U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
Gaithersburg, MD 20899

REPORT OF TEST

FR 3991

on

Pilot-Scale Fire-Endurance Tests of Subliming Fire-Barrier Panels

by

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January 6, 1993

Submitted to:

Office of Nuclear Reactor Regulation
United States Nuclear Regulatory Commission
Washington, DC 20555

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Executive Summary

These tests were carried out at the request of the U.S. Nuclear Regulatory Commission (NRC) to obtain information on the fire endurance of several configurations of NRC-supplied "1-hour" and "3-hour" fire-barrier panels when tested as horizontal planar units in a pilot-scale furnace. The test configurations were chosen primarily to assess the effects of the presence and perimeter constraints of a wire-mesh covering integral to one or both surfaces of these barrier panels.

For reasons presented later in this report, pilot-scale fire-endurance testing is limited to assessing the thermal-transmission characteristics of fire barriers, often under non-conservative edge-loss conditions. Furthermore, since the tests in the current series were conducted on planar units (i.e., as "ceilings" forming the top of the furnace), exposed to the furnace on only one surface, the results cannot be used to assess the performance of a cable-tray fire-barrier enclosure exposed to the furnace on four sides, which is a more severe exposure. **For these reasons, the reader is cautioned against using the results from this test series to assess the potential fire performance of full-scale cable-tray fire barriers.**

The tests were conducted in the pilot-scale fire-endurance furnace located at the U.S. Department of Commerce, National Institute of Standards and Technology (NIST). A total of 8 tests were conducted; 6 tests involving only NRC-supplied subliming fire-barrier panels, 1 test of a gypsum-board/steel-stud horizontal "wall" partition, and 1 cable-tray test consisting of a cable-tray assembly atop a subliming fire-barrier panel. The first 6 tests were performed to assess the effects of the presence and perimeter constraints of a wire mesh integral to one or both surfaces of the NRC-supplied fire-barrier panels. The gypsum-board partition was tested to provide a comparison between the pilot-scale fire-endurance of this common fire barrier, as determined in the NIST furnace, and its full-scale performance, as reported by Underwriters Laboratories (UL) [1][1]. The cable-tray test was conducted to obtain unexposed-surface, tray, and numerous cable temperatures throughout a cable-tray/barrier assembly exposed to the furnace on only one side.

Procedures specified in American Society for Testing and Materials (ASTM) E 119-88 generally were followed except when restrictions imposed by the pilot-scale precluded strict adherence to the procedure or suggested the procedure be modified (e.g., number and placement thermocouples)

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[1]The orientations, however, were different; the reduced-scale specimen was horizontal, whereas the full-scale was vertical.

The test results are summarized in Table ES1, which is located on pages 4 through 7. The primary results are:

1. For all assemblies using NRC-supplied fire-barrier material, the E-119 average-unexposed-surface-temperature criterion was reached before 1 hour or 3 hours, whichever applied to the test assembly.

2. Assemblies which provided enough support to prevent collapse of the exposed-surface char layer on NRC-supplied barrier materials did not burn through. Burnthrough did occur in all tests in which the char layer collapsed.

3. The UL full-scale fire-endurance rating for the gypsum-board assembly is 1 hour when tested as a wall. The fact that the pilot-scale horizontal assembly failed earlier (at 53.3 minutes) likely is due to the greater gravitational moments on gypsum panels in the horizontal orientation.

TABLE ES1. SUMMARY OF PILOT-SCALE FIRE-ENDURANCE RESULTS

	Fire-endurance period by E-119 criteria (hr:min)
"1-hour" Assemblies	
Test 1-2: Single sheet of 1-hour fire-barrier panel tested with ribbed surface as the unexposed surface and with wire-mesh covering constrained along perimeter.	0:22.0
Test 1-3: Single sheet of 1-hour fire-barrier panel tested with ribbed surface as exposed surface and with wire-mesh covering constrained along perimeter.	0:32.9
Test G-1: One layer of 16 mm (5/8 in) gypsum board (type SC) attached with drywall screws to both sides of 92 mm (3-5/8 in) steel studs; no insulation in stud cavity.	0:53.3
Test 1T-1: A 0.30 m wide steel cable tray, with one layer of cables, atop 1-hour fire-barrier panel with its ribbed (unexposed) surface facing upward and its wire mesh constrained along perimeter. Sides, top, and ends of tray were insulated.	0:35.0
"3-hour" Assemblies	
Test 3-1: Single sheet of 3-hour fire-barrier panel tested with ribbed surface as unexposed surface and with both wire-mesh coverings constrained along perimeters.	2:20.5
Test 3-2: Single sheet of 3-hour fire-barrier panel tested with ribbed surface as unexposed surface and with wire mesh on exposed surface unconstrained along perimeter and wire mesh on unexposed surface constrained along perimeter.	0:42.0
Test 1-4/5: Two sheets of 1-hour fire-barrier panel tested one atop the other with flat faces back-to-back. Wire mesh on exposed surface unconstrained along perimeter. Wire mesh on unexposed surface constrained along perimeter.	1:25.8
Test 1-6/7: Two sheets of 1-hour fire-barrier panel tested one atop the other with flat faces back-to-back. Wire meshes on unexposed and exposed faces of assembly constrained along perimeters.	2:37.0

TABLE ES1 (Cont.).

Exposure time (hr:min)	Times at which E-119 unexposed-surf.-temp. criteria were met. (hr:min:s) Avg. Temp.	Peak Temp.	Time at which NRC unexposed-surf.-temp. criterion (325°F) was met. (hr:min:s)	Max. deflect. of center of specimen[2]. (mm/in)
"1-hour" Assemblies				
1:00	0:22:00	0:28:00	0:17:50	17.9 / 0.70
1:00	0:33:00	0:46:00	0:26:27	41.1 / 1.62
1:00	0:53:15	0:53:40	0:52:45	Not measured.
1:00	0:35:00	0:47:30	0:26:57	Not measured.
"3-hour" Assemblies				
3:30	2:20:00	3:12:00	2:01:40	19.5 / 0.77
3:01	0:42:00	0:45:08	0:38:22	56.9 / 2.24
3:00	1:26:00	1:32:34	1:21:56	37.2 / 1.46
3:00	2:37:00	Not reached.	2:27:48	11.3 / 0.44

[2]Since only the center's deflection was measured, the listed values do not necessarily represent the maximum deflection of the specimen. Nevertheless, throughout the test series, the center's deflection was judged to be either the maximum or close to the maximum deflection of the specimen.

TABLE ES1 (Cont.).

	Unexp. surf.: Glowing first observed at edge of TC pad. (hr:min:s)	Unexp. surf.: Glowing first observed elsewhere. (hr:min:s)	Post-test inspection revealed burnthrough[3] beneath one or more thermocouple (TC) pads.
"1-hour" Assemblies			
Test 1-2	0:38:45	0:42:30	Yes
Test 1-3	None observed.	None observed.	No (but severely charred beneath 3 pads).
Test G-1	None observed, but paper scorched at most edges at 0:58:45.	None observed.	Cracks beneath all pads at 1:10:00.
Test 1T-1	Unexp. surf. could not be observed during test. No pads used.	Unexp. surf. could not be observed during test.	N.A., pads not used.
"3-hour" Assemblies			
Test 3-1	None observed.	None observed.	No
Test 3-2	1:17:45	1:16:00	Yes
Test 1-4/5	2:14:15	2:17:15	Yes
Test 1-6/7	None observed.	None observed.	No

[3]The term "burnthrough" is used in this report to indicate that only a very small amount of ash or light char remained attached to the wire mesh.

TABLE ES1 (Cont.).

Post-test inspect. revealed burnthrough[4] at locations other than beneath thermocouple (TC) pads	Comments
"1-hour" Assemblies	
Yes	No wire mesh or other support on exposed face to constrain char, which fell away during test, leading to burnthrough at numerous locations.
No	Wire mesh on exposed face was constrained on perimeter and apparently provided support for char layer, which remained intact throughout test.
No	Gypsum board continued to crack during cool down. Most of exposed area of lower panel fell into furnace prior to removal of test assembly.
No	No wire mesh on exposed face, but narrow steel support on E-W centerline (and perhaps smaller exposed area) apparently contributed to keeping the char layer intact throughout the test.
"3-hour" Assemblies	
No	Wire mesh on exposed face was constrained on perimeter and apparently provided support for char layer, which remained intact throughout test.
Yes	Wire mesh on exposed face was not constrained at perimeter. Mesh and char fell away during test, leading to burnthrough over 75 to 80 percent of exposed area.
Yes	Wire mesh on exposed face was not constrained at perimeter. Mesh and char fell away during test, leading to burnthrough over about 50 percent of exposed area.
No	Wire mesh on exposed face was constrained on perimeter and apparently provided support for char layer, which remained intact throughout test.

[4]See definition of "burnthrough" in footnote on previous page.

Objective

These tests were carried out at the request of the U.S. Nuclear Regulatory Commission (NRC) to obtain information on the fire endurance of several configurations of "1-hour" and "3-hour" subliming[5] fire-barrier panels when tested as horizontal planar units in a pilot-scale furnace. The configurations were chosen primarily to assess the effects of the presence and perimeter constraints of a wire-mesh covering integral to one or both surfaces of the subliming fire-barrier panels.

Definitions

We intend that certain terms in this report be understood as follows:

Fire endurance --- (also known as fire resistance) is a measure of the ability of a fire barrier to prevent the spread of fire past the barrier. Fire endurance is measured in time units per ASTM E 119-88, Standard Methods for Fire Tests of Building Materials. Perhaps equally important are some examples of what fire endurance is not. **It is not a measure of flammability; that is, it is not a measure of ignition, combustibility, heat release rate, or flame spread rate.**

Burnthrough --- indicates that essentially all of the material across the thickness the barrier disappeared as a result of burning or other degradation induced by the fire. In the case of the subliming fire-barrier material, burnthrough indicates that only a very small amount of char or ash remained attached to the wire mesh. If the furnace were shifted suddenly to positive pressure, flame and/or hot gases would be expected to pass immediately through burnthrough areas.

Constrained --- indicates that the panel or wire mesh extended over the sample-support lip (an unexposed region; see Fig. I.2) and, therefore, was supported by the lip and subjected to the vertical load from bricks placed atop the test assembly above the lip. Consequently, with its perimeter restrained (fixed), the mesh had an opportunity to provided resistance to and support for an expanding char layer.

Unconstrained --- indicates that the wire mesh was removed from the perimeter area of the specimen that would normally rest on the sample-support lip. Therefore, the mesh covered only the exposed

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[5]This term is used by the product manufacturer. NIST have not examined the product's chemical behavior to determine whether or not sublimation occurs or is effective during fire exposure.

area of the specimen, was neither restrained nor supported by the furnace lip, and was free to move with (rather than resist or retain) an expanding char layer.

