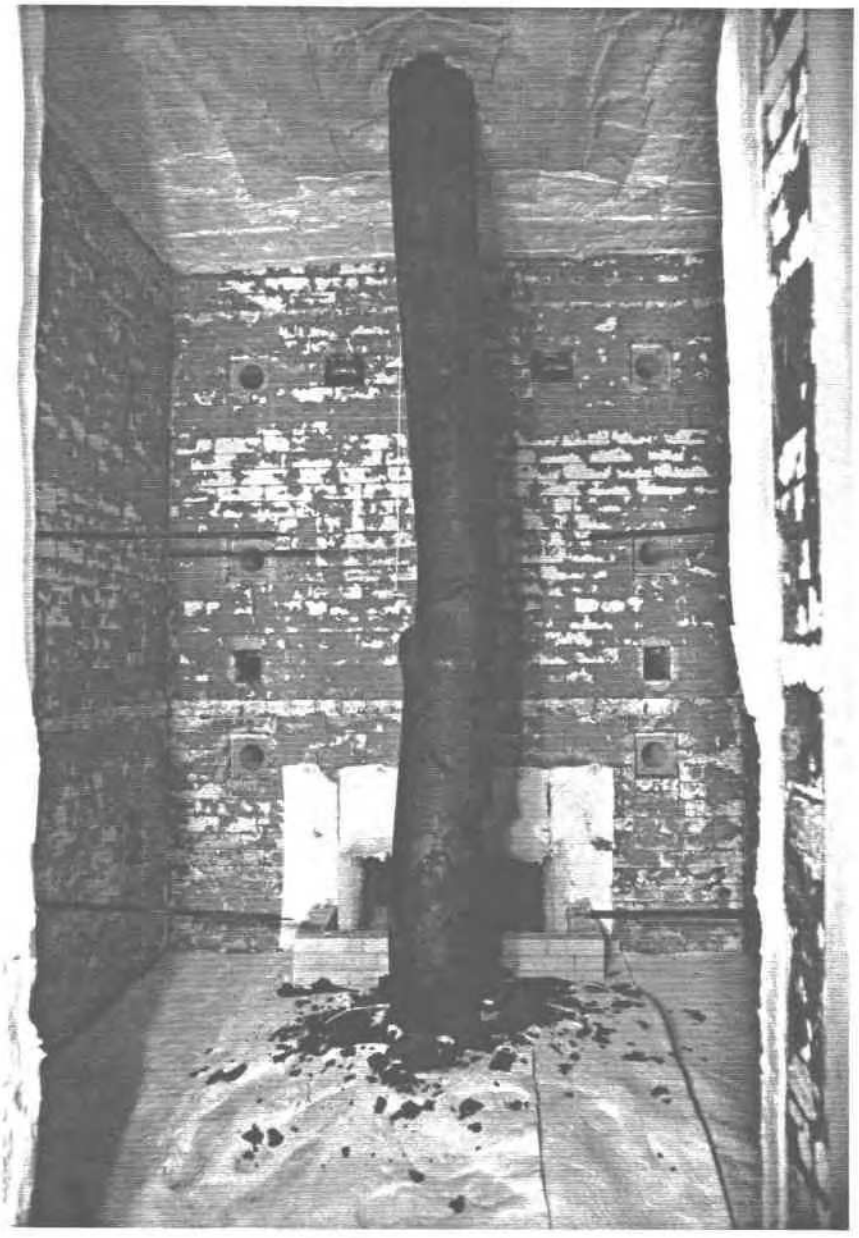


Figure B12. Column No. C-20 after test

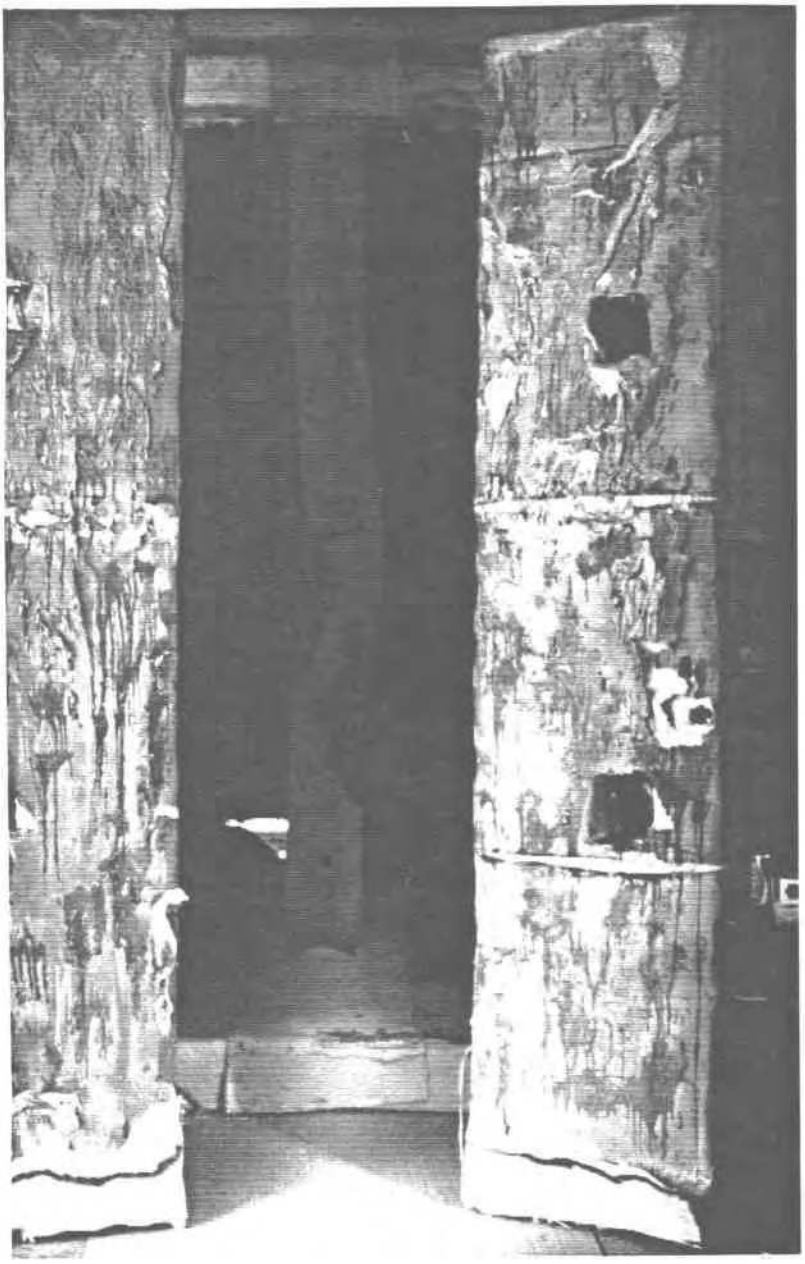


Figure B13. Column No. C-21 after test

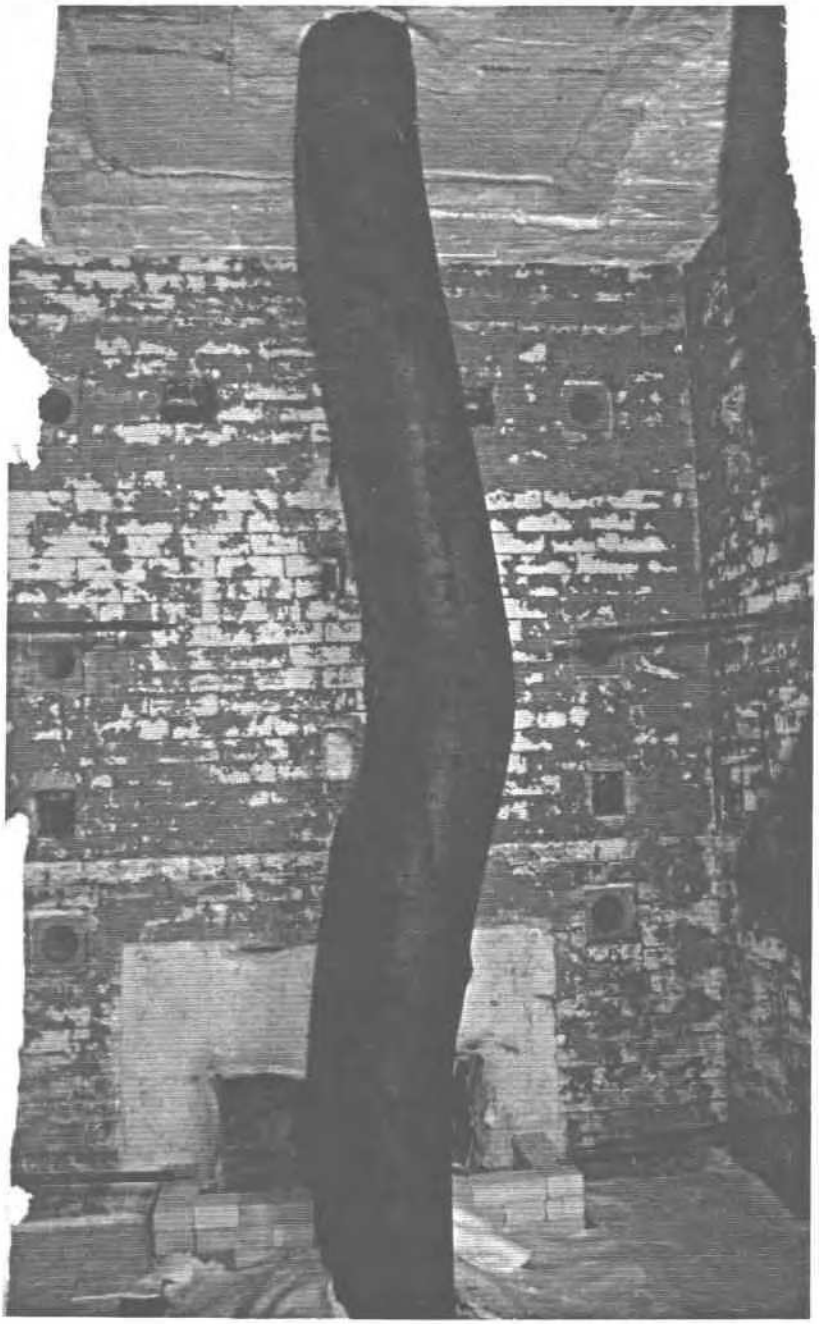


Figure B14 Column No. C-22 after test

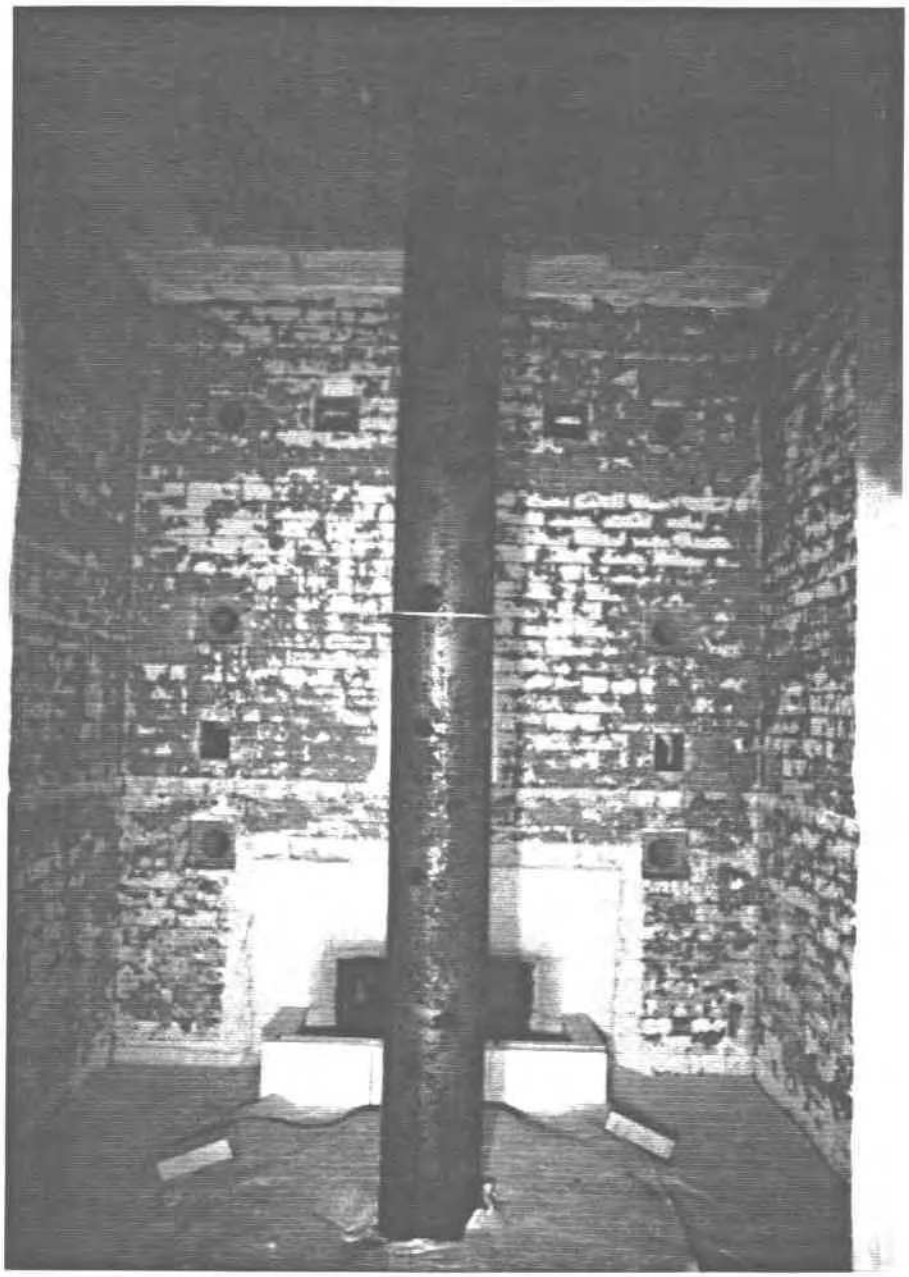


Figure B15. Column No. C-23 after test

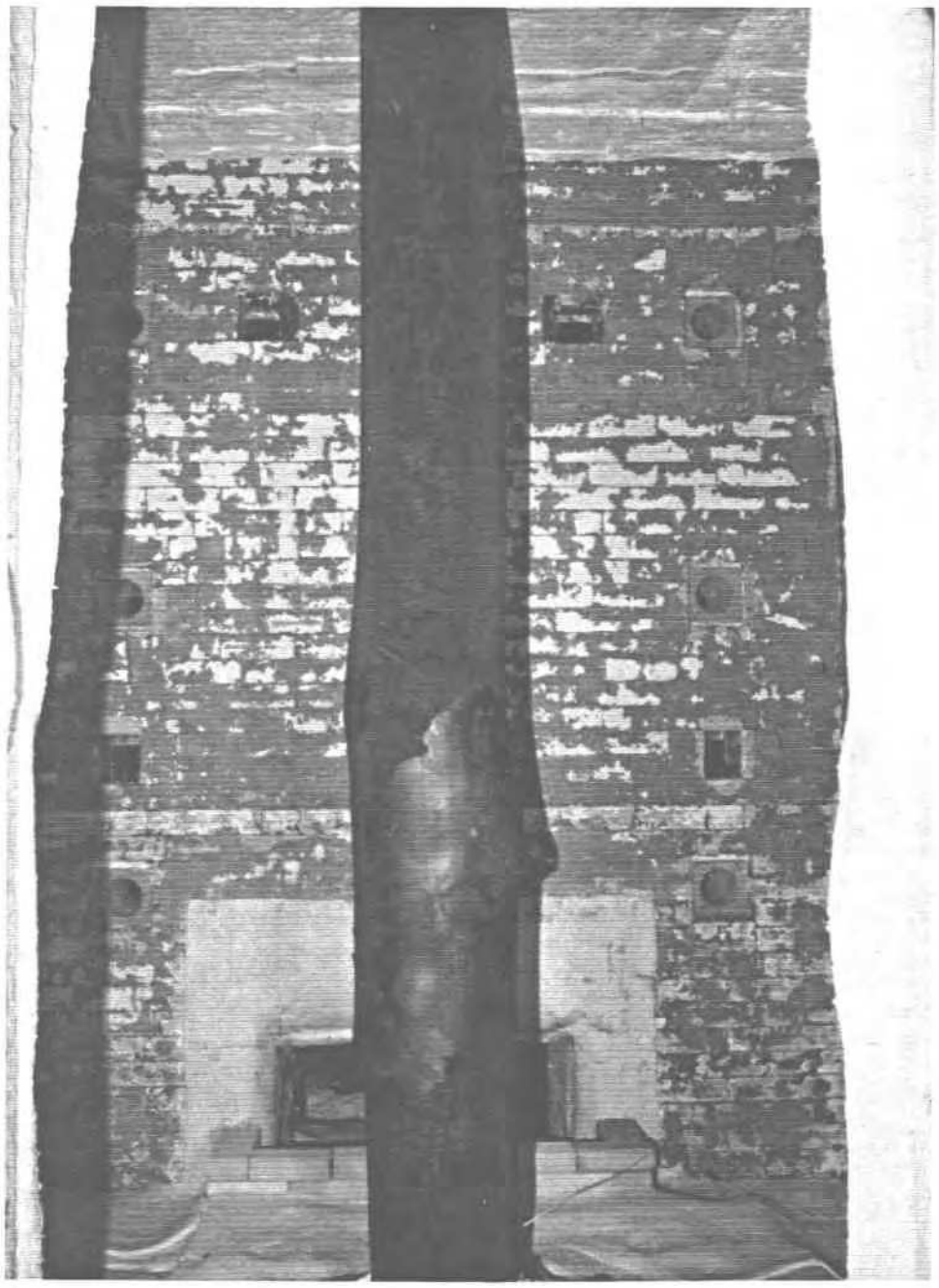


Figure B16. Column No. C-25 after test

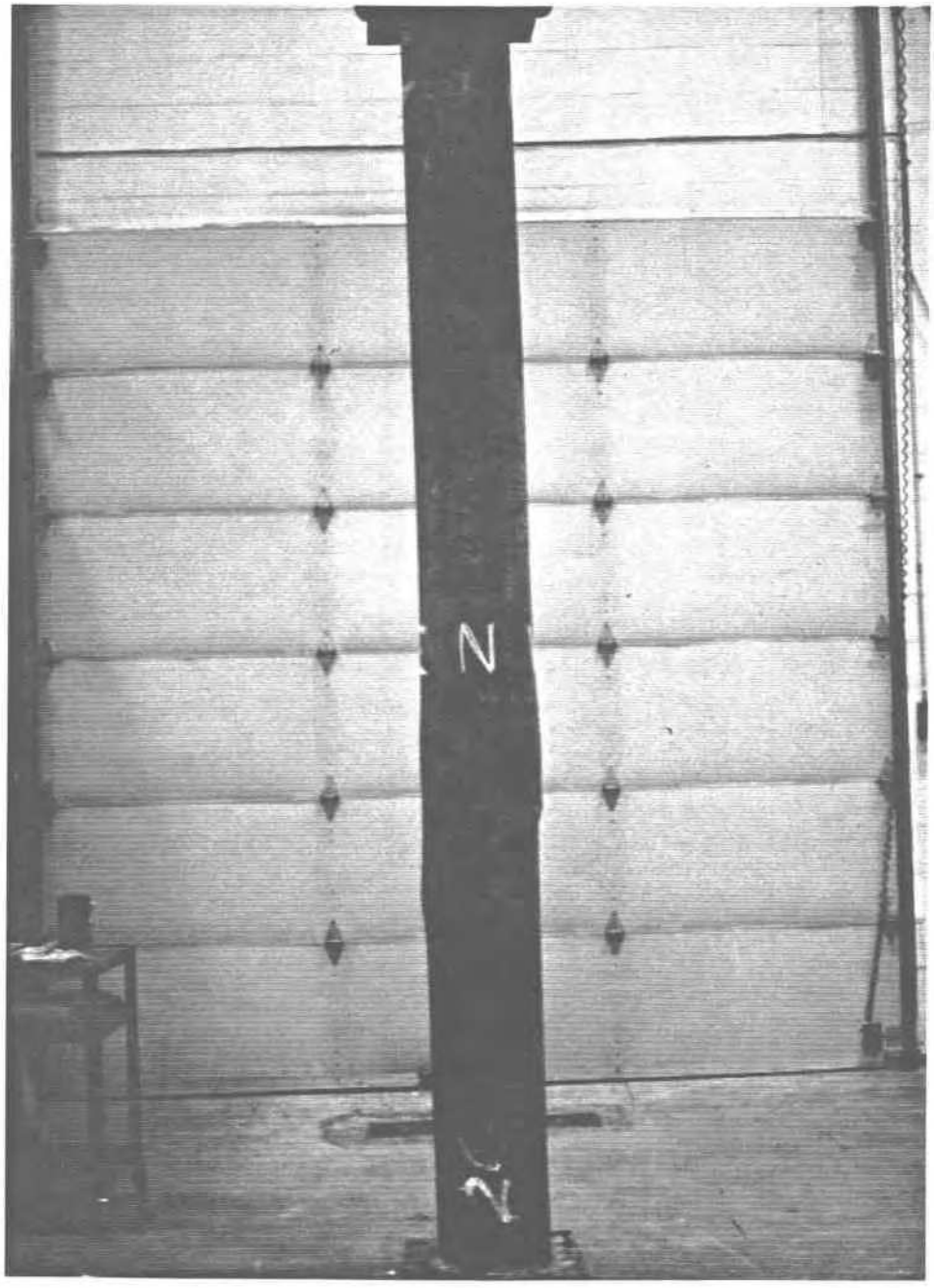


Figure B17. Column No. C-26 after test

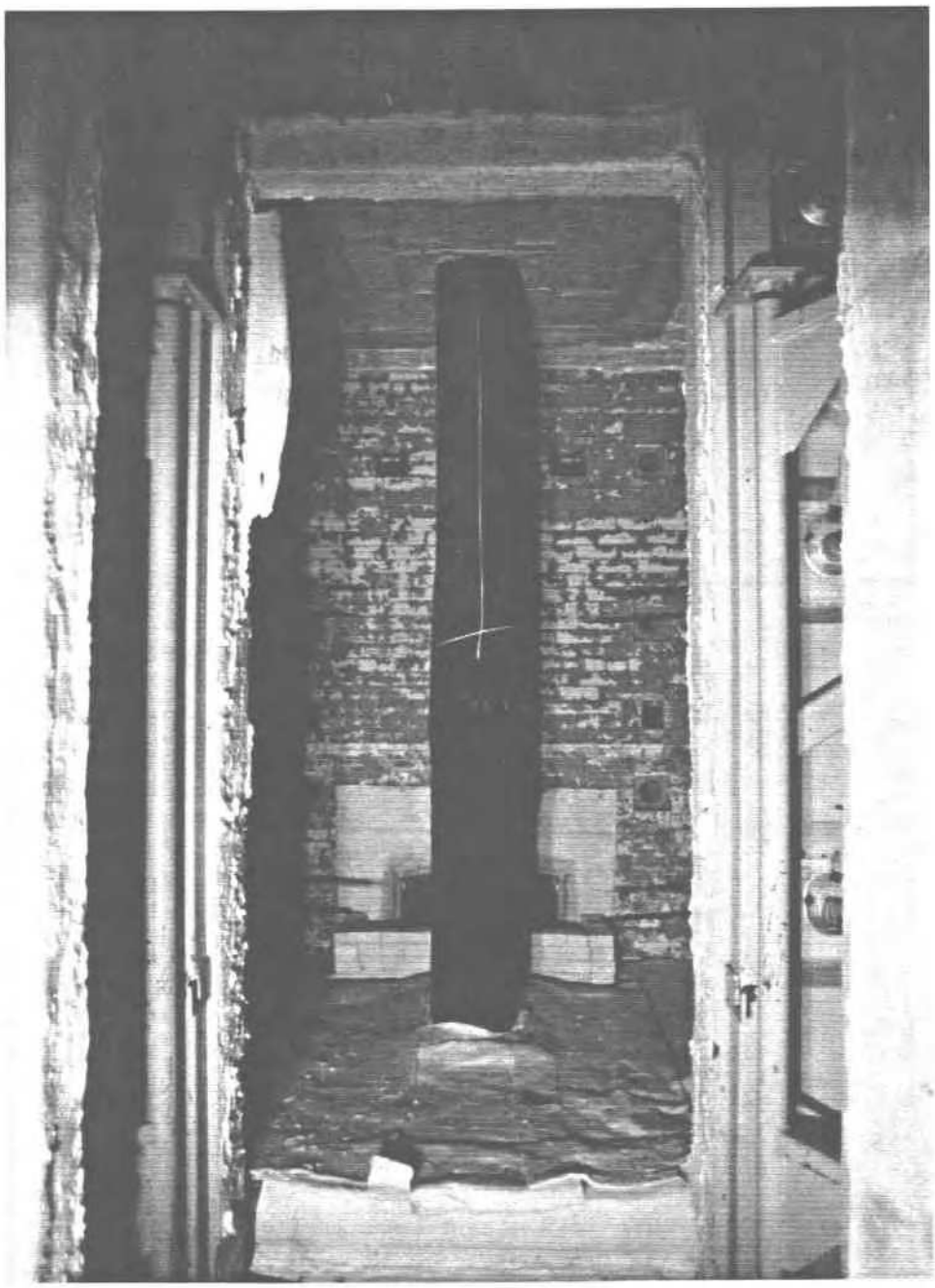


Figure B18. Column No. C-28 after test

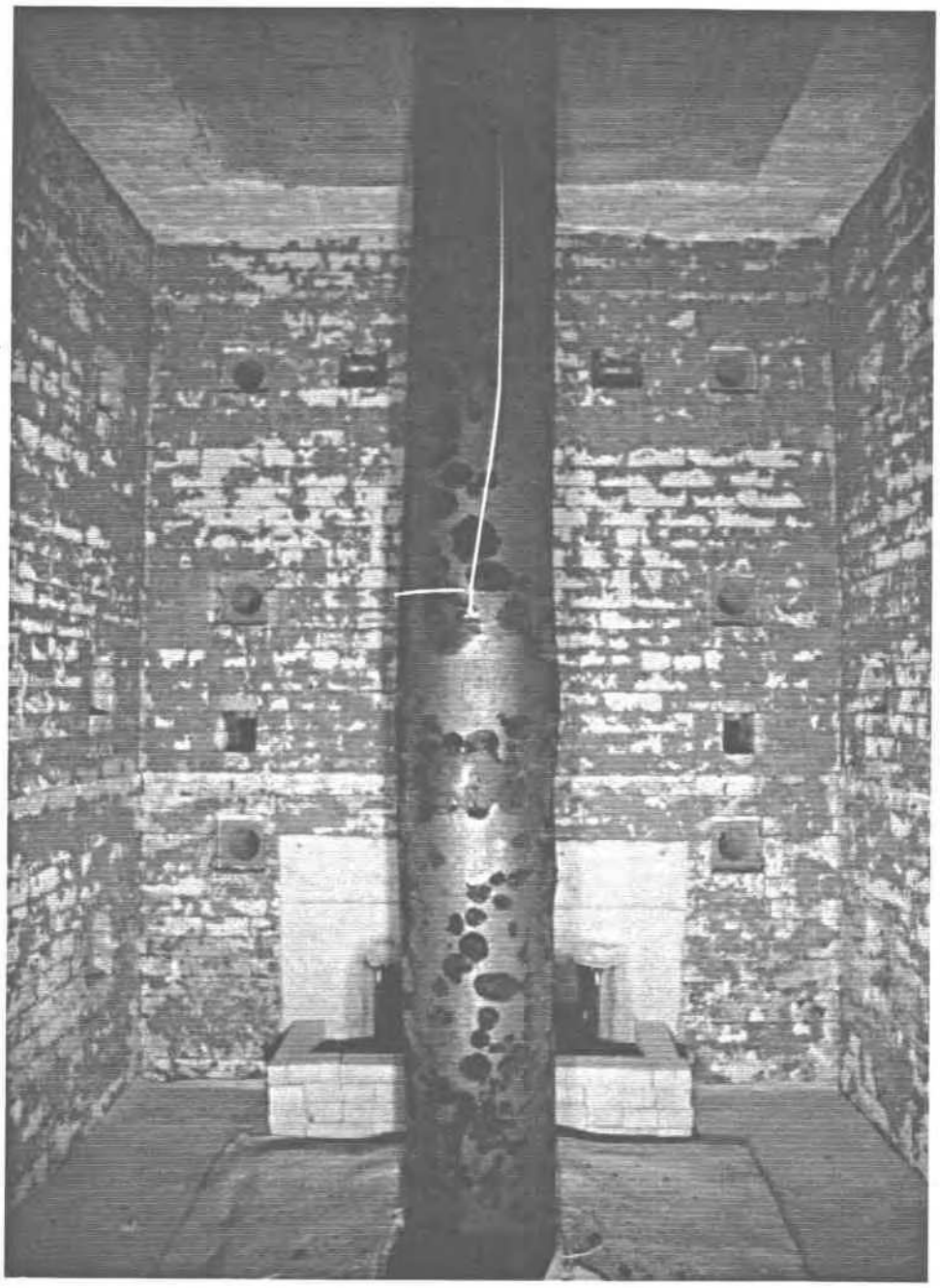


Figure B19. Column No. C-29 after test

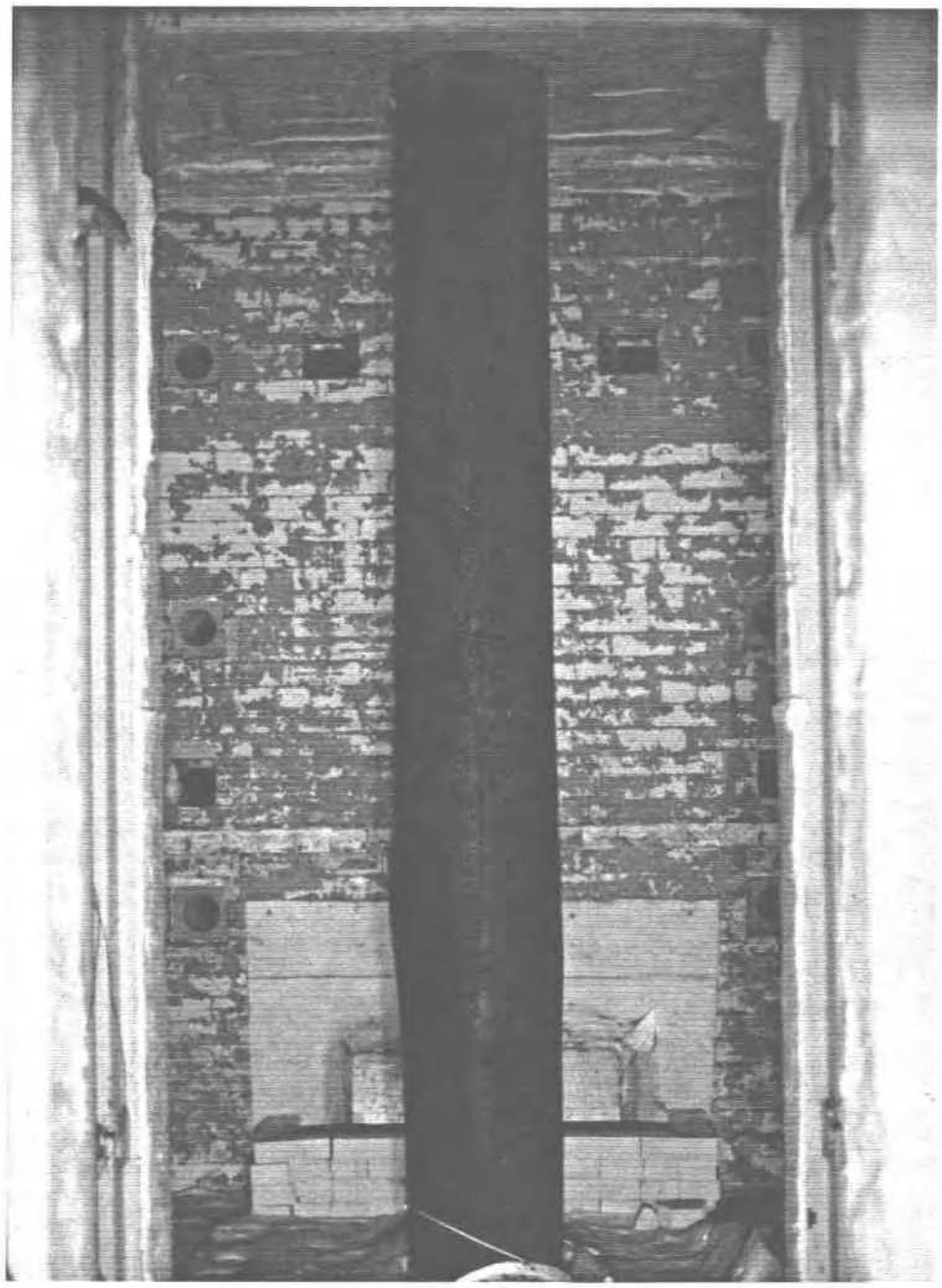