Significance of Pilot-Scale Fire-Endurance Test Results

It is important to note that pilot-scale fire-endurance tests on basically "planar" assemblies (e.g., walls, floor/ceilings), including those reported herein, generally produce fire-endurance periods that are greater (safer) than tests conducted on full-scale assemblies in a full-scale furnace. This is a consequence of important factors such as large-scale mechanical moments, joints, expansion, and other three-dimensional effects not being duplicated in pilot-scale tests. Also, edge heat losses play a more significant role at pilot-scale in a manner that makes the test assembly appear safer. For these reasons, pilot-scale fire-endurance testing is limited to assessing the thermal-transmission characteristics of fire barriers, often under non-conservative edge-loss conditions. In other words, achieving a given rating in a reduced-scale fire-endurance test is an insufficient condition for achieving the same rating in a full-scale ASTM E 119 test.

Furthermore, since the tests in the current series were conducted on planar units (i.e., as "ceilings" forming the top of the furnace), exposed to the furnace on only one surface, the results cannot be used to assess the performance of a cable-tray fire-barrier enclosure exposed to the furnace on four sides, which is a more severe exposure.

Consequently, owing to the inability to reproduce full-scale three-dimensional effects in the current test series and the use of a one-sided exposure, the reader is cautioned against using the test results to assess the potential fire performance of full-scale cable-tray fire barriers.

Scope of Test Series

The subject tests were conducted in the pilot-scale fire-endurance furnace located at the U.S. Department of Commerce, National Institute of Standards and Technology (NIST). A total of 8 tests were conducted; 6 tests involving only NRC-supplied subliming fire-barrier panels, 1 test of a gypsum-board/steel-stud horizontal "wall" partition, and 1 cable-tray test consisting of a cable-tray assembly atop a subliming fire-barrier panel. The first 6 tests were performed to assess the effects of the presence and perimeter constraints of a wire mesh integral to one or both surfaces of the subliming fire-barrier panels. The gypsum-board partition was tested to provide a comparison between the pilot-scale fire-endurance of this common fire barrier, as determined in the NIST furnace, and its full-scale performance, as reported by

Underwriters Laboratories (UL) [1][6]. The cable-tray test was conducted to obtain unexposed-surface, tray, and numerous cable temperatures throughout a cable-tray/barrier assembly exposed to the furnace on only one side.

Procedures specified in American Society for Testing and Materials (ASTM) E 119-88 generally were followed except when restrictions imposed by the pilot-scale precluded strict adherence to the procedure or suggested the procedure be modified (e.g., number and placement of furnace and unexposed-surface thermocouples and size of unexposed-surface thermocouple covers or pads). Another exception is that cotton waste was not used to check for ignition at burnthrough areas of specimens.

Hose-steam tests were not conducted.

Test Details and Results

I. Description of Laboratory Test Facility

A. Furnace Specifications and Specimen Mounting

The natural-gas-fired pilot-scale furnace has internal dimensions approximately 0.94 m x 0.94 m x 1.1 m (37 x 37 x 43 in) (Figs. I.1 and I.2). It has two recessed burners each having a 114 mm (4.5 in) diameter port. One burner port is located at the center of the east wall of the furnace and the other at the center of the west wall. There is no port for viewing the exposed surface of the specimen during a test.

The top of the furnace is equipped with a frame for supporting horizontal test specimens up to 0.806 m x 0.806 m (31.75 in x 31.75 in). An 85.7 mm (3.375 in) wide steel lip attached around the lower edge of the frame supports the sample (Fig. I.2). As this lip is insulated along its bottom, edge, and top with a ceramic-fiber blanket, the actual area of the sample exposed to the furnace is typically 0.58 m x 0.58 m to 0.61 m x 0.61 m (23 in x 23 in to 24 in x 24 in)

For the panel and partition experiments in this series, nominally square samples were cut with dimensions from 0.794 m to 0.800 m (31.25 in to 31.5 in) on a side. After being placed in the sample frame and centered, the 3 to 6 mm (0.12 to 0.24 in) gaps between the edges of the sample and the frame were loosely packed with strips of ceramic-fiber blanket. Bricks (each nominally 3.4 kg [7.5 lb] with dimensions 230 mm x 115 mm x 64 mm [9.0 x 4.5 x 2.5

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[6]The orientations of the specimens, however, were different; the reduced-scale specimen was test horizontally whereas the full-scale specimen was tested vertically.

in]) were then placed side-by-side, with the 115 mm (4.5 in) dimension at or near vertical, along the perimeter of the sample within the area of the supporting lip. This arrangement prevented the upturn of sample edges and attendant flow of ambient air into the furnace along the breaches.

For the cable-tray experiment in this series, the exposed area of the sample was reduced by the installation of an insulated steel "mask" into the specimen frame. Details are presented in section IX.

B. Thermocouples

Furnace temperatures were measured with three chromel-alumel thermocouples (designated SR1, SR2, and SR3) positioned within the furnace as shown in Figs. I.1 and I.2. Space restrictions dictated that the thermocouples be mounted through the side walls of the furnace. Insertion lengths were 368 ± 13 mm (14.5 ± 0.5 in). Governed by furnace construction details and arrangements, the thermocouples were located at distances of 240 to 315 mm (9.4 to 12.4 in) beneath the exposed surface of the specimen which is close to the 305 mm (12.0 in) distance required by ASTM E 119-88.

These thermocouple assemblies were fabricated by a commercial thermocouple manufacturer. Butt-welded 18-gauge chromel and alumel wires were protected by a standard weight nominal 1/2-inch Inconel[7] pipe per the recommendation in paragraph 5.1, ASTM E 119-88. Employing the method set forth in ASTM RR:E05-1001, the time constant of thermocouple SR2 was found to be 5.2 minutes, which is within the range 5.0 to 7.2 minutes required by ASTM E 119-88.

Unexposed surface temperatures were measured at 5 locations during each panel and partition test. Thermocouple junctions were formed by welding overlapping 30 gauge chromel and alumel wires and were installed beneath the centers of insulation pads (described below) per E 119 requirements.

During some tests, a movable or "roving" version of the thermocouple-pad combination described above was used to augment the fixed unexposed-surface thermocouples.

In the case of the cable-tray experiment, unexposed surface thermocouples were attached without insulation pads. In addition, numerous thermocouples were installed throughout the cable-tray assembly. Details are presented in section IX.

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[7]Inconel is a registered tradename of INCO Alloys, Inc., 3800 Riverside Dr., P.O. Box 1958, Huntingdon WV 25720.

C. Unexposed-Surface Thermocouple Insulation Pads

Historically, the ASTM-E-119 requirement that unexposed-surface thermocouples be installed beneath insulating pads is based on the following considerations [2]:

1) the pads are intended to simulate the effects of combustibles stacked against the unexposed surface of a wall (or floor),
2) it is often difficult to mount a sensor to record the true surface temperature; it is easier to mount one interstitially, and
3) the pad reduces the effects of convection currents at the unexposed face on the surface-temperature measurement.

The pads closely approximate adiabatic conditions at the centers of the unexposed-surface areas they cover (at least until temperature limits specified in ASTM E 119 are reached). **For a homogenous specimen, the temperatures measured beneath the pads are always greater than the surface temperatures at other locations. Consequently, the measured temperatures are inherently conservative with respect to fire performance and safety.**

Although the density and thickness of each pad used in the current study conformed to E 119, the size was reduced from the standard 152 mm x 152 mm (6.0 in x 6.0 in) to 76 mm x 76 mm (3.0 in x 3.0 in) to accommodate the pilot scale. The pads were held in place with dabs of high-temperature RTV sealant (having a maximum continuous operating temperature of 315°C (600°F)) placed near each of the corners. The RTV was allowed to cure for at least 24 hours prior to the test.

D. Deflection Gauge

The deflection of the center of the specimen was monitored with a linearly-variable differential transformer (LVDT) through a lever arm connected to a pin resting on the specimen's center. It should be noted that owing to non-homogeneities of a given specimen, as well as variations in edge constraint forces, the center's deflection was not necessarily the maximum deflection experienced by the specimen. Nevertheless, throughout the test series, the center's deflection was judged to be the either the maximum or close to the maximum deflection of the specimen.

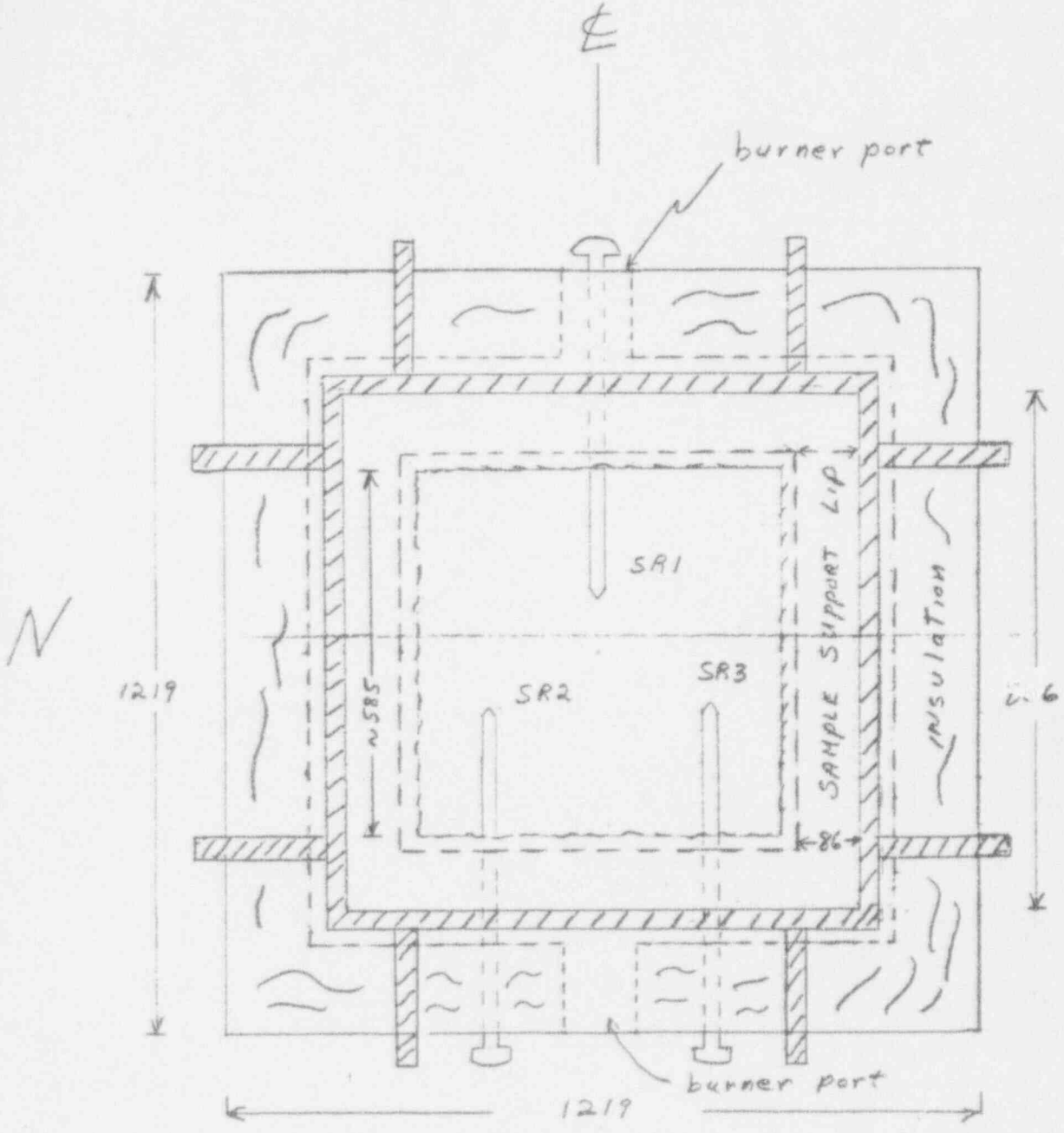

Fig. I-1. Furnace plan. All dimensions in millimeters.

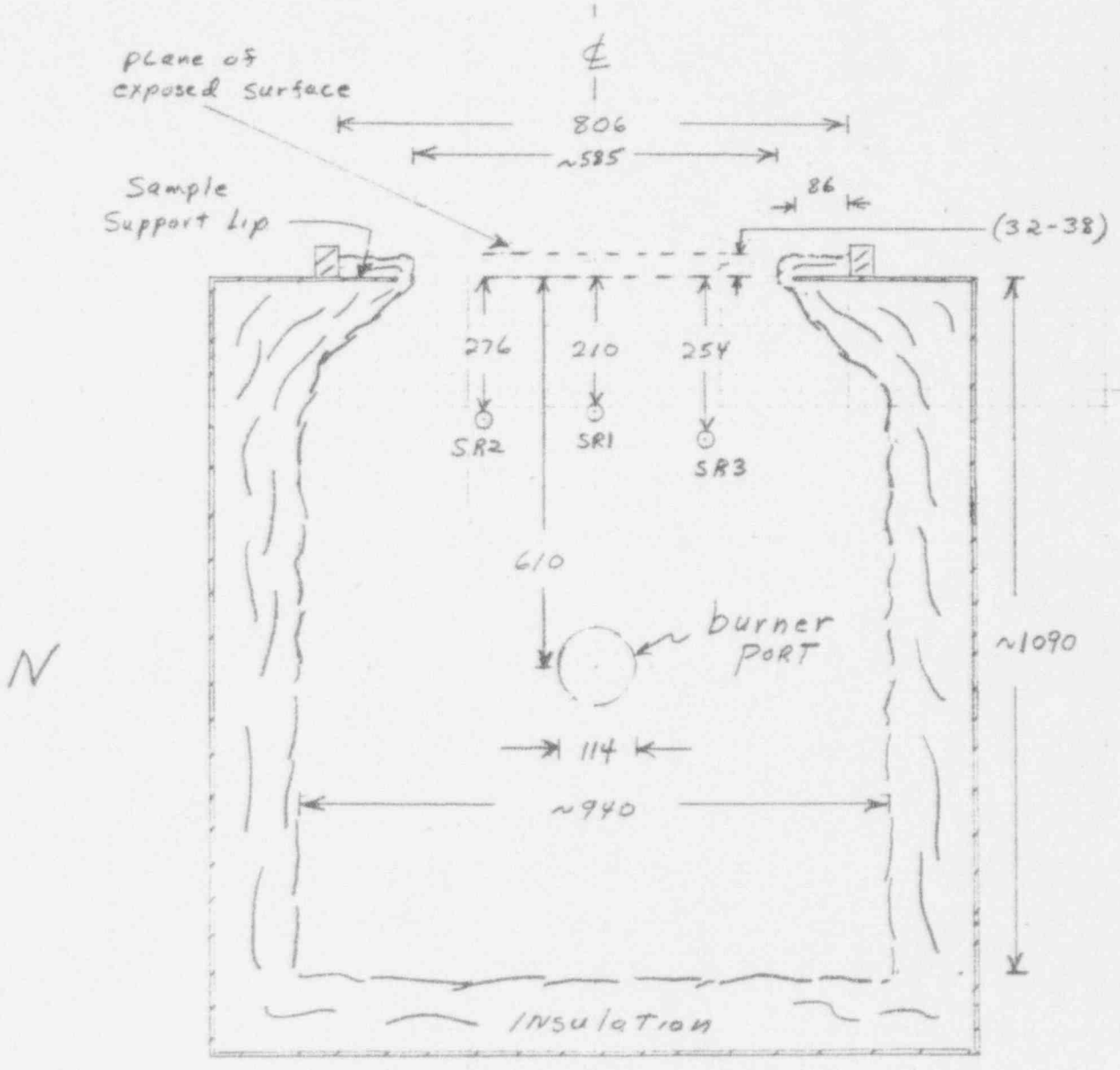

Fig. I.2. Furnace elevation. All dimensions in millimeters.

II. Test 1-2

A. Description of Test Assembly

The test assembly consisted of a single sheet of NRC-supplied 1-hour subliming fire-barrier panel. This panel is manufactured with a "flat" face, a ribbed face, and a wire mesh covering only the ribbed face. The specimen was tested with its ribbed surface as the unexposed surface and with the wire mesh covering the entire ribbed face.

The fire barrier specimen, designated sample 1-2, was cut to the dimensions shown in Fig. II.1 from a panel labeled by the manufacturer as F9203030 and F080891.

Thickness was measured at 32 locations; 12 in the "valleys" immediately adjacent to ribs, 15 approximately midway between ribs, and 5 off-rib locations marked as quality control measurement points by the manufacturer. These measurements can be summarized as follows:

	Thickness (mm [in])			
	avg.	std. dev.	max.	min.
"valleys"	16 [0.62]	1.7 [0.067]	19 [0.73]	14 [0.54]
between ribs	17 [0.65]	1.1 [0.043]	18 [0.71]	15 [0.59]
Mfrs. Q.C. pts.	17 [0.67]	1.1 [0.043]	18 [0.72]	16 [0.63]

Thicknesses at ribs were not measured. The pre-test mass of the specimen was estimated[8] to be 12.8 kg (28.1 lb). Pre-test photographs of the exposed and unexposed surfaces of the specimen are shown in Figs. II.2 and II.3.

The specimen was tested with its ribbed surface as the unexposed surface (facing upward) and with the wire mesh covering unaltered; i.e., the entire upper face was covered by the wire mesh. In this configuration, the wire mesh on the upper surface was constrained by the vertical load of the bricks located along the perimeter of the specimen.

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[8]The sample was not weighed before the test. The estimated figure is based on the areal density of the remnants of the panel from which the sample was cut.

B. Fire Test Procedures and Results

The test was conducted on July 15, 1992 and was witnessed by the following official observers: V. Babrauskas (NIST), P. Madden (NRC), R. Architzel (NRC), J. Ulie (NRC), and R. Paul (NRC).

The specimen was subjected to a 1-hour fire exposure controlled by the ASTM E 119-88 standard temperature-time curve. Plots of the furnace temperatures recorded by the individual furnace thermocouples and their average values are presented in Fig. II.4 and tabulated in Table II.1. The average furnace temperatures and the standard temperature-time curve are shown in Fig. II.5.

Unexposed-surface thermocouples measured surface temperatures beneath insulation pads at 5 locations designated 31 to 35 in Fig. II.1. The thermocouples at these locations are designated TC31 to TC35, respectively, and their outputs are plotted in Fig. II.6 and tabulated in Table II.1. Included in the table are the averages of the unexposed-surface temperatures as a function of time. Note that 4 of the 5 unexposed-surface thermocouples eventually exceeded the furnace temperature by up to approximately 100°C and all 5 thermocouples eventually cooled while the furnace temperature continued to increase. We comment on these apparent anomalies in the analysis section below.

The deflection at the center of the specimen was measured throughout the test and is plotted in Fig. II.7 and tabulated in Table II.1. Positive deflection indicates sag into the furnace. The maximum recorded deflection of 17.9 mm (0.705 in) occurred at 3600 seconds (1:00:00) (hr:min:s), when the test was terminated.

Figures II.8 to II.11 show the development of the pyrolysis zone on the unexposed surface during the test. A portion of the unexposed surface began to discolor (light brown) about 0:29:00. At 0:35:05 a black spot appeared about 25 mm (1 in) off the southwest corner of TC pad 32. Glowing appeared under the east edge of pad 32 at 0:38:45, through pin holes west of pad 32 at 0:42:30, and through a hole in the same area at 0:46:30. No flame passage was observed during the test -- presumably a consequence of having maintained the furnace at negative pressure. A log of observations and temperatures measured with the movable thermocouple are presented in Table II.2.

The exposed and unexposed surfaces after the test are shown in Figs. II.12 and II.13, respectively. The sample burned through underneath four TC pads and at a several points between pads. As shown in Fig. II.12, white char with thickness from near 0 to 10 mm (0 to 0.4 in) covered about 50 percent of the exposed area. There was no solid material left atop this char. The black char, which covered the remaining area, was 25 to 50 mm (1 to 2 in) thick. Solid material atop this char varied from 0 to 6 mm (0 to

0.12 in). The unexposed surface shown in Fig. II.13 shows that about 90 percent of its exposed area was blackened.

The post-test mass of the specimen was 6.52 kg (14.4 kg). A small pile of char was found at the bottom center of the furnace.

C. Analysis of Test Results

Concerning the apparent anomalies associated with the unexposed-surface temperature measurements (first exceeding the furnace temperature by up to 100°C and then cooling rapidly while the furnace temperature continued to increase), we first note these occurred well after the unexposed surface reached the temperatures specified in ASTM E 119-88 (listed below) and after the maximum working temperature of the RTV adhesive holding the thermocouple pads in place was exceeded (315°C)[600°F]. At the time of the test, we hypothesized the following scenario to explain the apparent anomalies.

The specimen material beneath an unexposed-surface thermocouple pad reacted and fell away until material immediately beneath the thermocouple began reacting exothermicly with oxygen in the furnace or oxygen flowing into the furnace (operating at negative pressure) at burnthrough areas of the unexposed surface along the perimeter of the pad. The additional energy released in the vicinity of the back-insulated thermocouple increased its temperature above that of the furnace. Eventually the pad adhesive failed and the thermocouple was no longer in contact with the unexposed surface. As more of the area around and beneath the pad burned through, more ambient air passed beneath the loosened pad and past the attendant thermocouple. The increased cooling effect of the air and the diminished heating as the specimen material beneath the pad burned out, eventually produced thermocouple temperatures below the furnace temperature.