Figure B20. Column No. C-30 after test

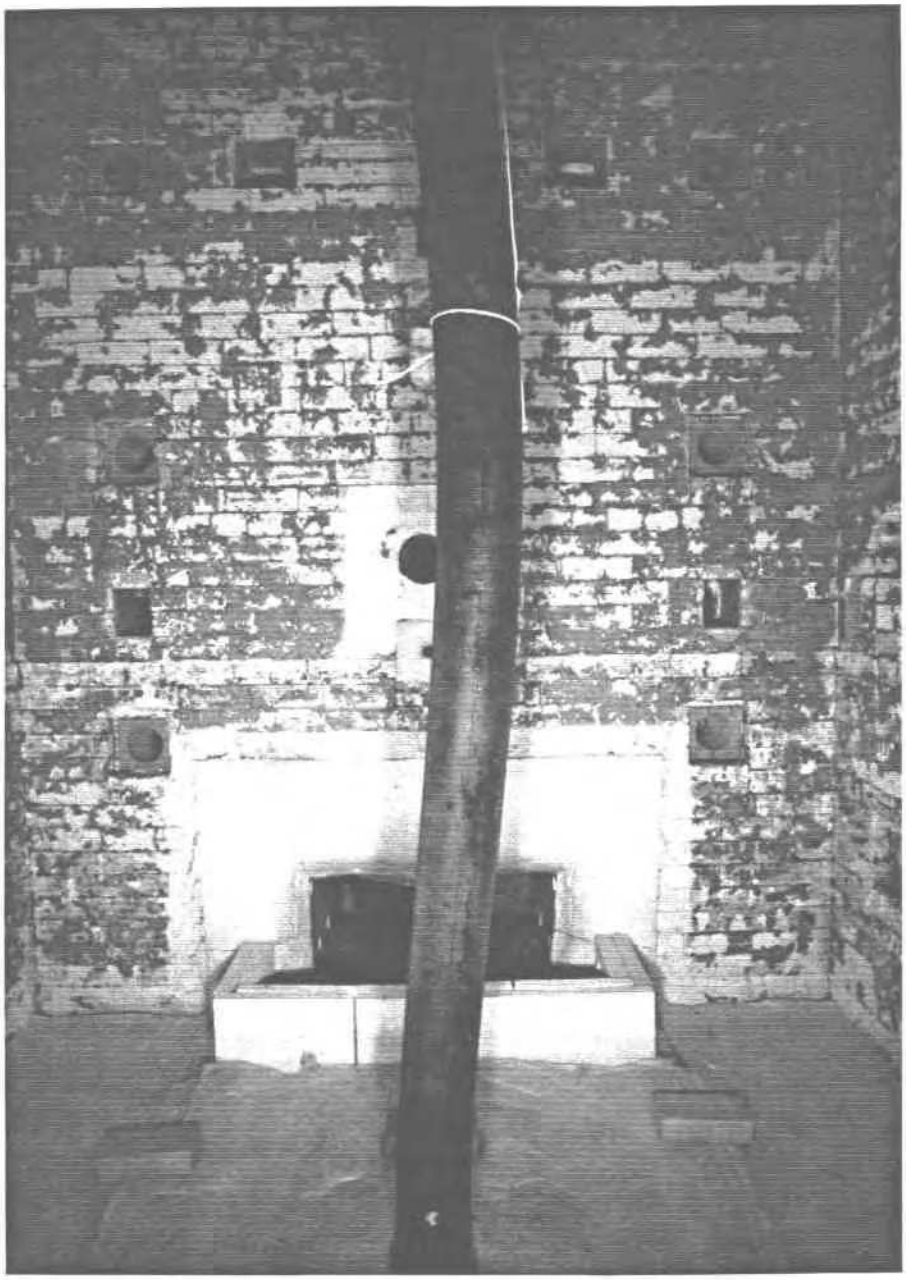


Figure B21. Column No. C-31 after test

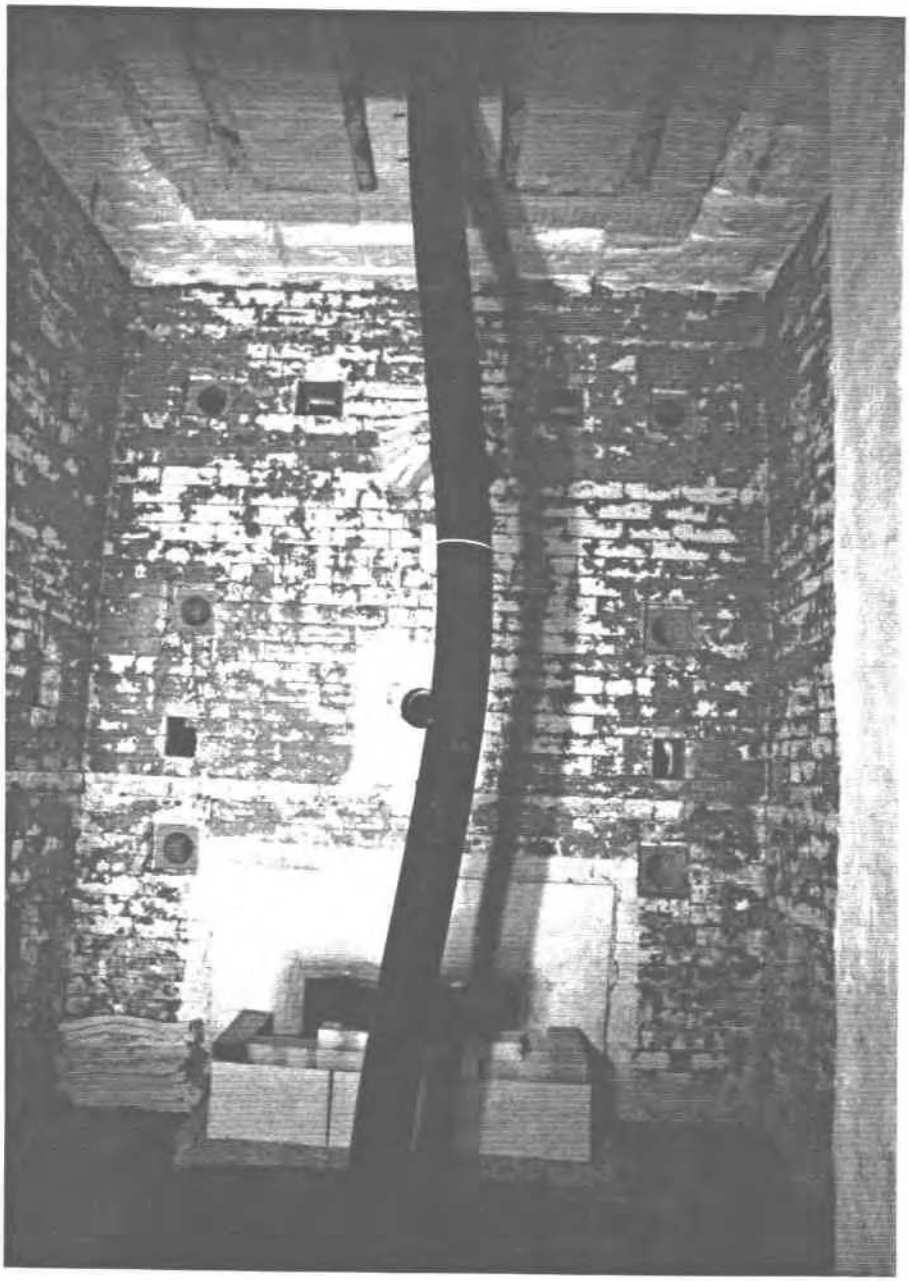


Figure B22. Column No. C-32 after test

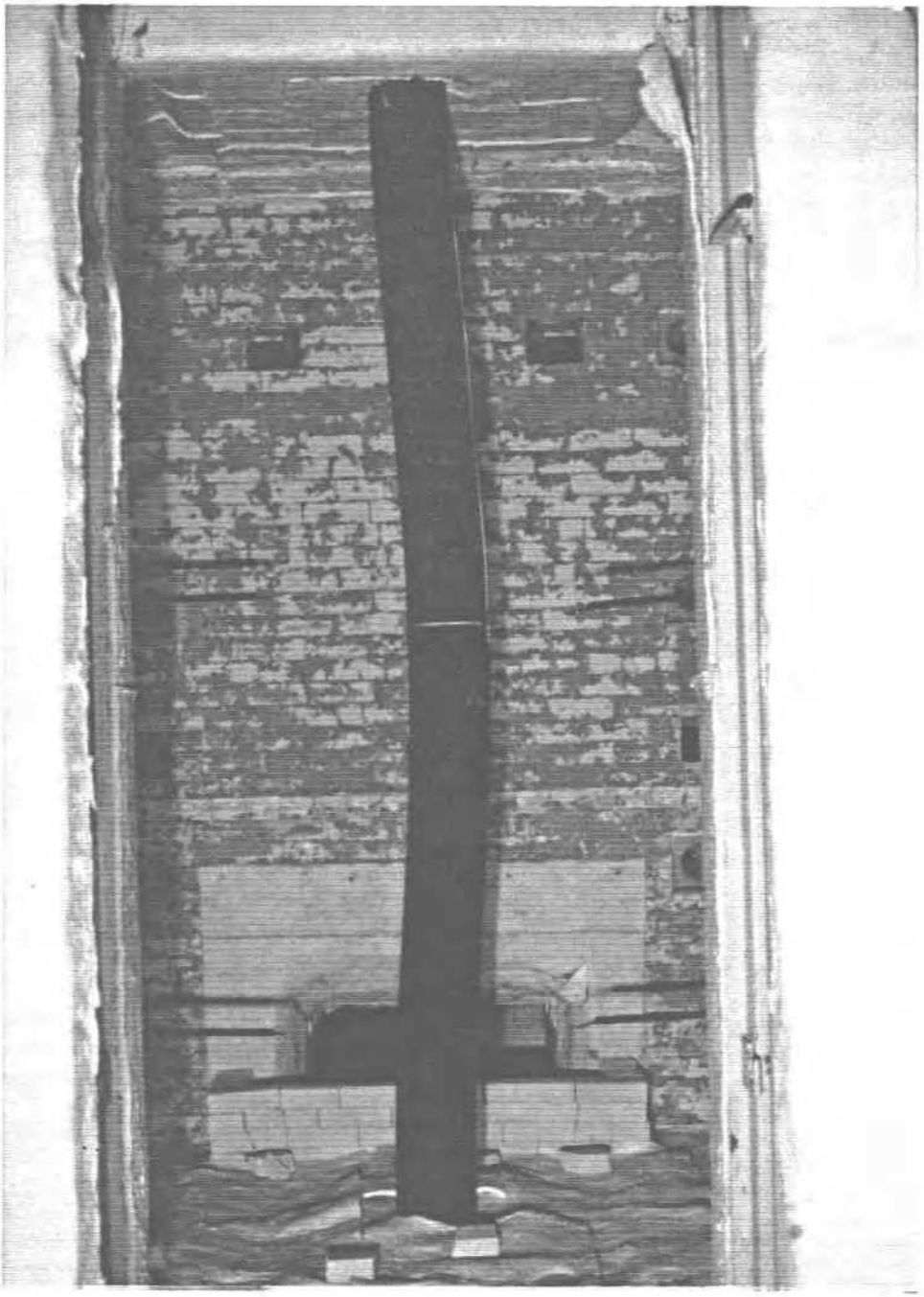


Figure B23. Column No. C-34 after test

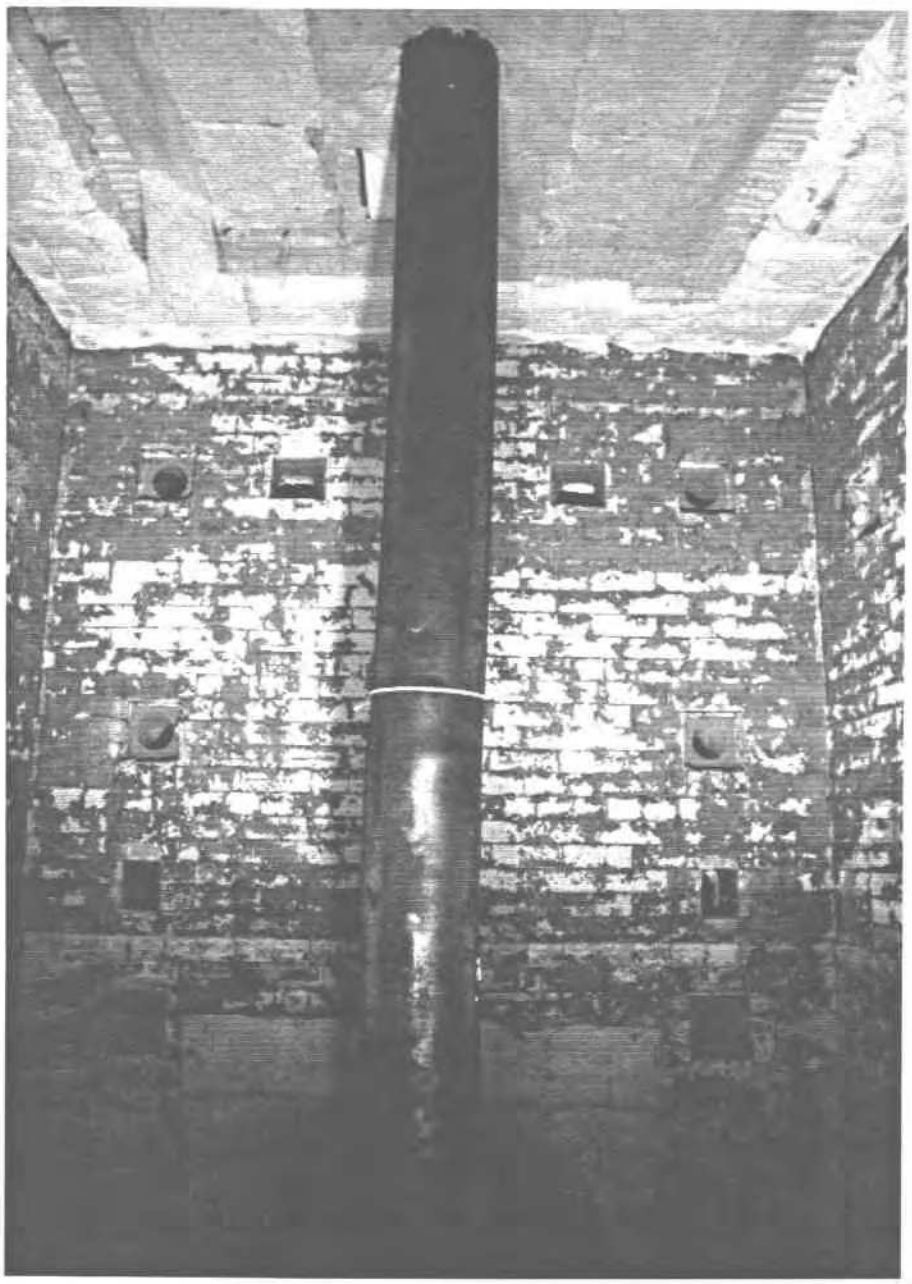