Recently, we formed a second hypothesis. The scenario is similar, but adds the possibility of catalysis of the combustion products of the specimen by the exposed thermocouple materials (chromel and alumel), leading to more-complete combustion and higher temperatures in the region of the thermocouple.

Proving either of these hypotheses *post facto* would be very time consuming and is beyond the scope of the current test series. However, in future work, the use of metal-sheathed thermocouples should be used to eliminate the possibility of catalysis.

The ASTM E 119-88 thermal transmission acceptance criteria are that the average temperature rise of the unexposed-surface thermocouples shall not exceed 139°C (250°F) above its initial temperature (in this test, 25°C [77°F]) and the temperature rise of

any of these thermocouples shall not exceed 181°C (325°F) above the initial temperature. Another criterion is that at no time during the test should hot gases or flame pass through the assembly so as to ignite cotton waste held against the unexposed surface. In addition to these criteria, NRC requirements include monitoring the time at which any of the unexposed-surface thermocouples reaches 162.8°C (325°F).

On the basis of the experimental temperature data presented in Table II.1, the above temperature criteria were met at the following locations and times:

Criterion	Location	Time (sec)	Time [hr:min:sec]
E 119 avg. unexposed surf. temp. (164°C) [327°F]		1320	[0:22:00]
E 119 peak unexposed surf. temp. (206°C) [403°F]	TC 32	1680	[0:28:00]
NRC unexposed surf. temp., 1st occurrence (162.8°C) [325°F]	TC 32	1078	[0:17:58]

Concerning E 119 criteria, the average temperature was the controlling factor and **the E 119 fire-endurance period was 1320 seconds (22 minutes)**. Since the period is less than 1/2 hour, no correction was required to account for deviations of the actual average furnace temperature from the standard temperature-time curve (see ASTM E 119-88, Par. 7.4).

Although glowing was observed through the unexposed face of the specimen during the test, the E 119 cotton-waste test was not conducted. It should be noted that post-test inspection revealed burnthrough areas both beneath[9] and between thermocouple pads. It appears that a lack of wire mesh or other support on the exposed face to constrain the char and retain its insulating effect allowed the char to fall away, exposing layer after layer of virgin barrier material until essentially all the material, except the upper wire mesh, was gone.

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[9]Maximum temperatures are expected to occur beneath pads (see section I.C).

TABLE II.1. Temperatures, test 1-2.

NRC TEST 1-2

TIME	TEMPERATURE (°C) FURNACE				UNEXPOSED SURFACE						SAMPLE DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
-110	25	25	25	25	25	25	25	25	25	25	-0.0
-100	25	25	25	25	25	25	25	25	25	25	-0.0
-90	25	25	25	25	25	25	25	25	25	25	-0.0
-80	25	25	25	25	25	25	25	25	25	25	-0.0
-70	25	25	25	25	25	25	25	25	25	25	-0.0
-60	25	25	25	25	25	25	25	25	25	25	-0.0
-50	25	25	25	25	25	25	25	25	25	25	-0.0
-40	25	25	25	25	25	25	25	25	25	25	-0.0
-30	25	25	25	25	25	25	25	25	25	25	-0.0
-20	25	25	25	25	25	25	25	25	25	25	-0.0
-10	25	25	25	25	25	25	25	25	25	25	-0.0
-1	25	25	25	25	25	25	25	25	25	25	-0.0
0	25	25	25	25	25	25	25	25	25	25	0.1
10	25	25	25	25	25	25	25	25	25	25	0.1
20	25	25	25	25	25	25	25	25	26	25	0.3
30	27	28	27	27	25	25	25	25	25	25	0.8
40	32	32	32	32	25	25	25	25	25	25	1.3
50	41	38	40	39	25	25	25	25	26	25	1.8
60	53	46	51	50	25	25	25	25	25	25	2.3
70	69	57	65	63	25	25	25	25	25	25	2.7
80	87	70	82	79	25	25	25	25	25	25	3.1
90	108	86	101	98	25	26	25	25	26	25	3.4
100	131	105	123	119	25	26	25	25	26	26	3.7
110	156	127	145	142	26	26	26	25	26	26	4.0
120	182	151	170	167	26	27	26	26	26	26	4.3
130	209	176	196	193	26	27	26	26	26	26	4.5
140	237	202	224	220	26	28	27	26	26	27	4.8
150	265	228	253	248	27	29	28	26	27	27	5.0
160	295	256	282	277	27	30	28	27	27	28	5.1
170	325	284	312	306	28	32	29	27	28	29	5.3
180	355	312	341	335	29	33	30	28	29	30	5.6
190	384	340	369	364	30	34	31	29	29	31	5.8
200	412	367	396	391	31	36	32	30	30	32	6.0
210	438	392	420	416	32	38	34	30	31	33	6.2
220	461	415	442	439	33	39	35	31	32	34	6.3
230	483	437	463	460	34	41	36	32	33	36	6.5
240	503	457	482	480	36	43	38	33	34	37	6.7
250	519	476	499	498	37	45	39	35	36	38	6.9
260	533	492	514	513	39	47	41	36	37	40	7.0
270	544	507	528	526	40	48	42	37	38	41	7.2
280	554	520	539	537	41	50	44	38	39	43	7.3
290	562	531	549	547	43	52	45	40	41	44	7.4
300	569	541	558	556	44	54	47	41	42	46	7.6

TABLE II.1. Temperatures, test 1-2 (cont.).

NRC TEST 1-2

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
360	602	587	597	595	54	66	57	49	51	55	8.6
420	628	618	624	622	63	77	67	58	60	65	9.4
480	648	639	643	643	72	87	77	67	68	74	10.2
540	667	656	658	660	81	97	86	75	76	83	10.8
600	688	678	678	681	89	106	95	82	84	91	11.3
660	707	698	700	701	96	114	102	90	90	98	11.8
720	720	710	712	713	103	121	109	97	97	105	12.1
780	734	722	723	725	110	127	116	103	103	112	12.4
840	751	738	740	742	116	134	122	109	109	118	12.6
900	763	748	751	753	122	141	128	116	114	124	12.8
960	776	756	759	763	127	149	134	121	119	130	13.0
1020	791	769	768	776	133	156	141	127	123	136	13.2
1080	797	775	775	782	139	163	147	132	126	142	13.2
1140	799	779	779	785	146	168	153	138	132	147	13.3
1200	813	793	794	800	153	172	158	144	138	153	13.3
1260	826	806	807	813	160	176	163	150	145	159	13.3
1320	812	794	794	800	165	180	167	155	151	164	13.2
1380	822	803	803	809	170	183	170	160	158	168	13.2
1440	837	819	819	824	174	187	174	164	163	172	13.1
1500	833	817	819	822	177	190	177	167	168	176	13.1
1560	844	827	829	833	180	196	180	170	173	180	13.1
1620	856	840	840	845	184	201	183	173	176	183	13.1
1680	849	836	829	837	187	206	187	175	180	187	12.8
1740	843	828	825	831	190	212	191	178	183	191	12.9
1800	855	839	838	843	194	219	196	181	185	195	12.7
1860	856	841	841	845	199	226	201	184	189	200	12.6
1920	850	834	833	839	204	237	207	187	193	205	12.4
1980	862	846	845	850	210	251	213	191	198	213	12.2
2040	861	846	845	850	216	279	220	196	205	223	11.8
2100	864	851	851	855	225	335	230	201	212	241	11.8
2160	879	866	866	870	236	391	244	206	221	260	11.7
2220	868	856	853	859	251	640	274	211	231	322	11.6
2280	874	862	859	864	279	850	316	218	249	382	11.8
2340	890	877	875	880	314	903	357	226	269	414	11.8
2400	883	872	867	873	497	807	671	238	301	503	12.5
2460	894	884	879	885	624	725	774	257	356	547	13.3
2520	910	899	896	901	702	691	818	276	418	581	13.8
2580	924	914	910	915	776	654	852	294	494	614	14.6
2640	930	923	918	923	845	532	935	312	579	641	15.4

TABLE II.1. Temperatures, test 1-2 (cont.).

NRC TEST 1-2

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
2700	926	923	919	922	874	452	929	343	662	652	15.6
2760	924	925	922	923	946	432	779	386	719	653	15.6
2820	921	925	924	923	942	413	683	444	753	647	15.8
2880	917	921	920	919	913	407	598	488	789	639	15.8
2940	910	915	914	913	875	407	563	533	805	637	15.7
3000	907	909	909	908	855	448	589	574	815	656	15.6
3060	919	916	917	917	853	415	531	610	844	651	16.2
3120	910	909	910	909	843	422	543	644	937	678	16.5
3180	906	903	906	904	840	428	537	664	931	680	16.1
3240	907	902	906	904	840	428	550	670	911	680	16.1
3300	911	903	907	907	845	448	573	666	875	681	16.3
3360	916	907	911	911	848	437	567	650	853	671	16.7
3420	919	909	913	913	850	439	575	625	843	666	16.9
3480	922	910	914	915	854	464	590	603	835	669	17.3
3540	926	914	918	919	858	475	602	581	833	670	17.6
3600	928	916	920	921	860	493	579	560	833	665	17.9

TABLE II.2. Observations, test 1-2.

The following observations were made during and after the test:

(Note: MTC indicates surface temperature measured with movable thermocouple)

Time	
0:06:15	No obvious changes to unexposed surface.
0:07:30	Slight bowing of the sample.
0:16:30	Some outgassing from unexposed surface.
0:20:00	No change in appearance of TC pads.
0:24:00	Outgassing continues -- may be stronger on E. side of sample.
0:26:00	Still no obvious discoloration.
0:29:00	Outgassing is a bit stronger. Don't see hot spots but there may be a general darkening E. of TC pads 32 and 33. Can see "sparkling" W. of 33 (tiny crystals).
0:32:00	Outgassing stronger.
0:35:05	Darkening all around TC pad 32. Black spot appeared about 1 in off S.W. corner of pad 32. Temperature of spot 206°C (403°F)(MTC).
0:36:00 (aprx)	Black spot developing quickly E. of pad 32. Spot is about 1 in diameter. See "sparkling" around pad 33. Much outgassing around 32.
0:38:00	Vigorous smoking around pad 32. Hot spot developing on other side of ridge S. of 32.
0:38:45	Glowing under 32 (viewed from West.).
0:40:00	Bubbling around W. side of 33 and S. side of 35.
0:42:30	Glowing along N. edge of pad 31. Some glowing pin holes to W. of 32 in direction of 31.
0:43:30	365°C (689°F)(MTC) just W. of 31.
0:46:30	Glowing S. of 32 along N edge of 31 (between 31 and the ridge). Viewing from S.E. corner, can see hole near 35 (N. of 31) through which can see either the interior of the furnace or the glowing char matrix beneath the wire mesh.
0:52:00	550+°C (1022+°F)(MTC) W. of pad 31. Temperature did not stabilize (continued to increase). Abandoned MTC measurement because of increase in smoke concentration above furnace.
0:55:10	Bubbling on ridge between 31 and 35.
0:59:00	Glowing S. of 32; some E. of 32 between 32 and 31; N. of 31 on both sides of ridge; and along the perimeter of 33.
1:00:00	Began shut down (reducing fuel pressure to furnace).
1:01:45	Lifted and propped W. edge of sample.

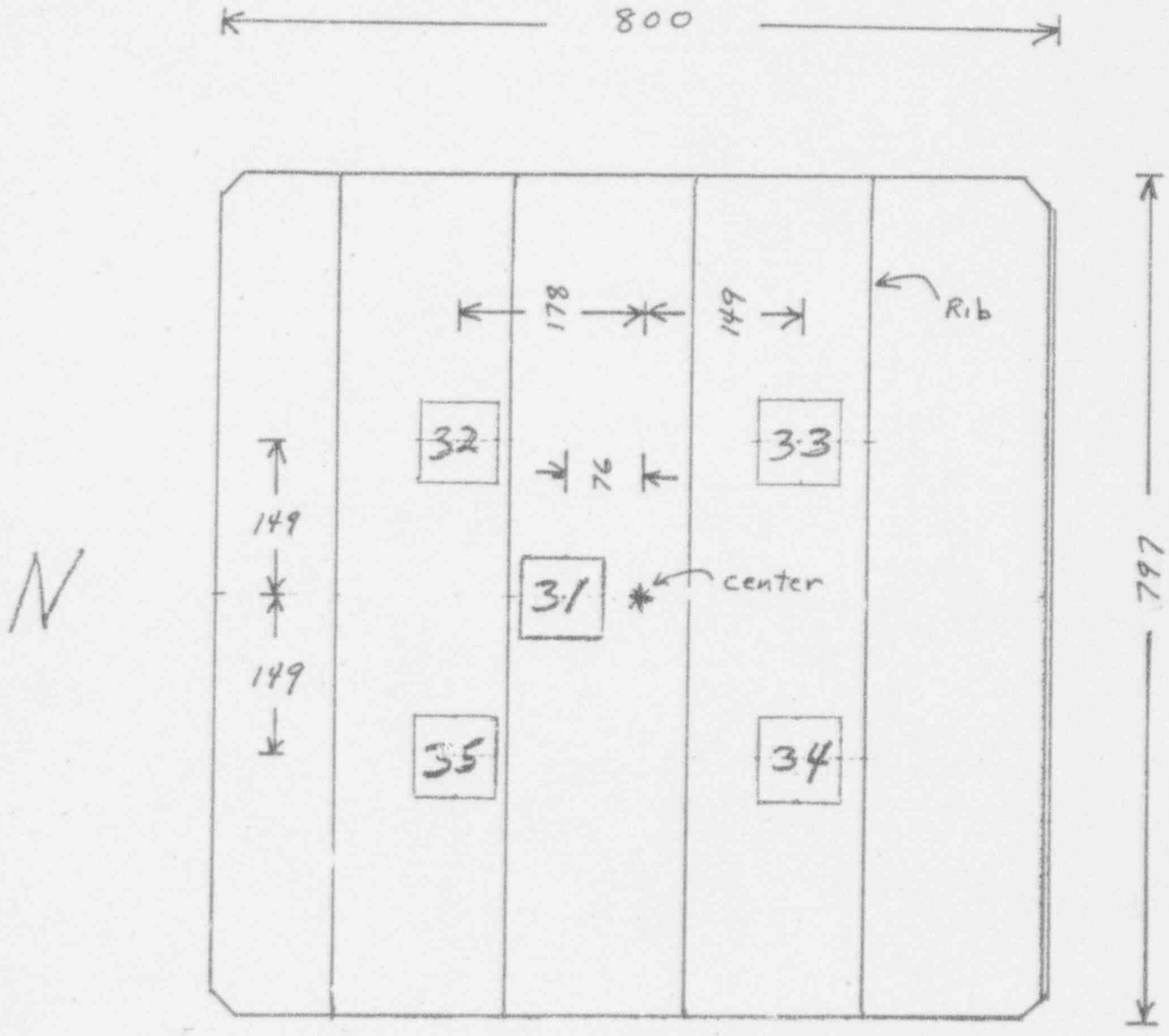

Fig. II.1. Dimensions, sample 1-2. All dimensions in millimeters. Numbered squares denote unexposed-surface thermocouple pads.

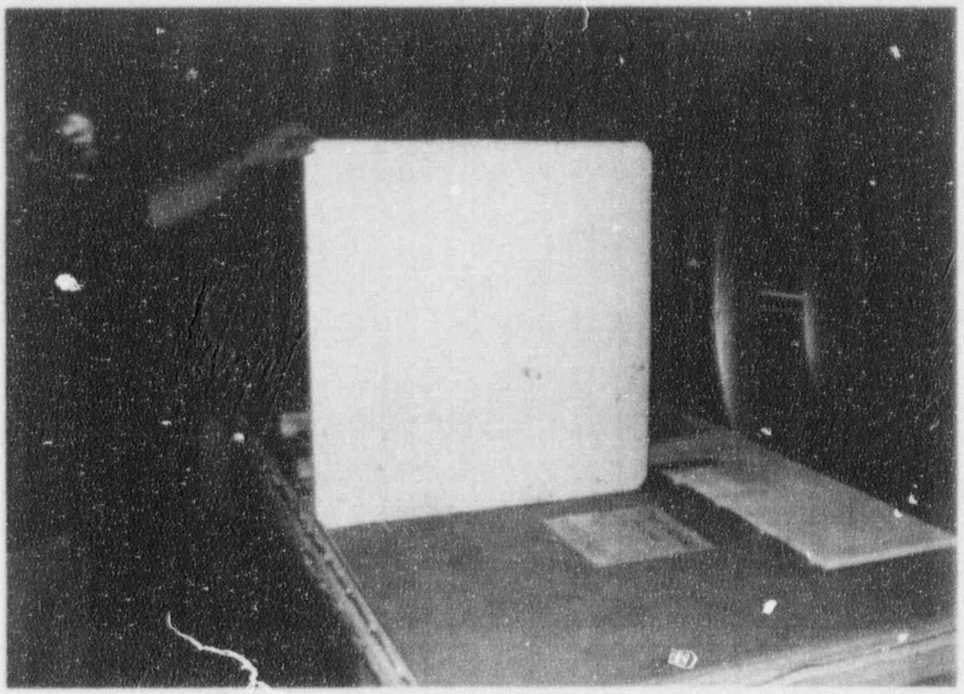

Fig. II.2. Pre-test exposed surface, sample 1-2.

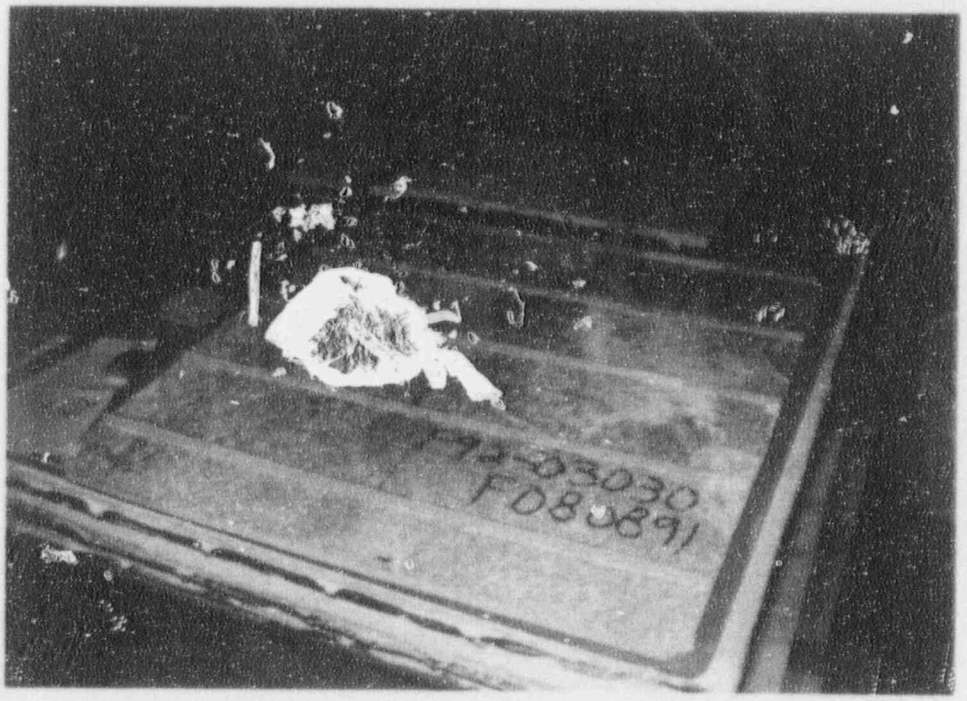

Fig. II.3. Pre-test unexposed surface, sample 1-2.