Figure B24. Column No. C-35 after test

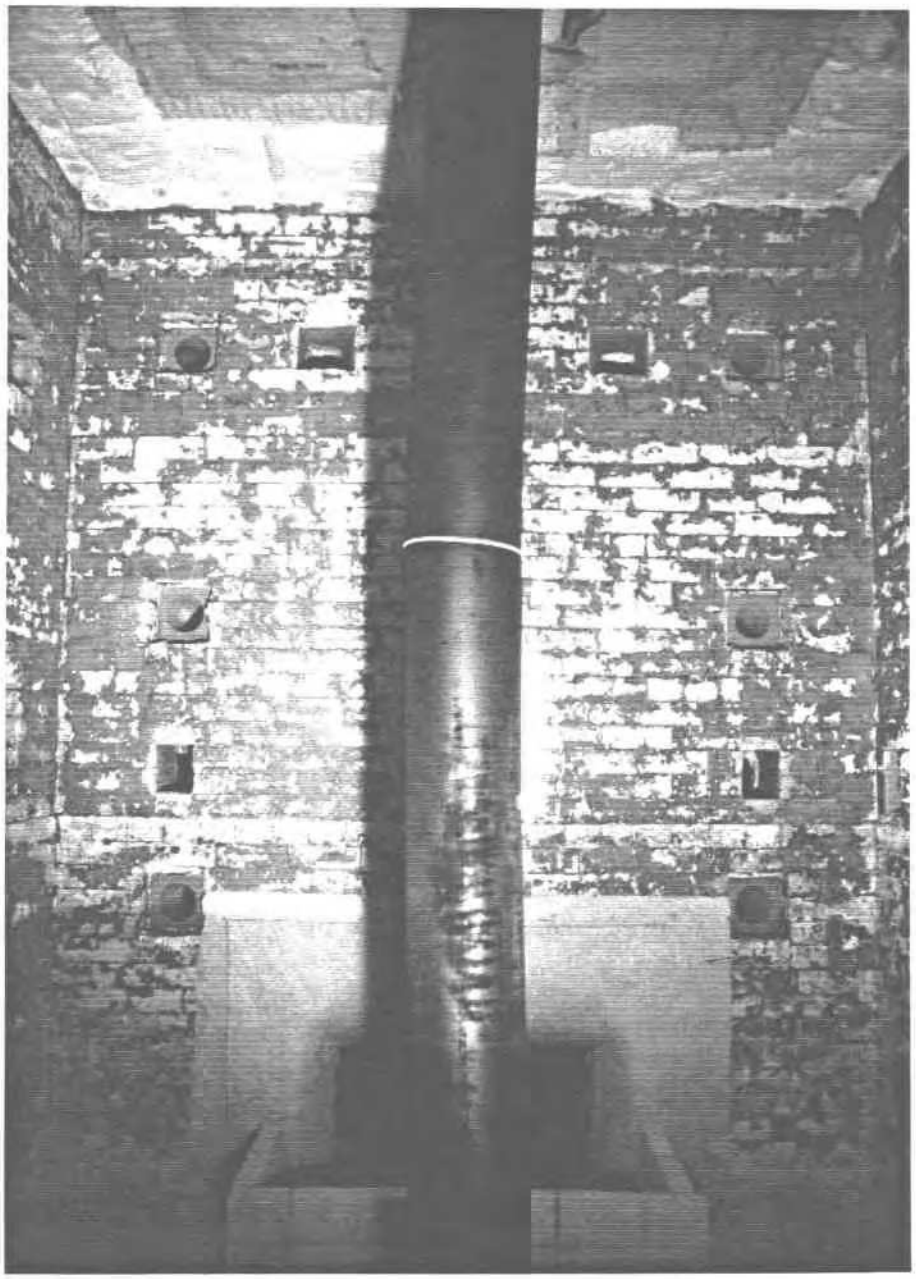


Figure B25. Column No. C-37 after test

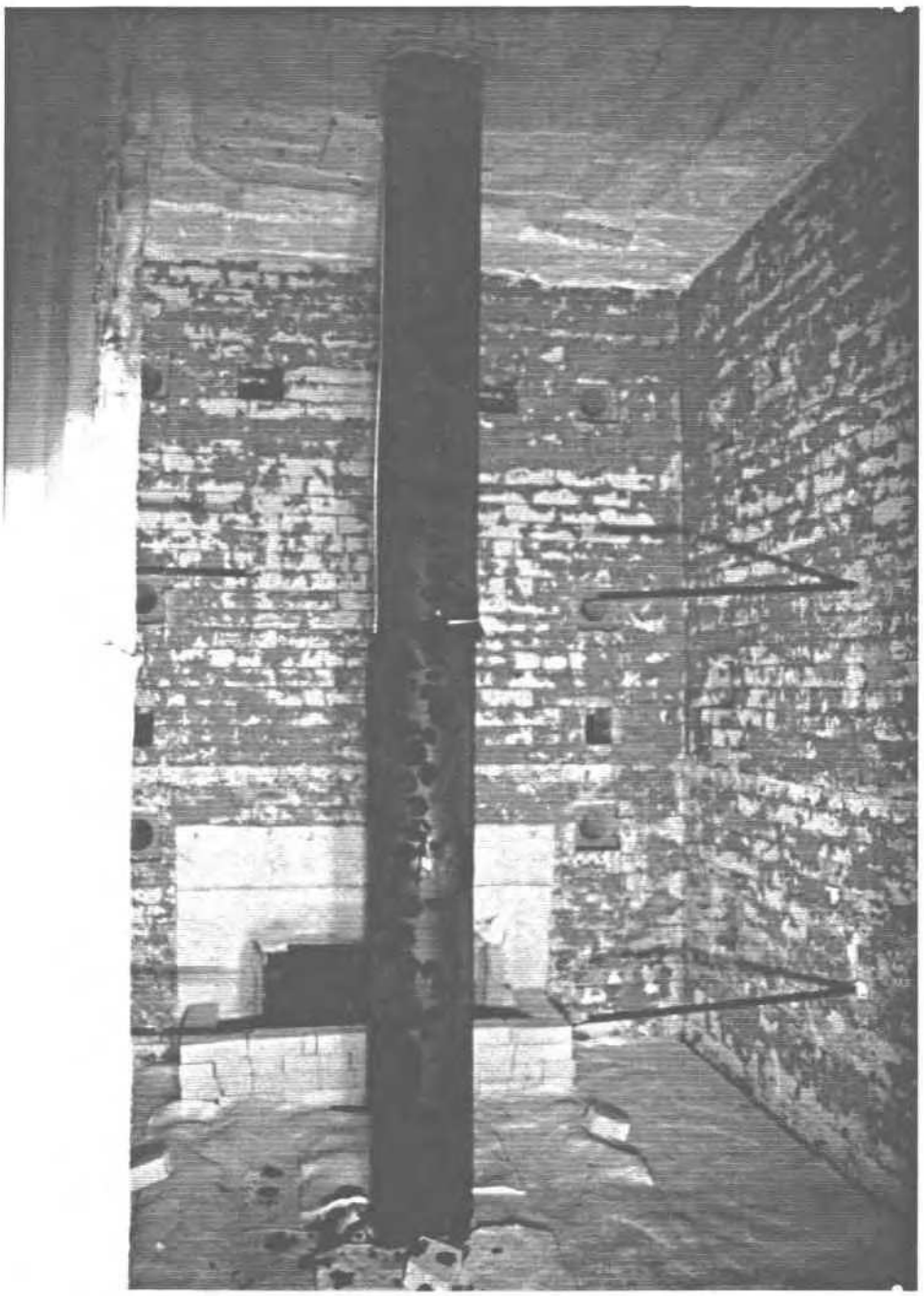


Figure B26. Column No. C-40 after test

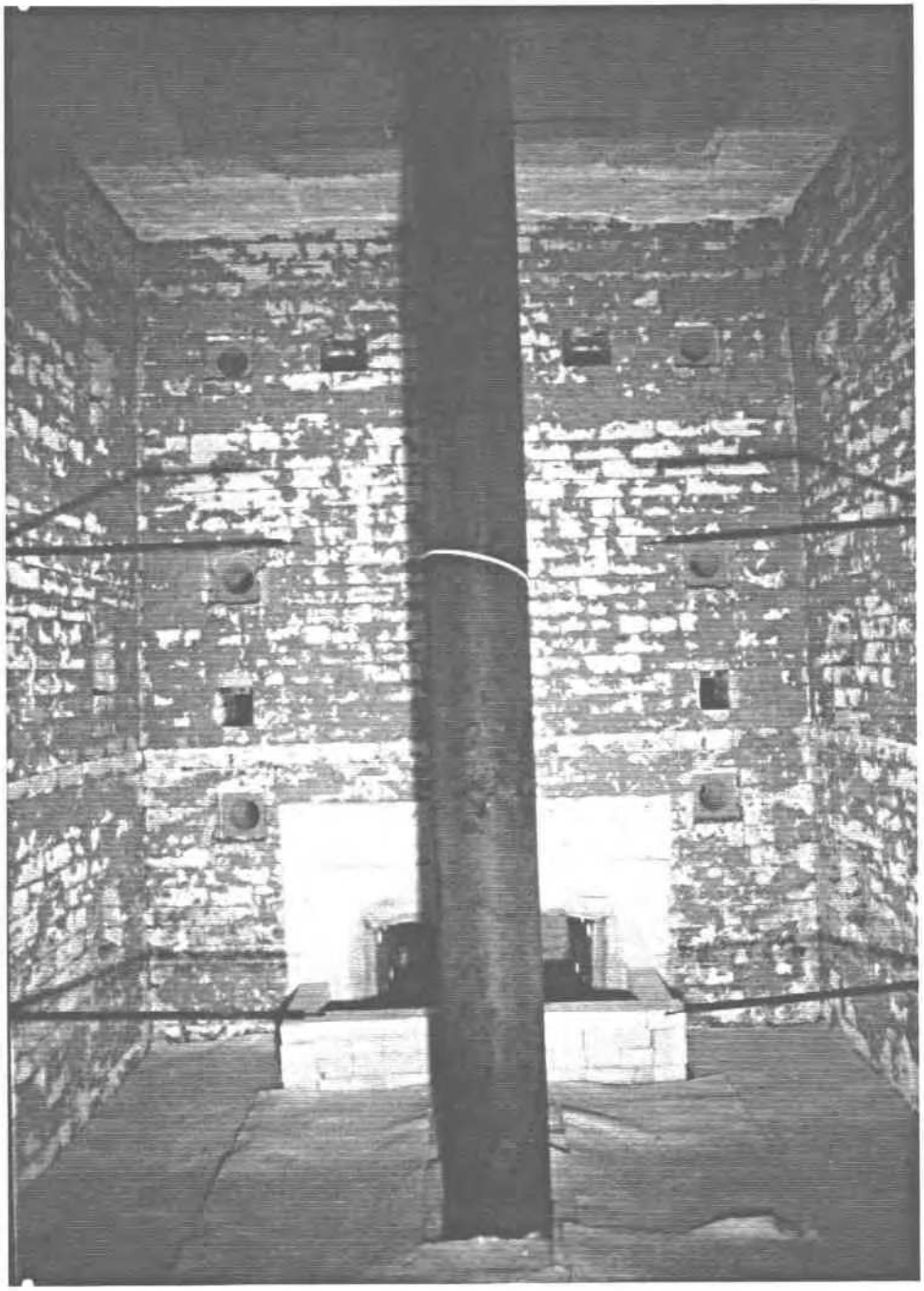


Figure B27. Column No. C-41 after test

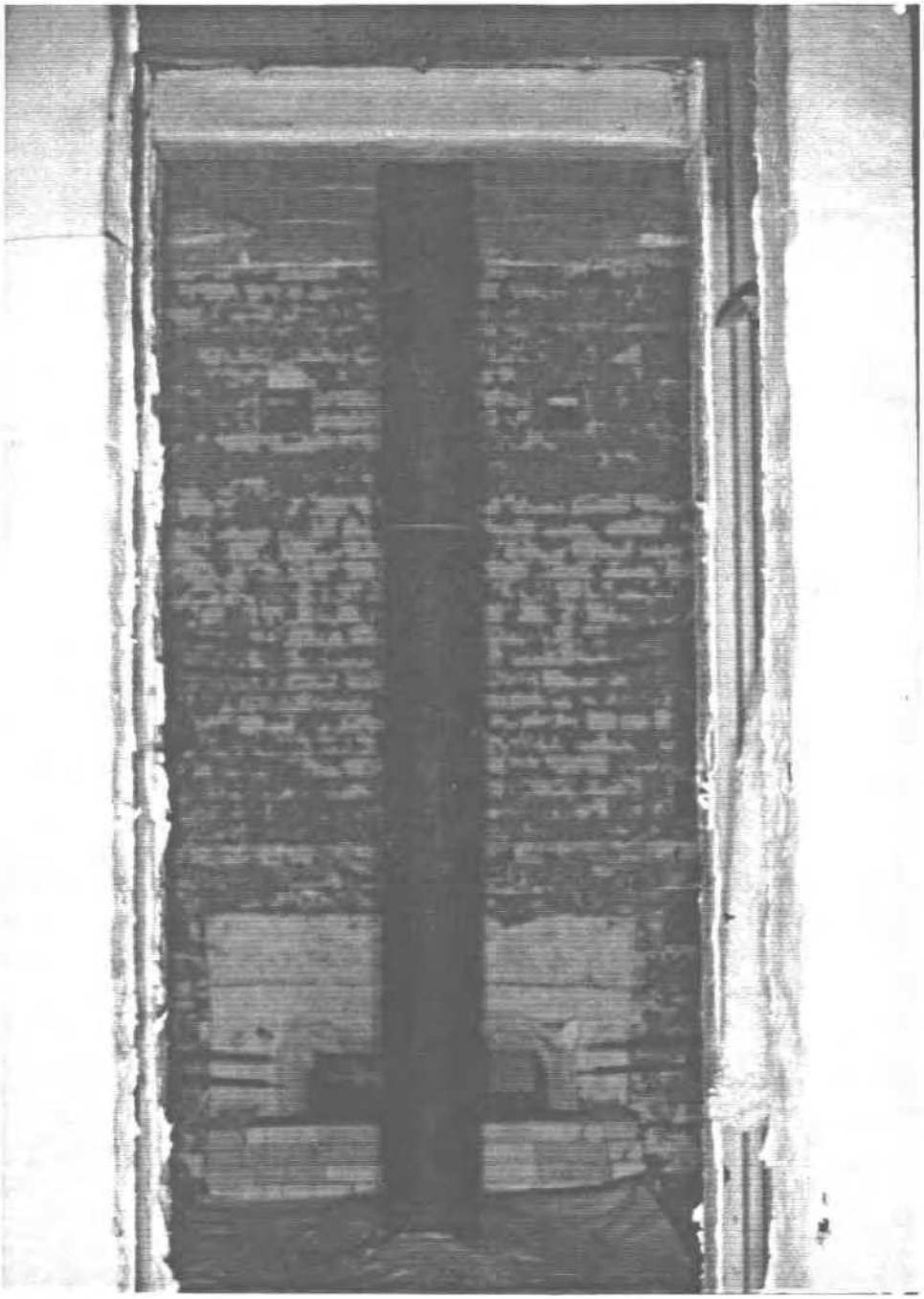