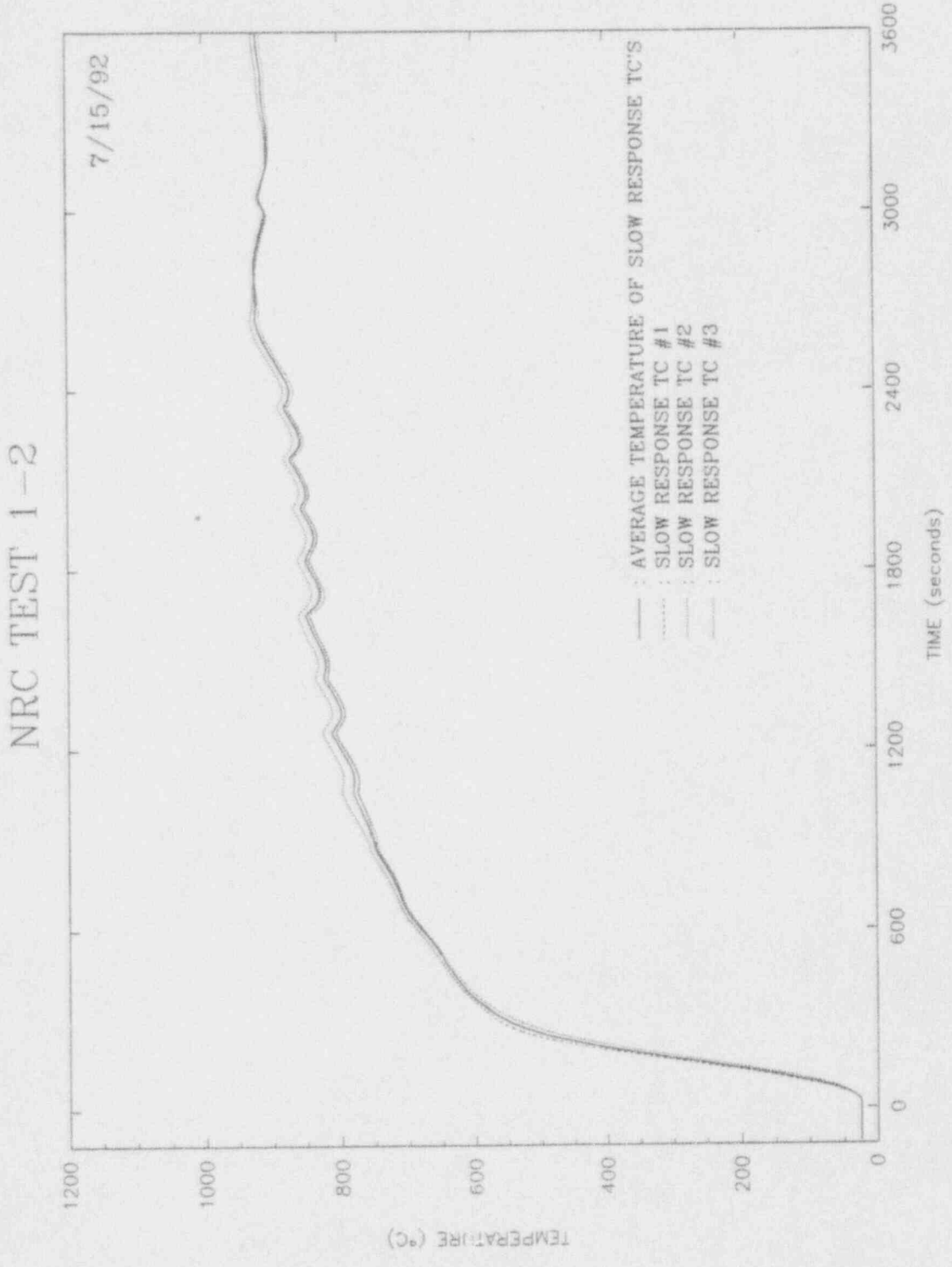

Fig. II.4. Furnace temperature, test 1-2.

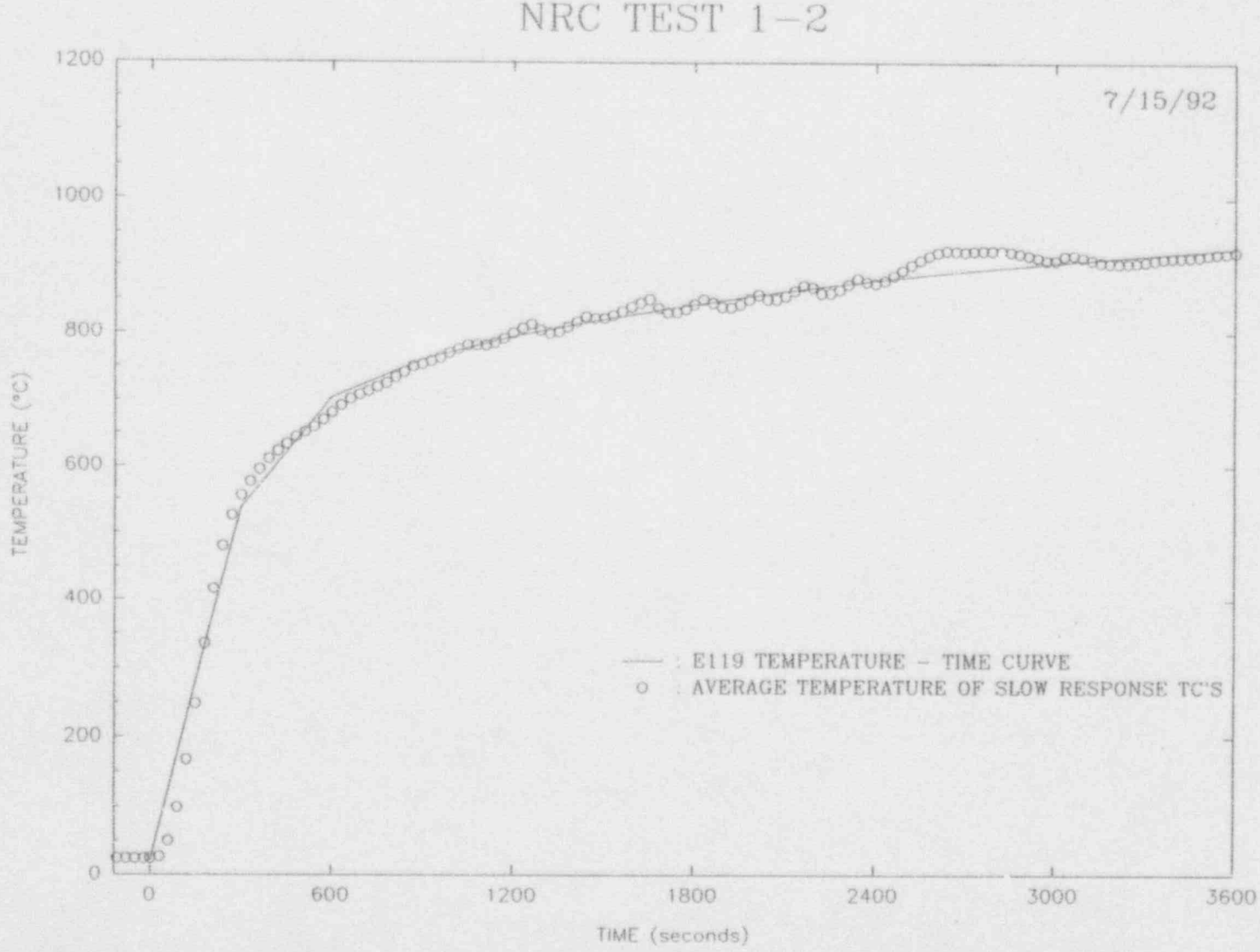

Fig. II.5. Furnace temperature, test 1-2.

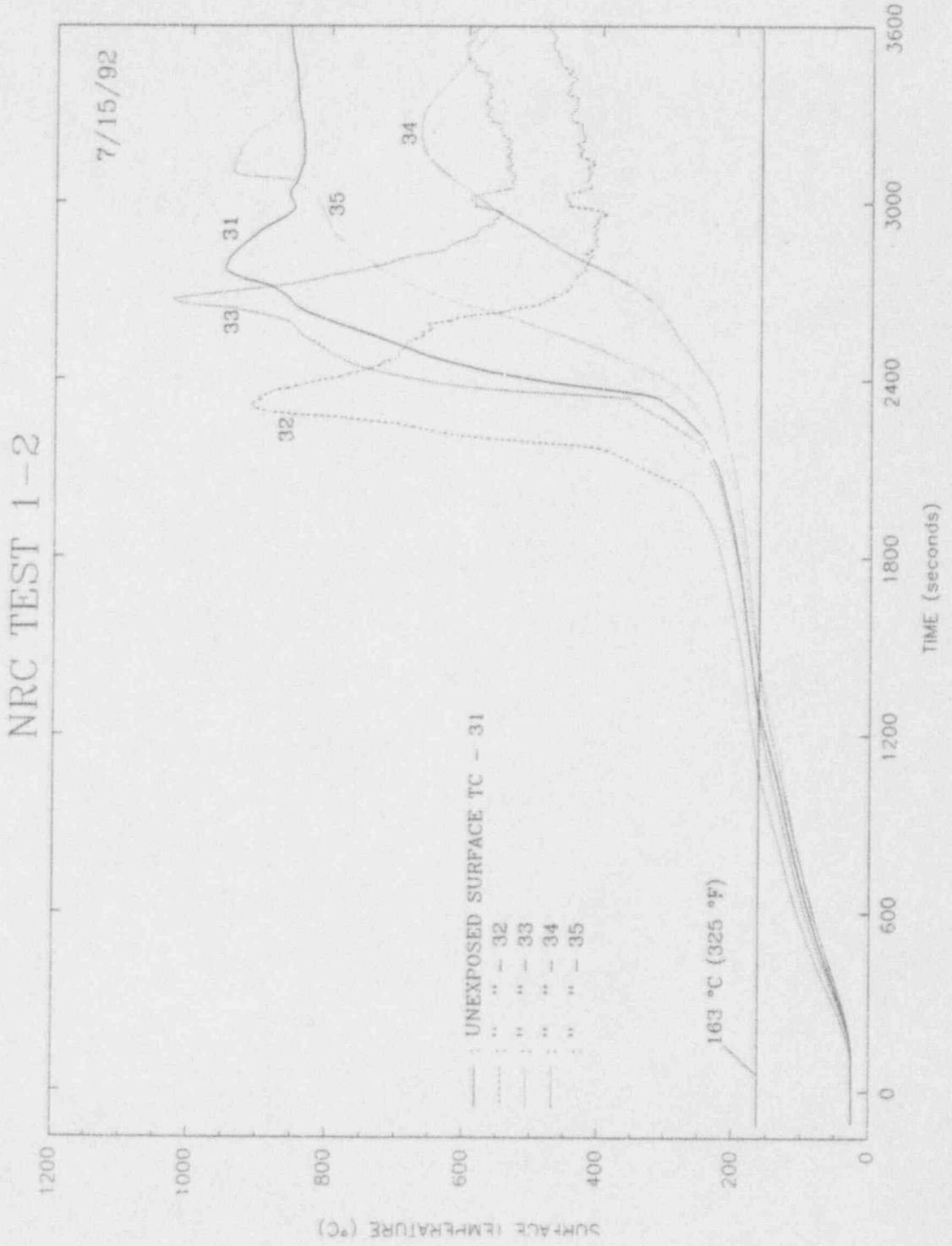

Fig. II.6. Unexposed-surface temperatures, test 1-2.