Figure B28. Column No. C-42 after test

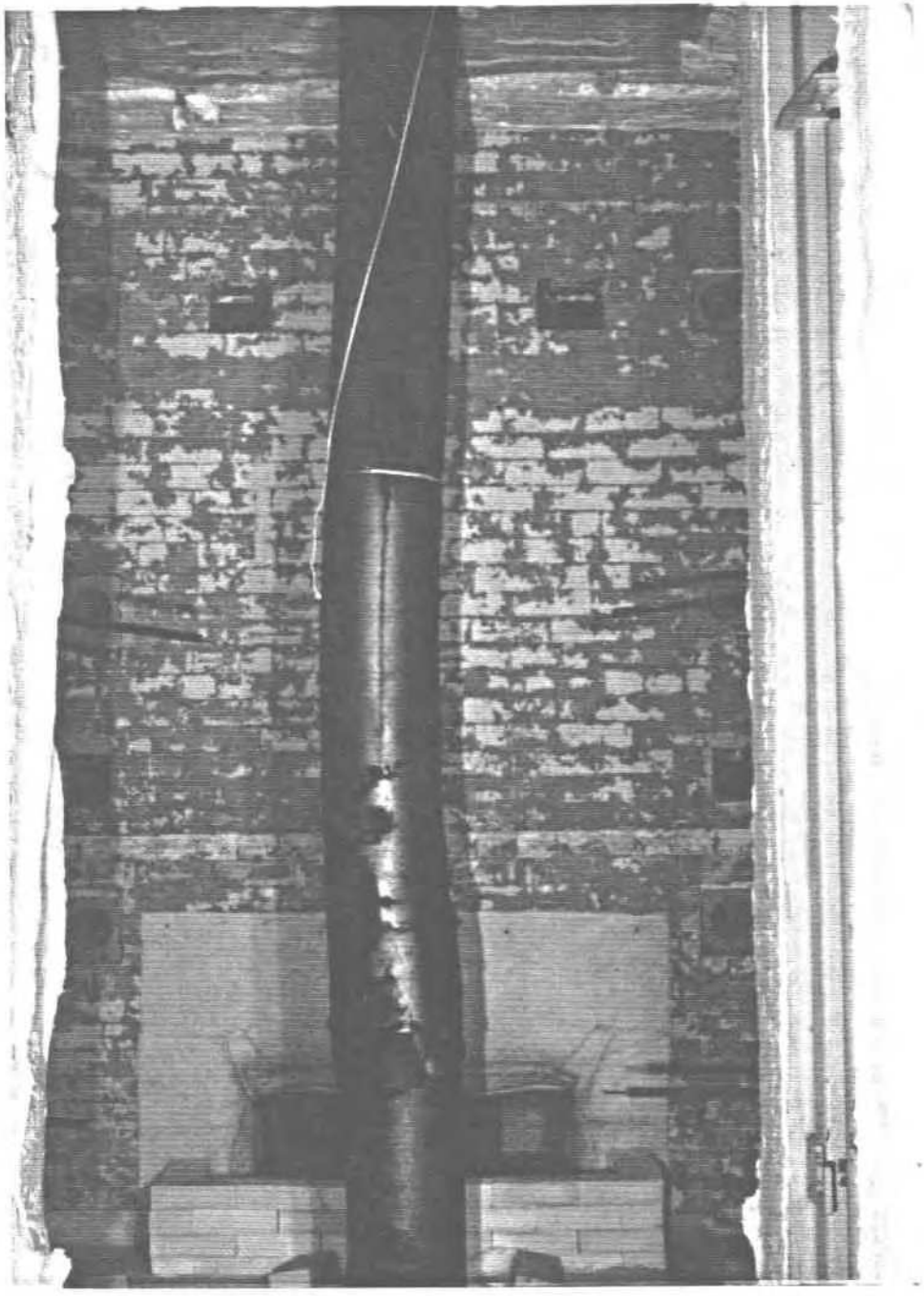


Figure B29. Column No. C-44 after test

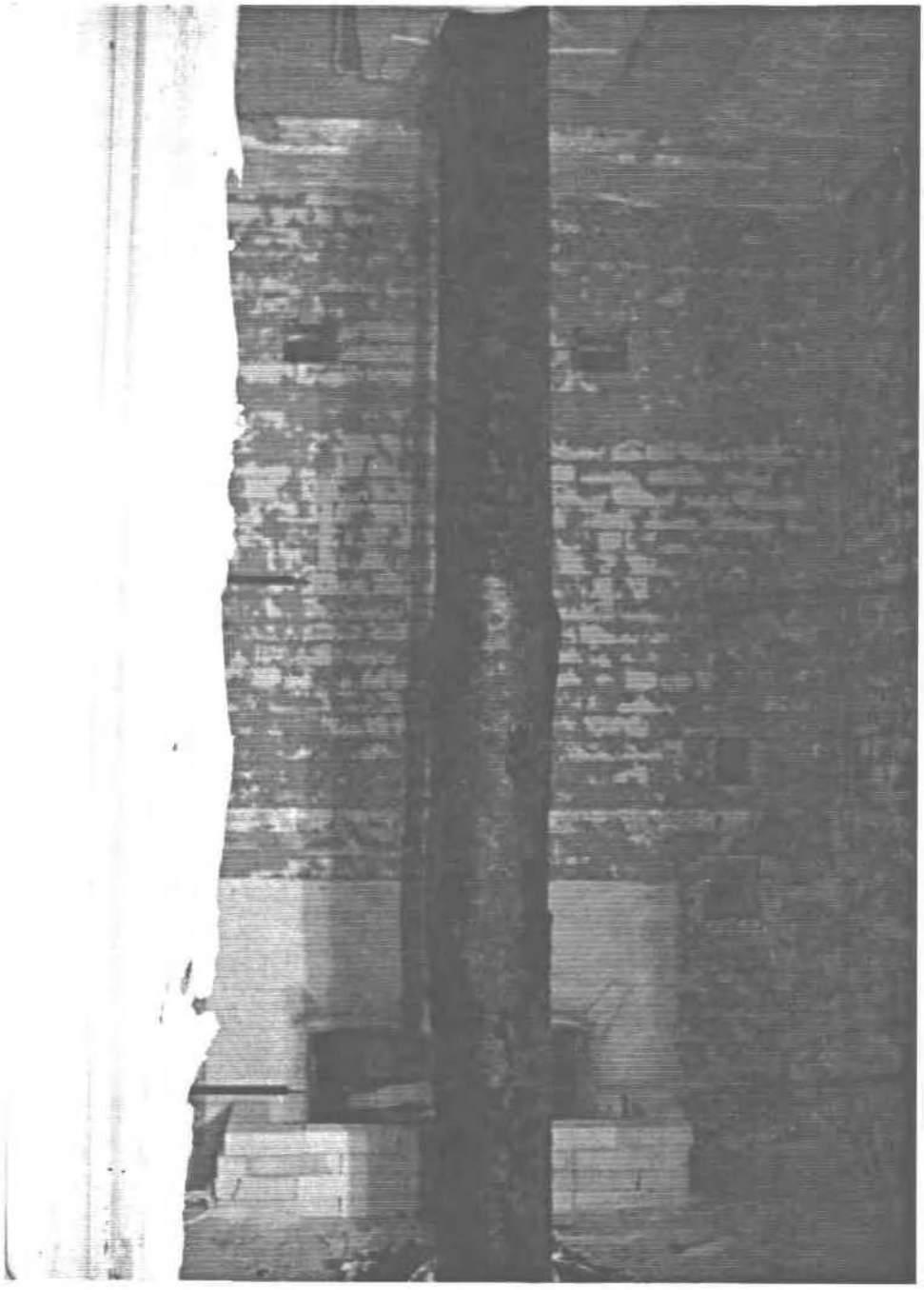


Figure B30. Column No. C-45 after test

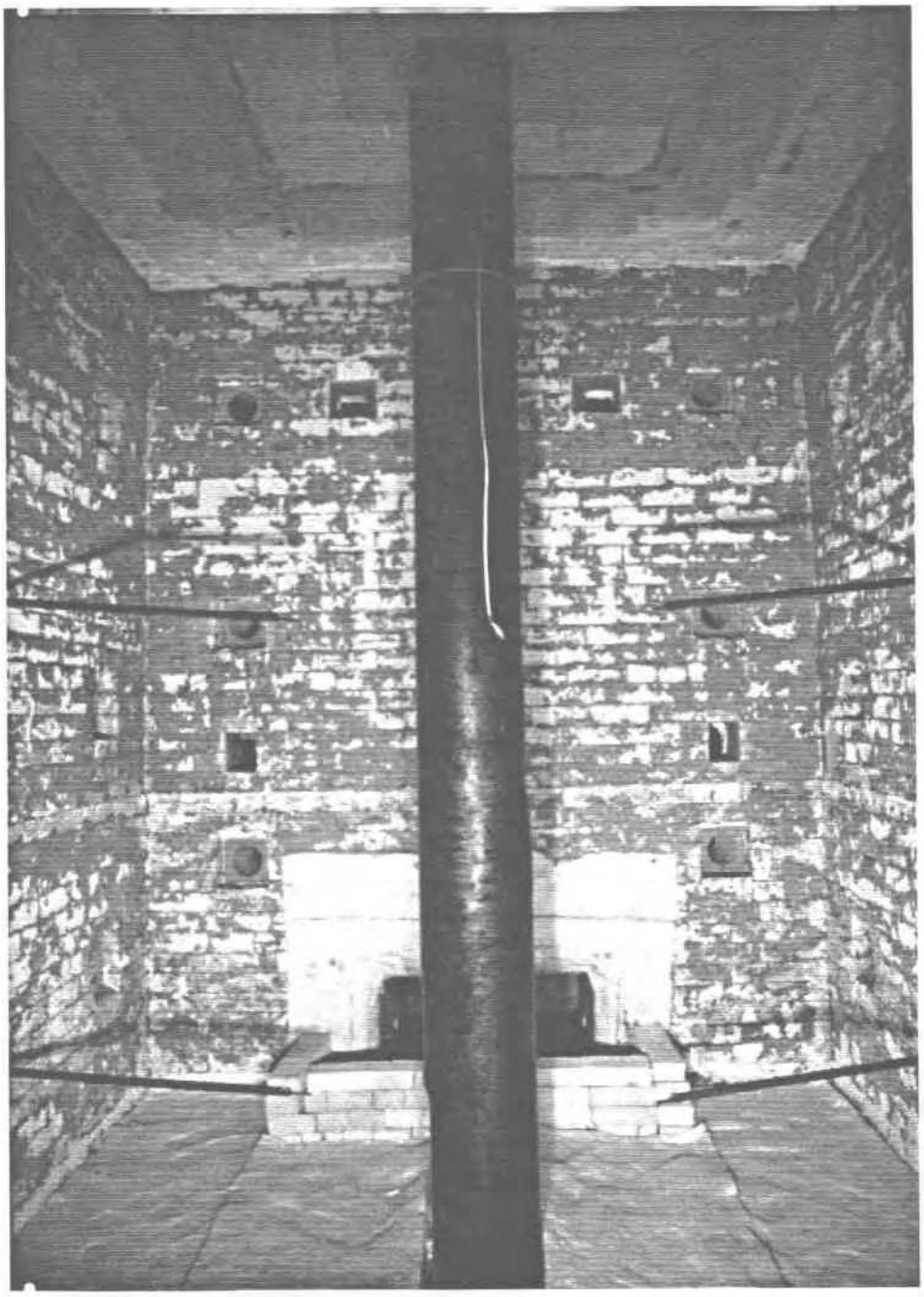


Figure B31. Column No. C-46 after test

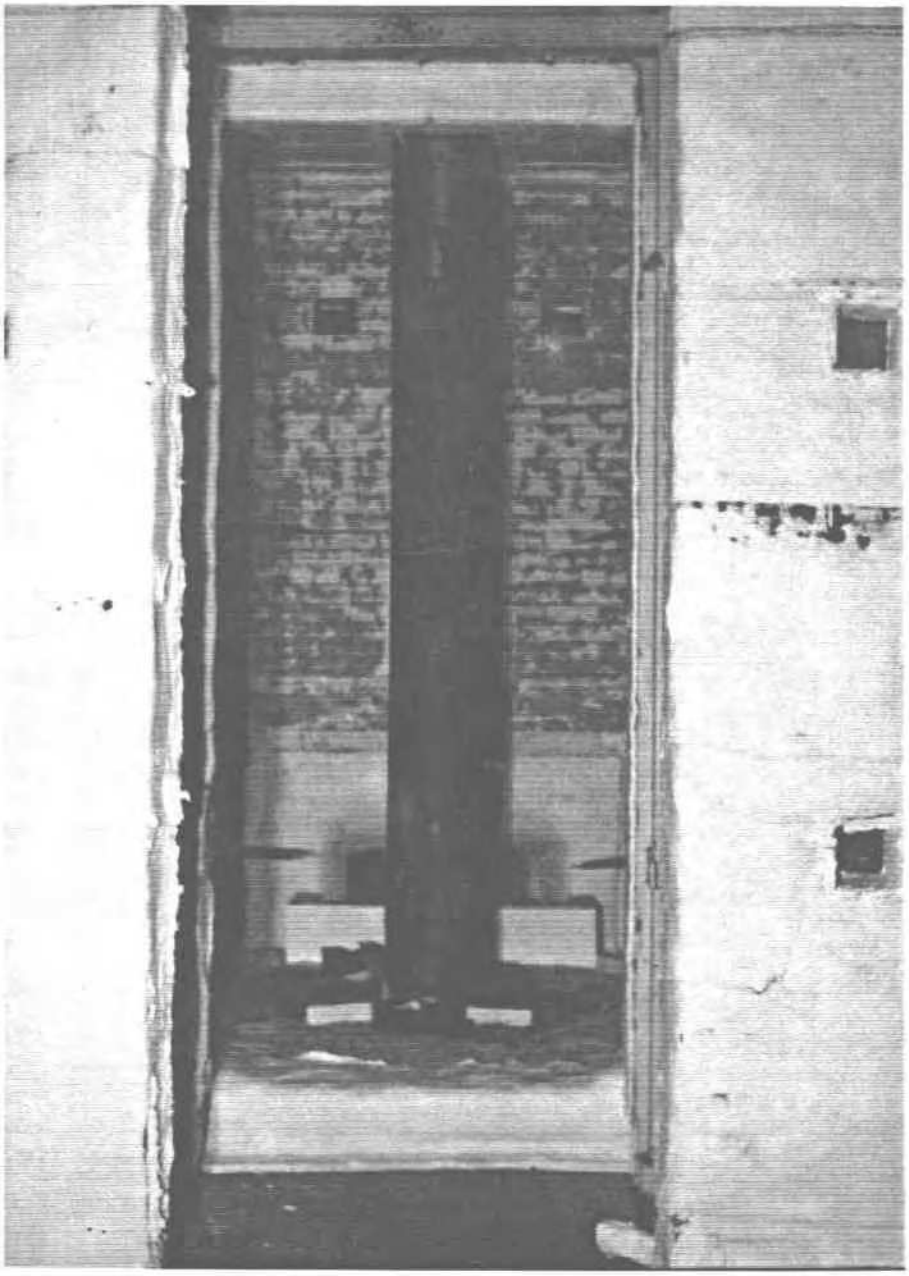


Figure B32. Column No. C-50 after test

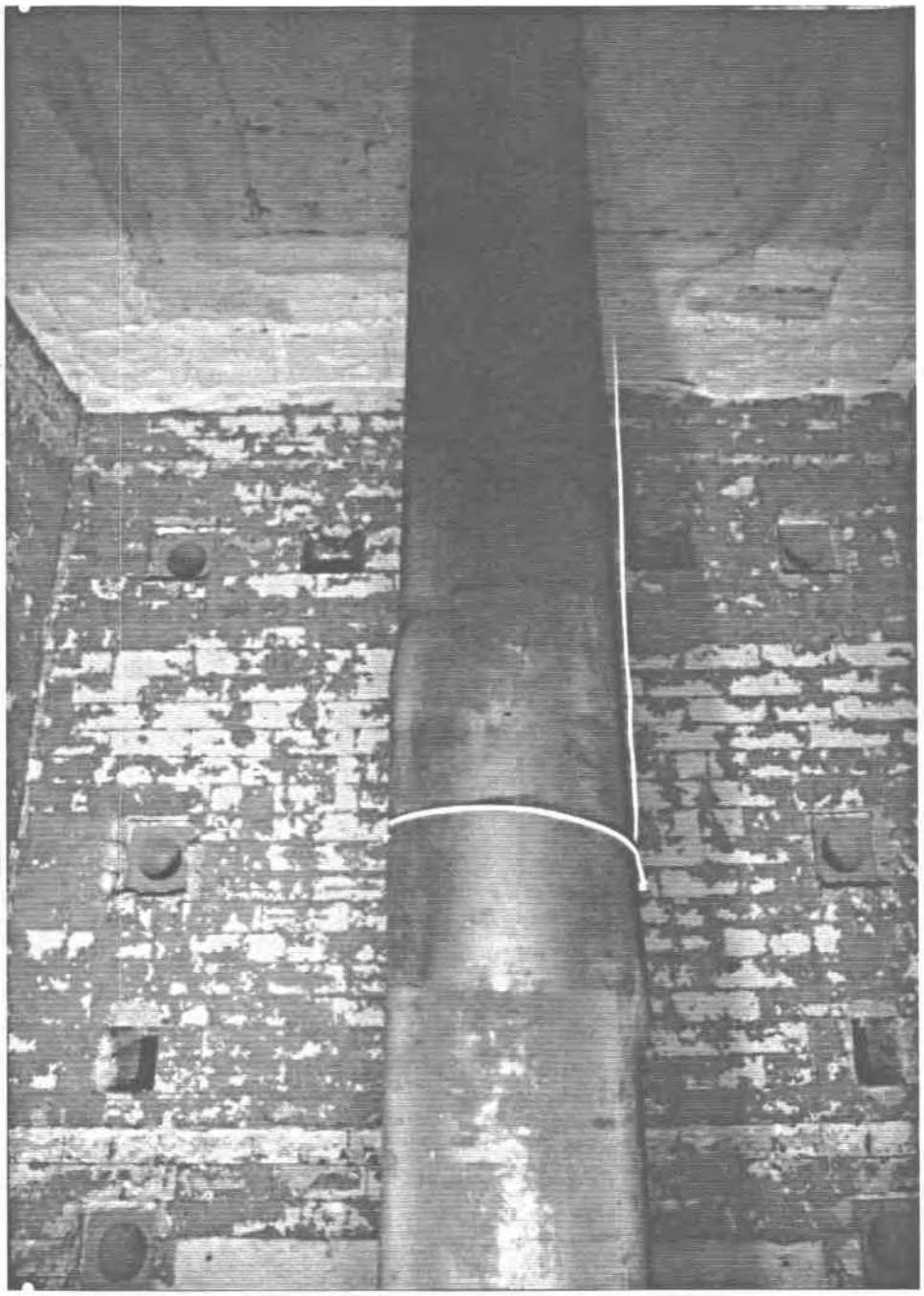


Figure B33. Column No. C-51 after test

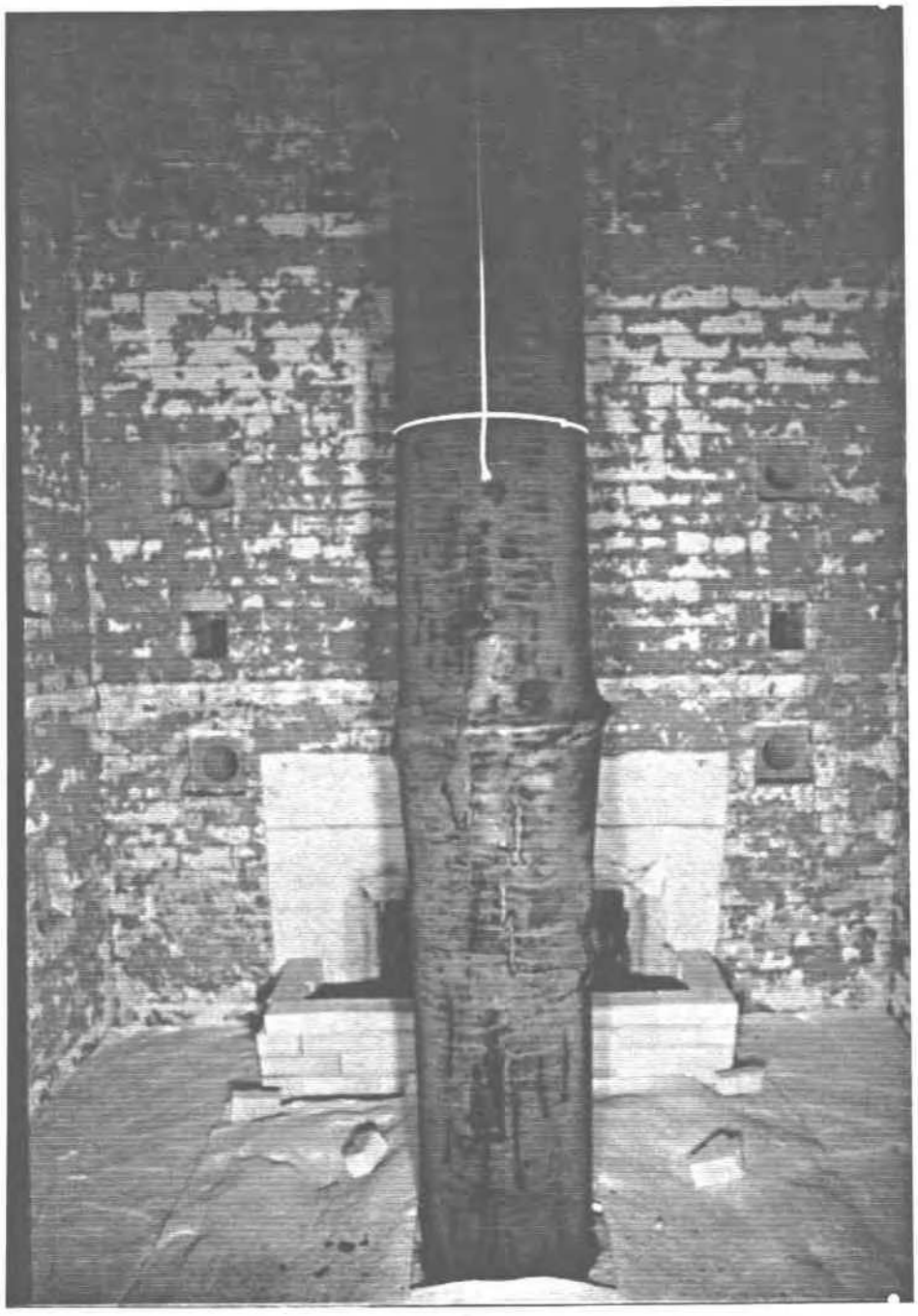


Figure B34. Column No. C-53 after test

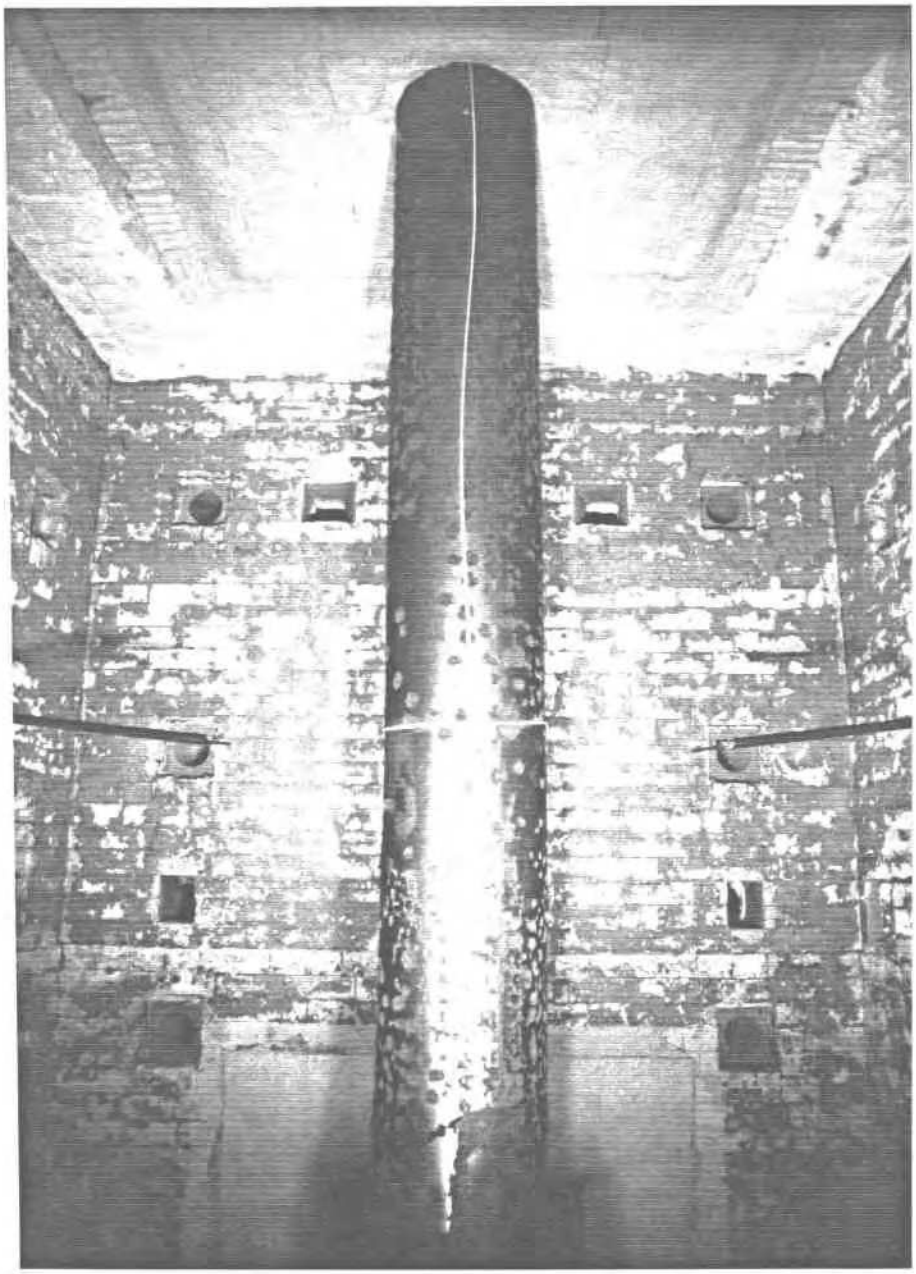


Figure B35. Column No. C-55 after test

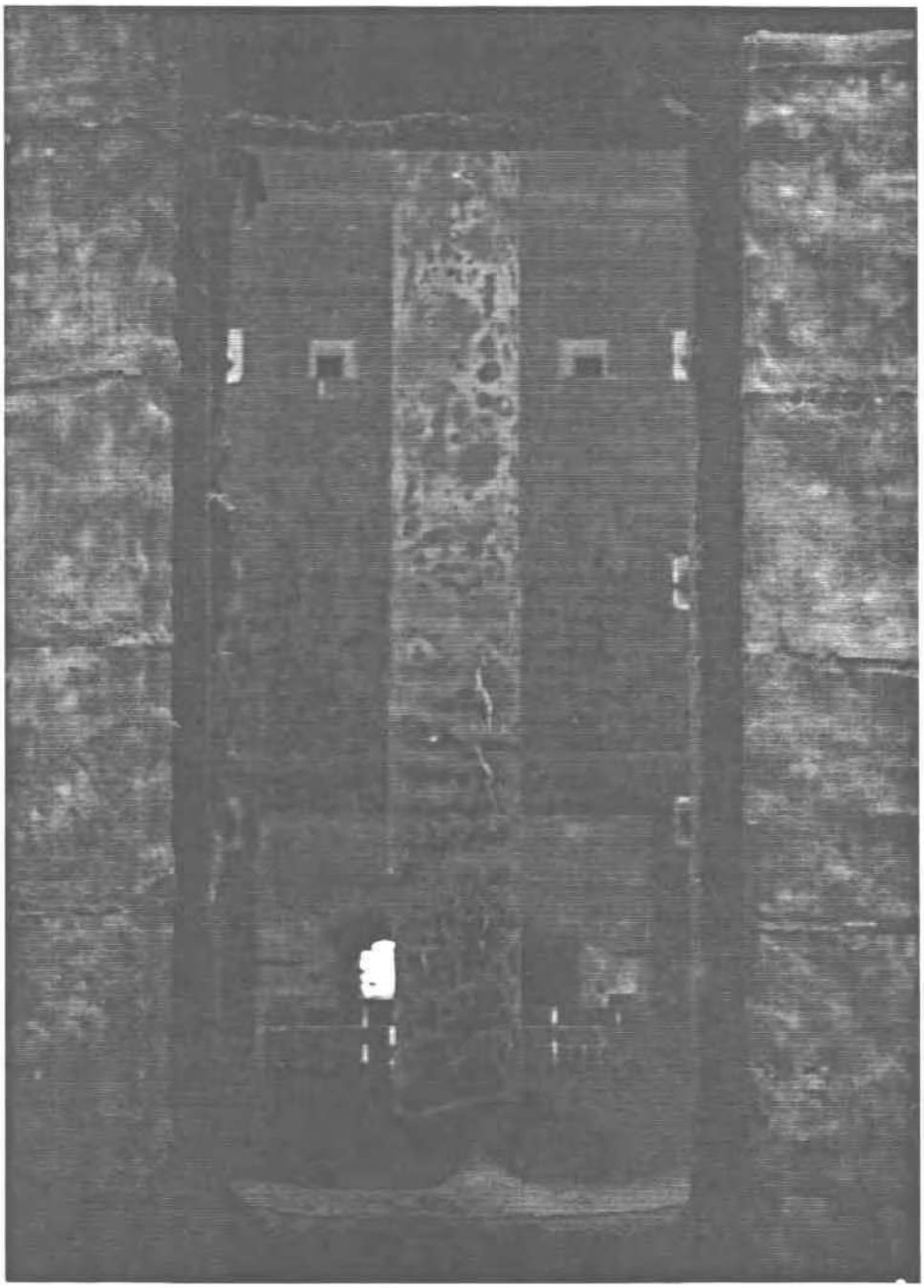


Figure B36. Column No. C-57 after test