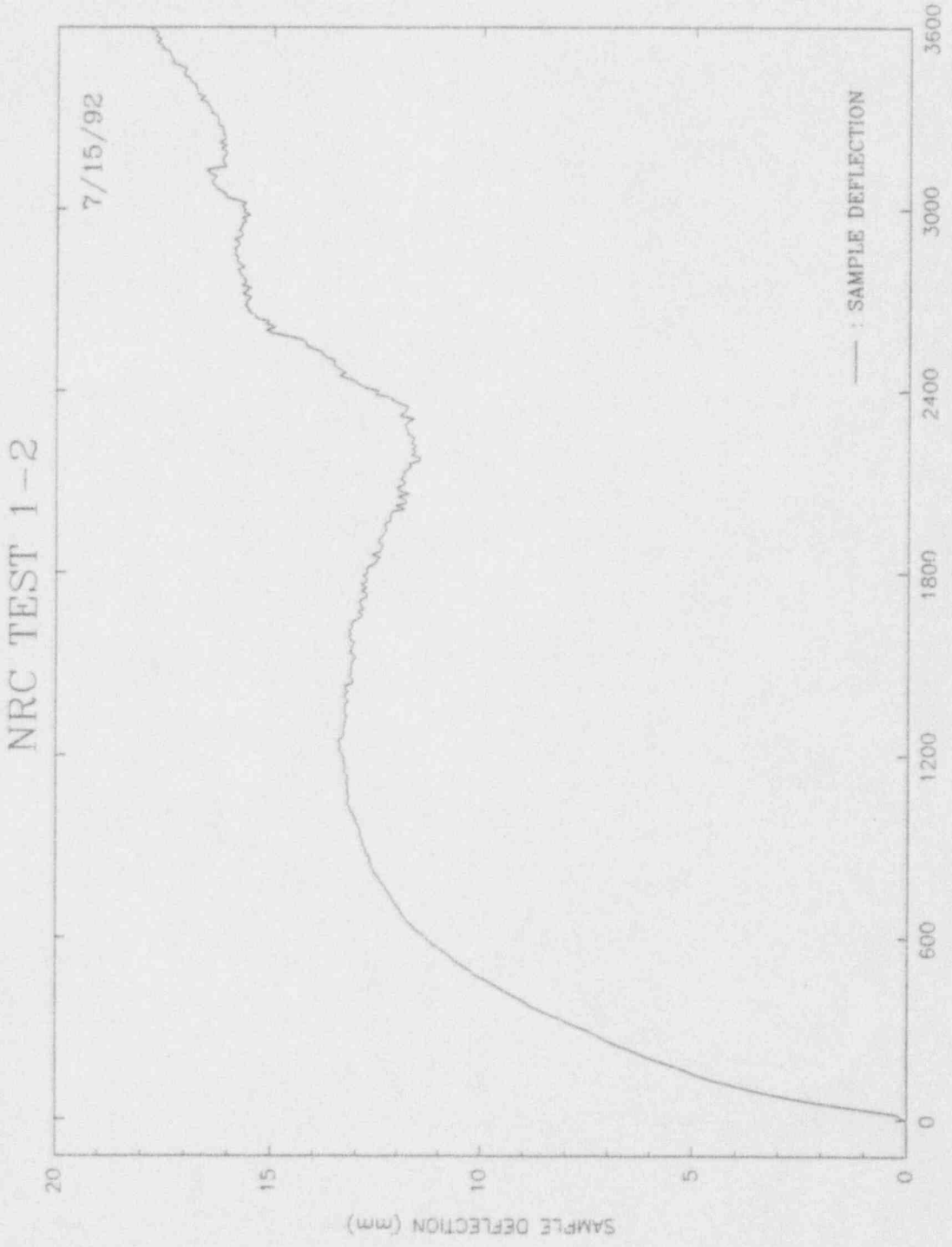

Fig. II.7. Deflection at center of specimen, test 1-2.

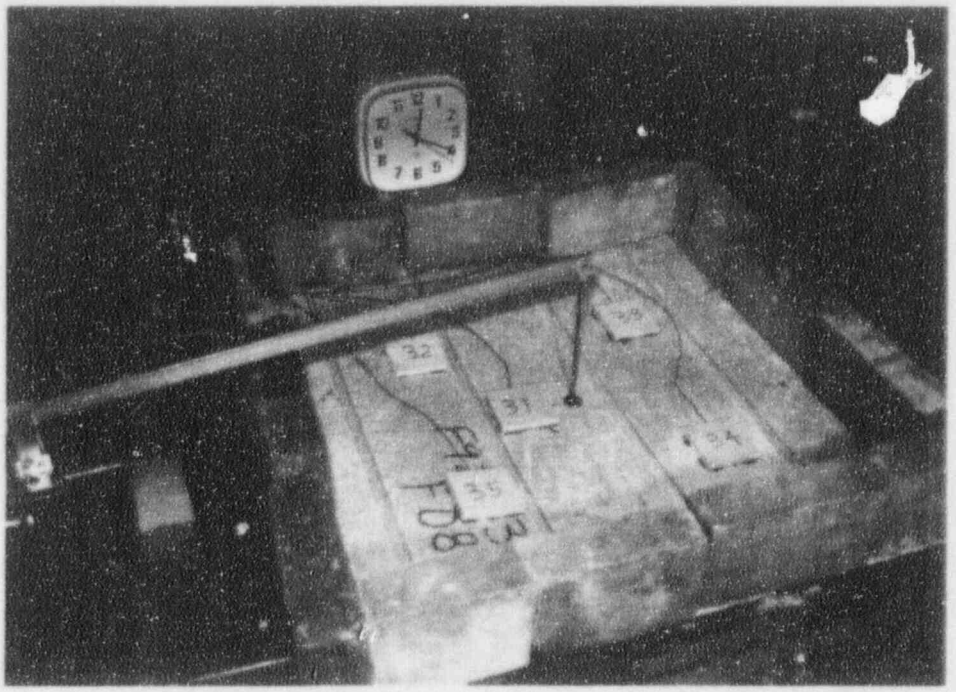

Fig. II.8. Photograph of unexposed surface during test 1-2.

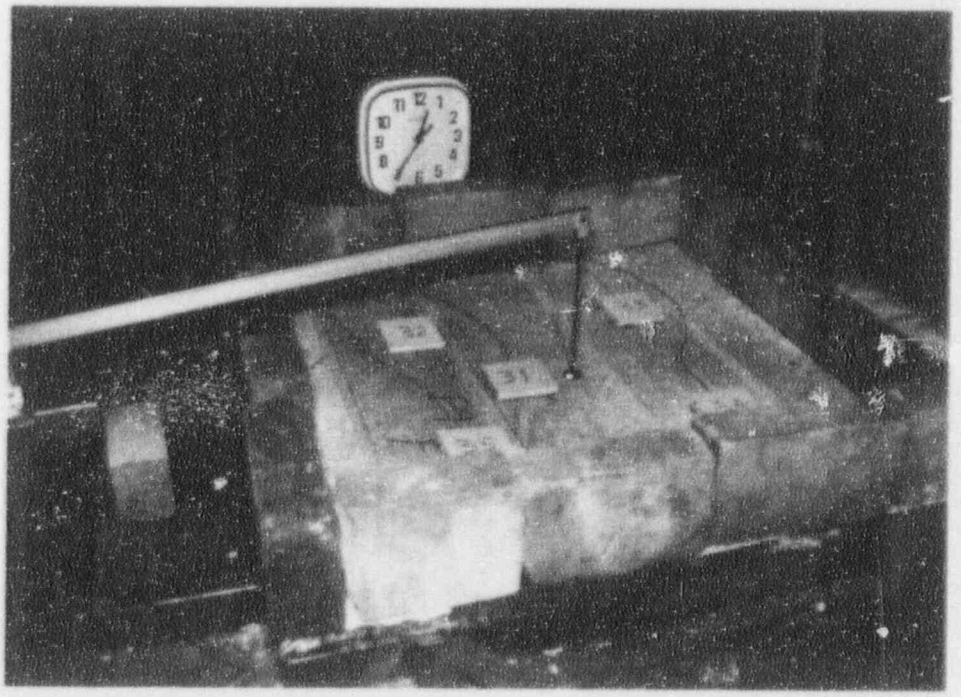

Fig. II.9. Photograph of unexposed surface during test 1-2.

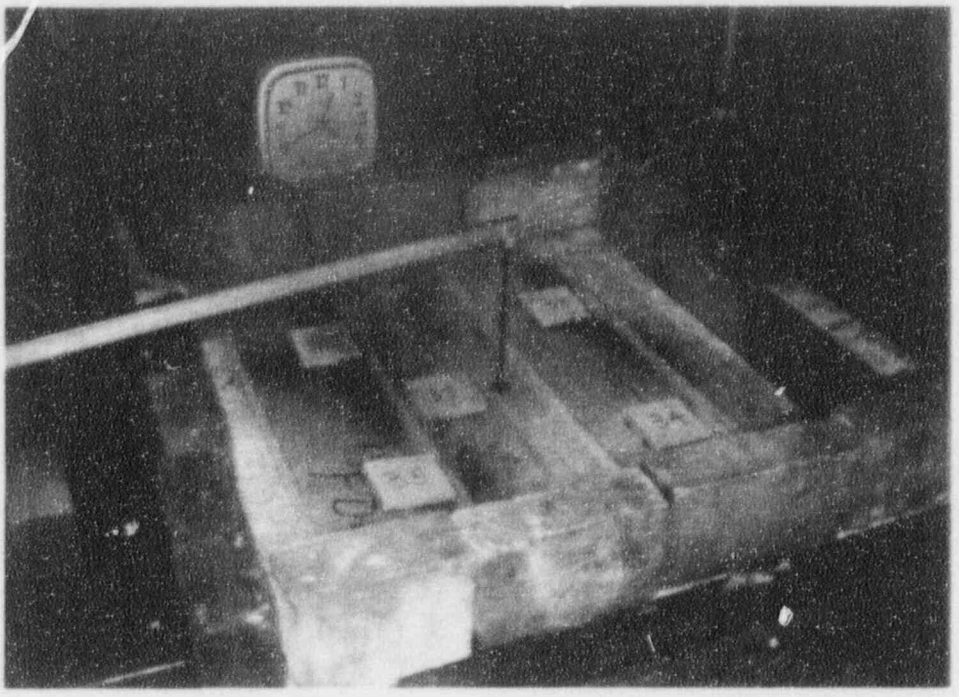

Fig. II.10. Photograph of unexposed surface during test 1-2.