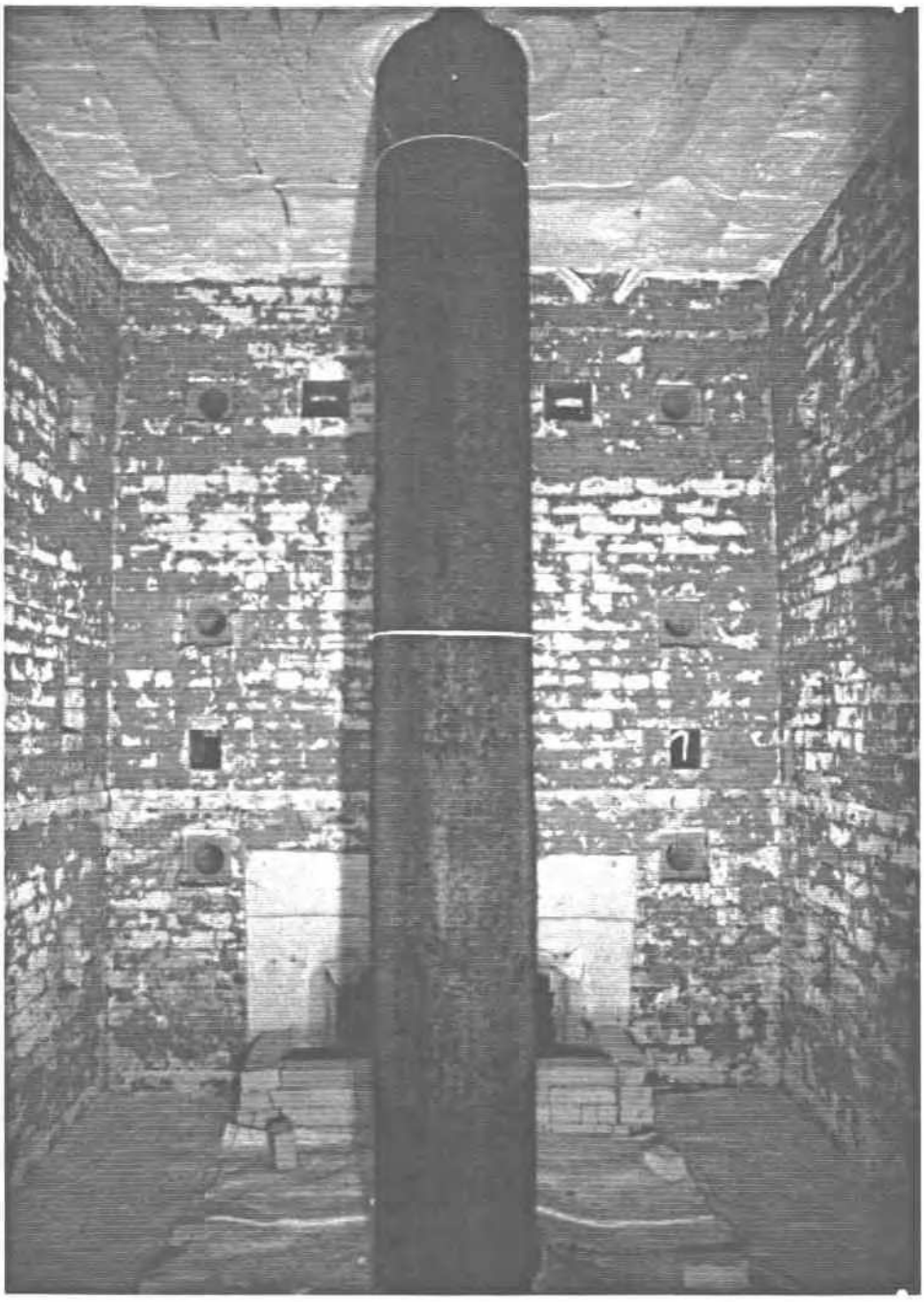


Figure B37. Column No. C-59 after test

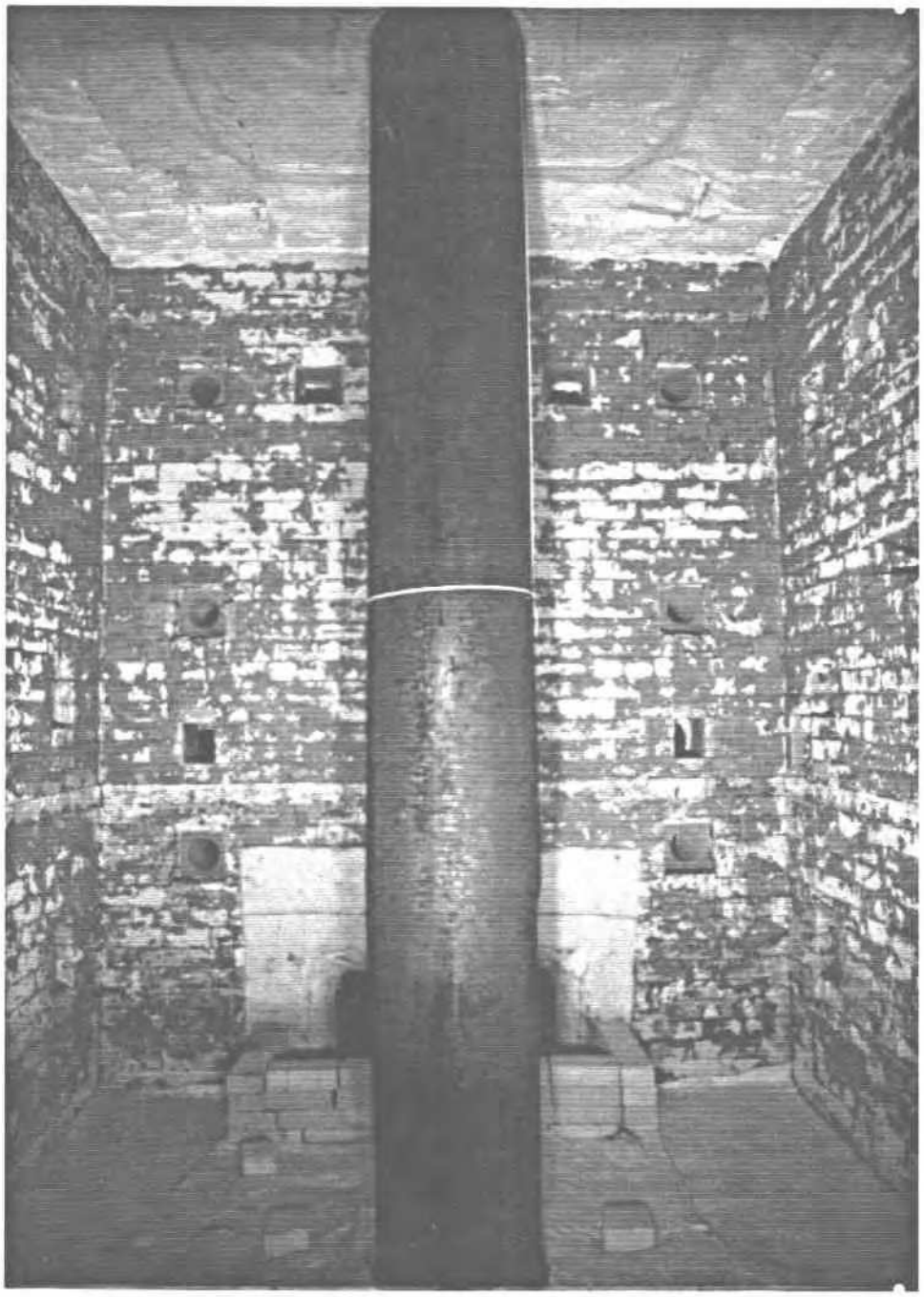


Figure B38. Column No. C-60 after test

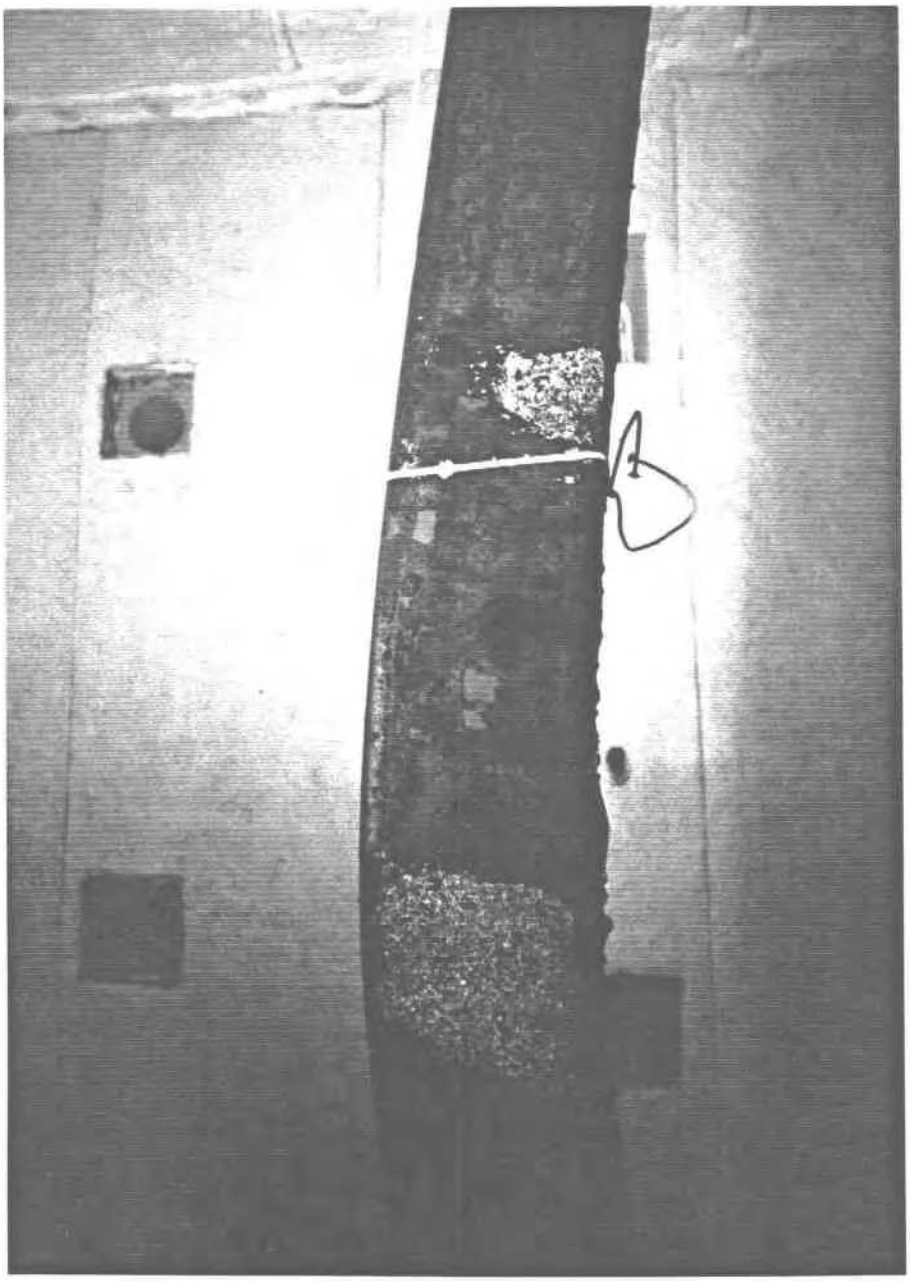


Figure B39. Column No. SQ-01 after test

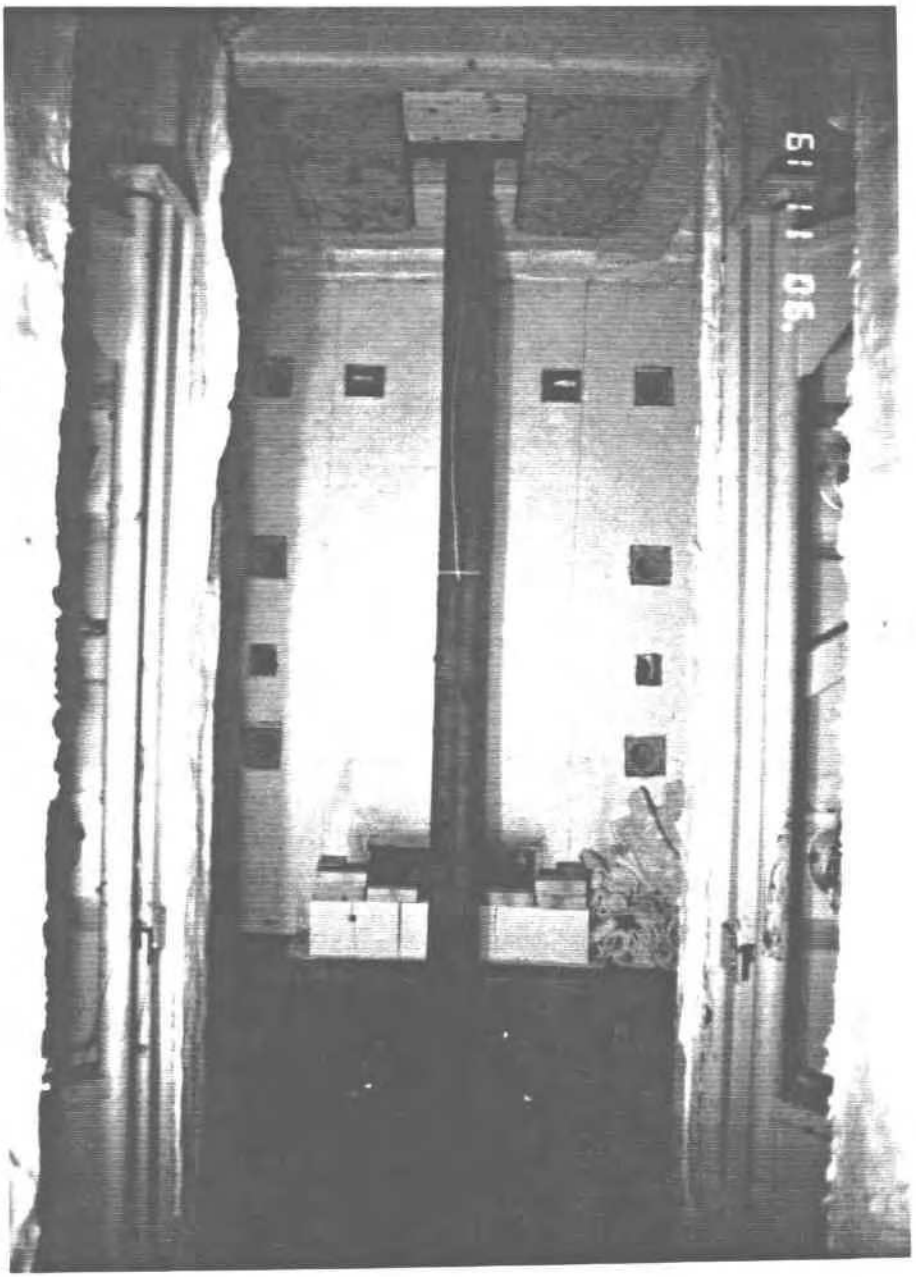


Figure B40. Column No. SQ-02 after test

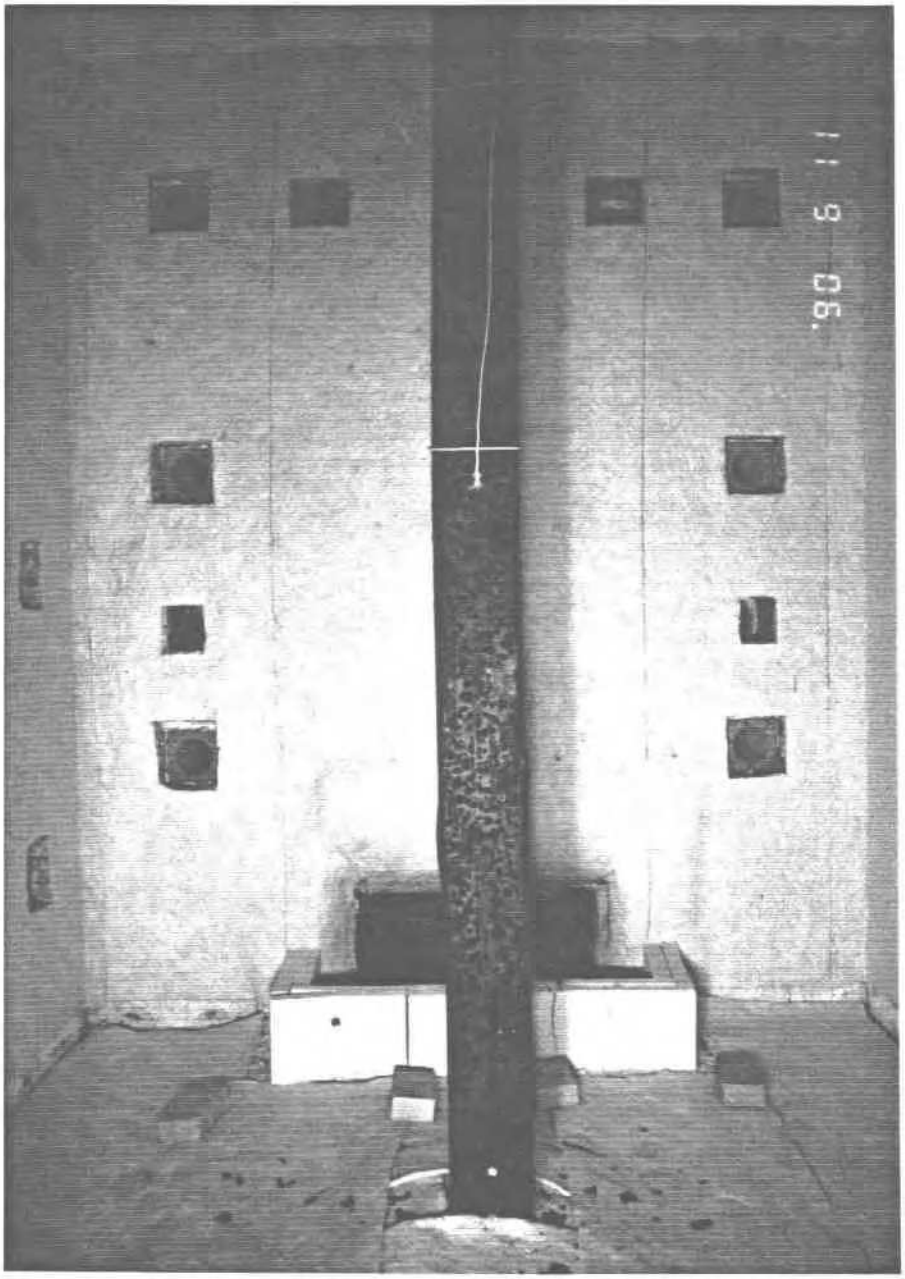


Figure B41. Column No. SQ-07 after test

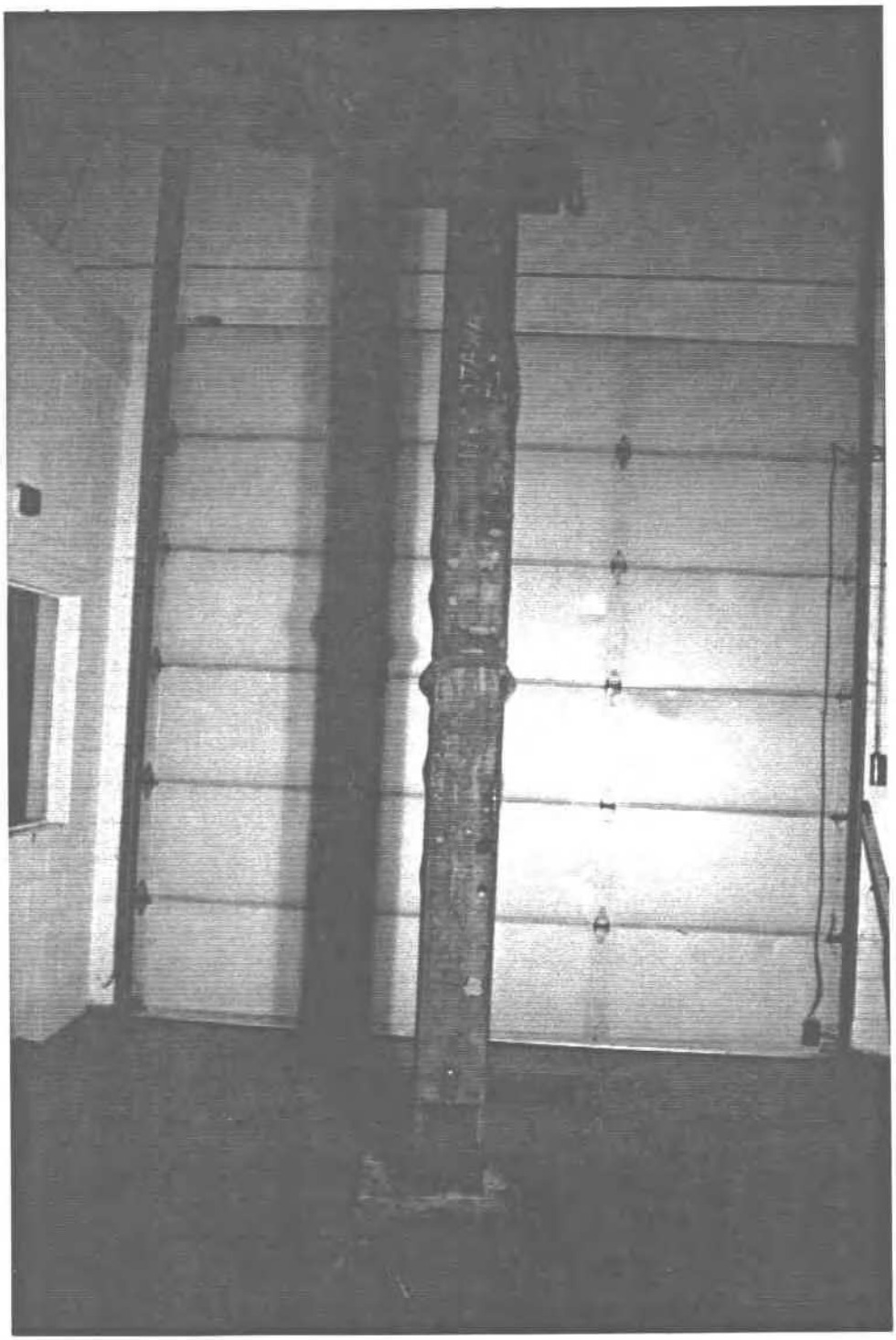


Figure B42. Column No. SQ-17 after test

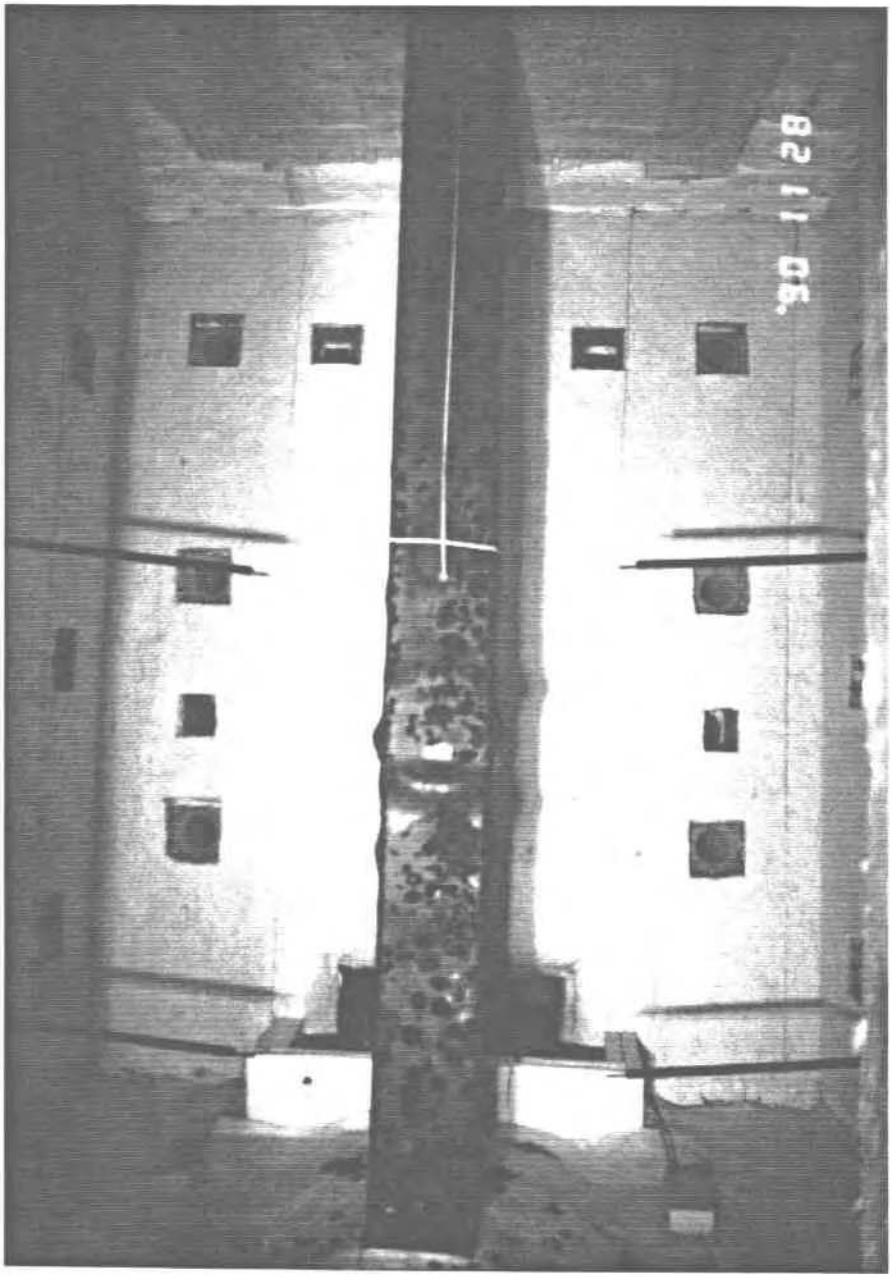


Figure B43. Column No. SQ-20 after test

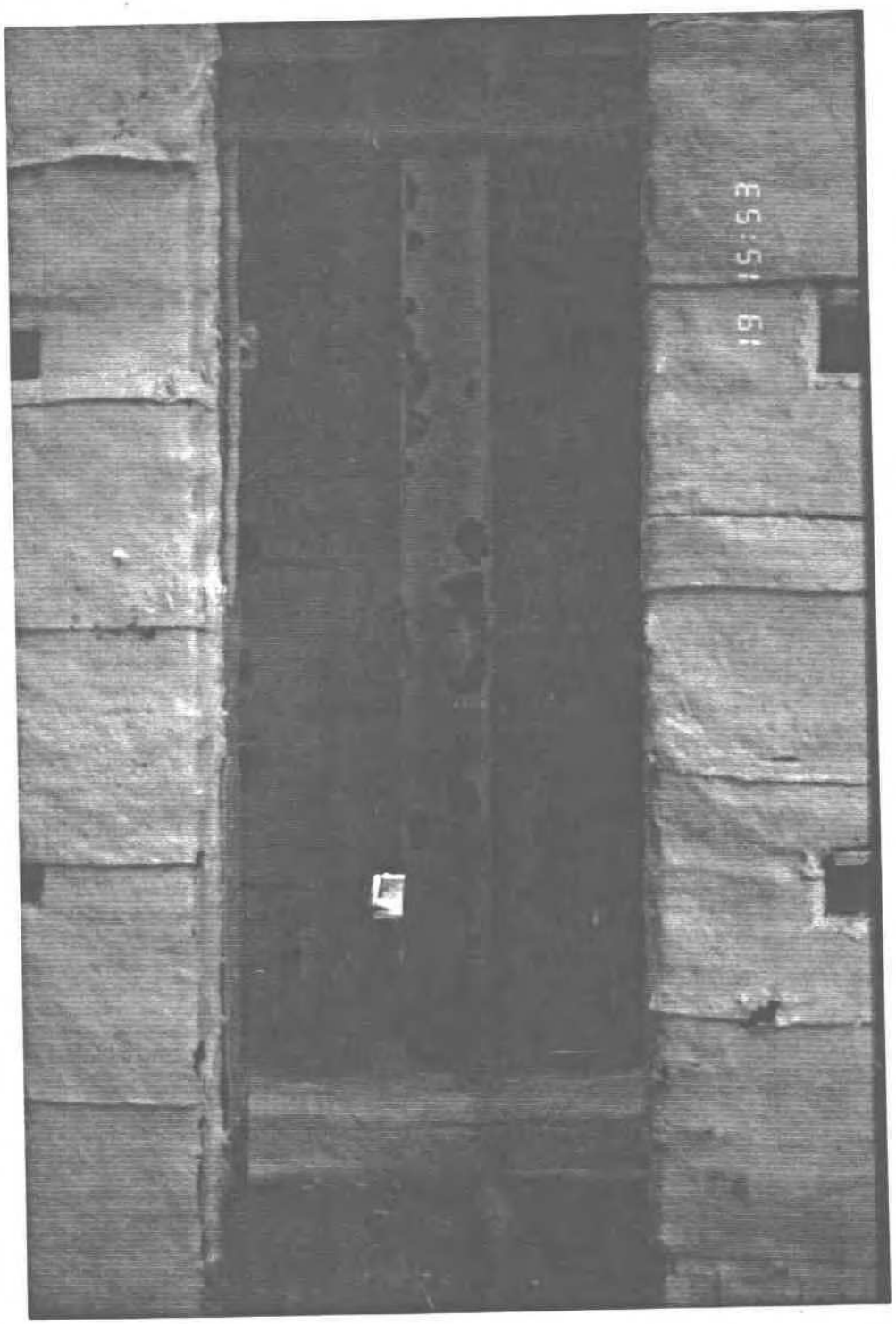


Figure B44. Column No. SQ-24 after test