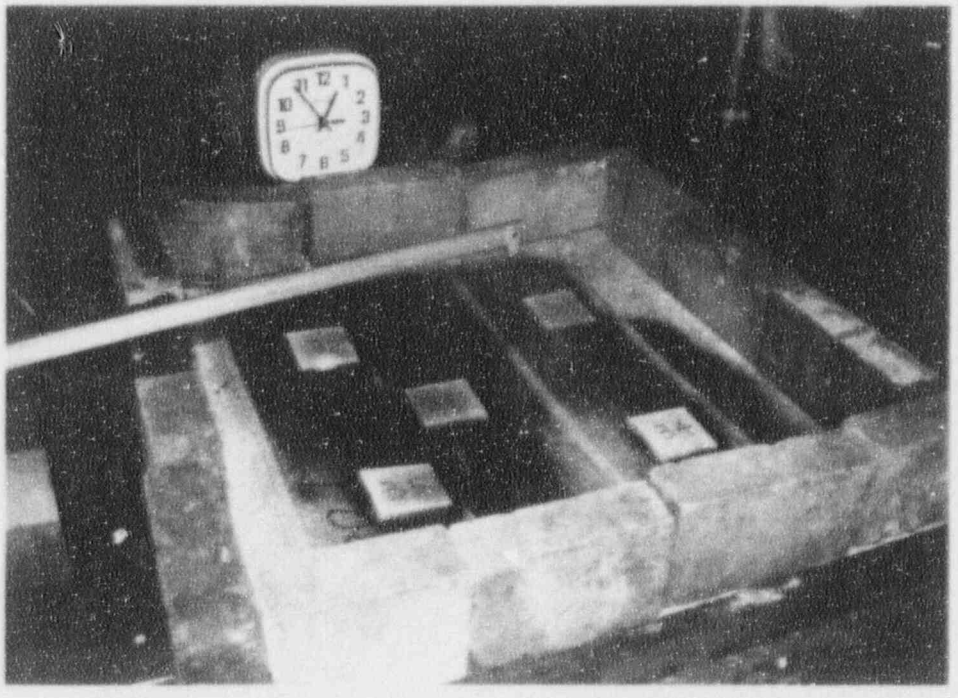

Fig. II.11. Photograph of unexposed surface during test 1-2.

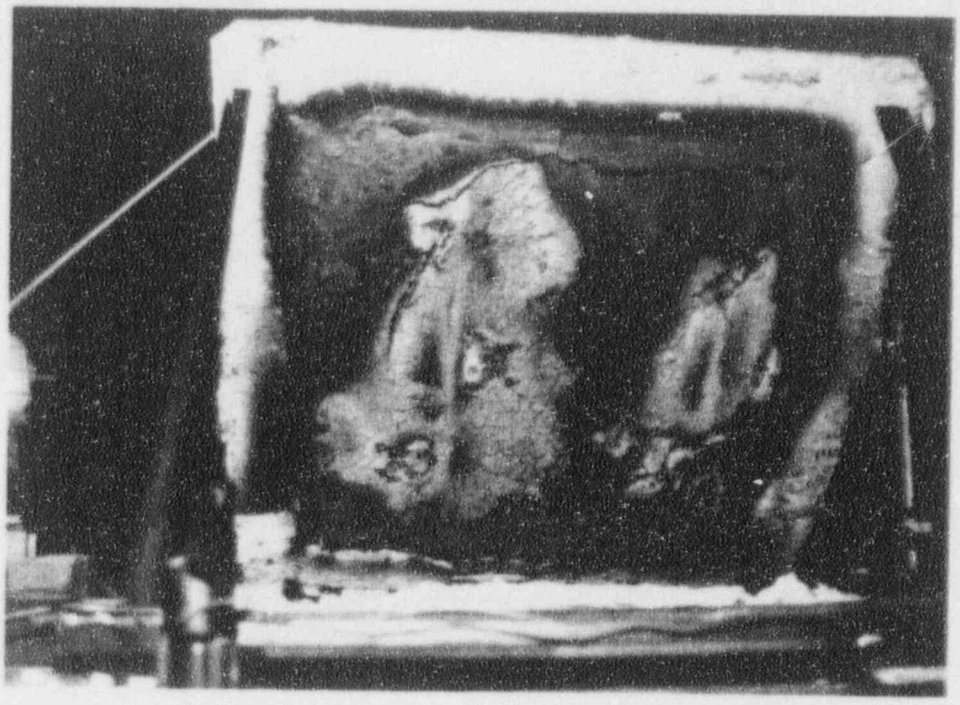

Fig. II.12. Post-test photograph of exposed surface.

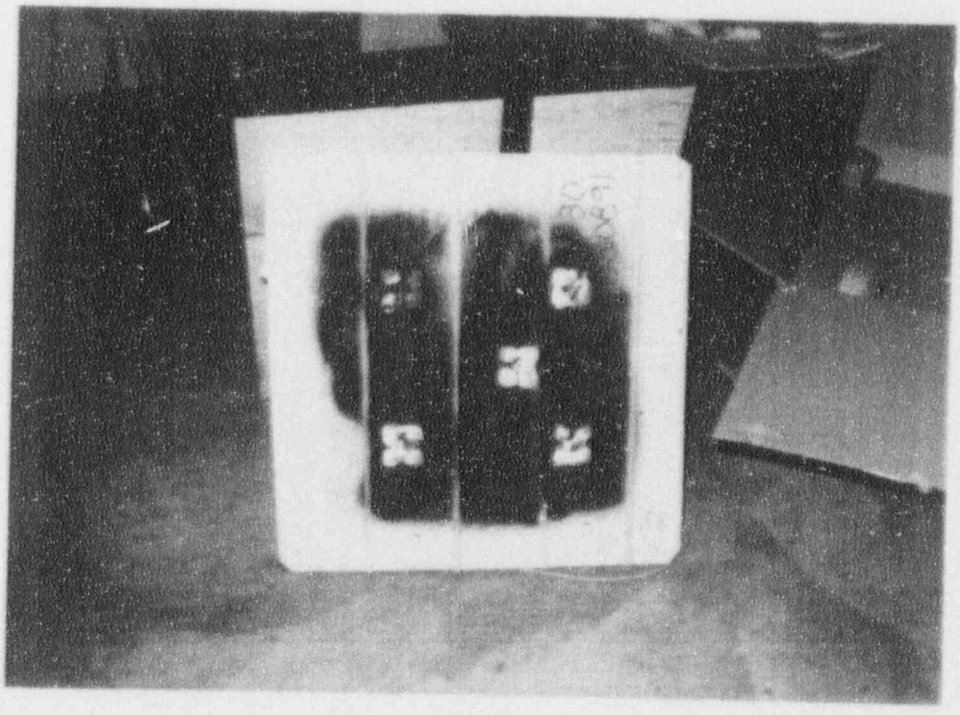

Fig. II.13 Post-test photograph of unexposed surface.

III. Test 3-1

A. Description of Test Assembly

The test assembly consisted of a single sheet of 3-hour subliming fire-barrier panel. This panel is manufactured with a "flat" face, a ribbed face, and a wire mesh covering both faces. The specimen was tested with its ribbed surface as the unexposed surface and with the wire mesh entirely covering both faces.

The fire barrier specimen, designated sample 3-1, was cut to the dimensions shown in Fig. III.1 from a panel labeled by the manufacturer as F-9109032 and F031491. An edge view (Fig. III.2) reveals that the sample has two distinct layers.

Figure III.1 shows off-rib thicknesses of the specimen along the perimeter and also beneath the surface-temperature pads. These 29 measurements can be summarized as follows:

Off-Rib Thickness (mm [in])			
avg.	std. dev.	max.	min.
33.7 [1.33]	2.7 [0.11]	39.9 [1.57]	27.9 [1.10]

Thicknesses at ribs varied from 38 to 41 mm (1.5 to 1.6 in). No marks indicating manufacturer's measurement points were found on the specimen. The pre-test mass of the specimen was estimated[10] to be 20.6 kg (45.4 lb). Pre-test photographs of exposed and unexposed surfaces of the specimen are shown in Figs. III.3 and III.4, respectively.

The specimen was tested with its ribbed surface as the unexposed surface (facing upward) and with the wire mesh coverings unaltered; i.e., the entire upper and lower faces were covered by the wire mesh. In this configuration, both the upper and lower wire meshes were constrained by the vertical load of the bricks located along the perimeter of the specimen.

B. Fire Test Procedures and Results

The test was conducted on July 17, 1992 and was witnessed by the following official observers: P. Madden (NRC), S. West (NRC), M. Widmann (NRC), I. Moghissi (NRC), H. Fossett (NRC), and G. Mulley, Jr. (NRC).

The specimen was subjected to a 3.5-hour fire exposure controlled

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[10]The sample was not weighed before the test. The estimated figure is based on the areal density of sample 3-2 which was cut from the same panel.

by the ASTM E 119-88 standard temperature-time curve. Plots of the furnace temperatures recorded by the individual furnace thermocouples and their average values are presented in Fig. III.5 and tabulated in Table III.1. The average furnace temperatures and the standard temperature-time curve are shown in Fig. III.6.

Unexposed-surface thermocouples measured surface temperatures beneath insulation pads at 5 locations designated 31 to 35 in Fig. III.1. The thermocouples at these locations are designated TC31 to TC35, respectively, and their outputs are plotted in Fig. III.7 and tabulated in Table III.1. Included in the table are the averages of the unexposed surface temperatures as a function of time.

The deflection at the center of the specimen was measured throughout the test and is plotted in Fig. III.8 and tabulated in Table III.1. Positive deflection indicates downward deflection or sag. The maximum recorded deflection of 19.5 mm (0.77 in) occurred at 12600 seconds (3:30:00) (hr:min:s), when the test was terminated.

Figures III.9 to III.13 show the appearance of the unexposed surface during the test. The S.E. corner of the unexposed surface began to discolor (light brown) about 2:20:00. By 2:50:00 the S.E. corner was a darker brown and browning had begun N. of pad 32 and into the N.E. corner. No glowing or flame-passage was observed during the test. Shortly after shutdown of the furnace burners, an attempt to lift the sample was thwarted by flames emerging from the specimen along the raised edge. The western side of the sample was successfully lifted and propped 13 minutes after shutdown. The flame which occurred upon opening quickly self-extinguished but flaming persisted on the eastern pivot edge due radiation from the furnace. A log of observations and temperatures measured with the movable thermocouple are presented in Table III.2.

The exposed and unexposed surfaces after the test are shown in Figs. III.13 and III.14, respectively. There was no indication of burnthrough. A char matrix with a few large fissures covered the entire exposed area of the exposed surface; that is, little if any char had fallen away during the test. Very brittle wire mesh, which flaked away easily upon touching, still covered a large portion of the exposed area. The char thickness ranged from 76 mm (3.0 in) in the center to 60 mm (2.4 in) at the corners. Approximately 10 mm (0.39 in) of solid sticky material remained above the char. The unexposed surface exhibited light-to-dark brown discoloration over approximately 90 percent of its exposed area. The areas beneath the thermocouple pads were dark brown but not burned through.

The post-test mass of the specimen was 15.6 kg (34.4 lb). There was no significant residue at the bottom of the furnace.

C. Analysis of Test Results

The ASTM E 119-88 thermal transmission acceptance criteria are that the average temperature rise of the unexposed-surface thermocouples shall not exceed 139°C (250°F) above its initial temperature (in this test, 24°C [75°F]) and the temperature rise of any of these thermocouples shall not exceed 181°C (325°F) above the initial temperature. Another criterion is that at no time during the test should hot gases or flame pass through the assembly so as to ignite cotton waste held against the unexposed surface. In addition to these criteria, NRC requirements include monitoring the time at which any of the unexposed-surface thermocouples reaches 162.8°C (325°F).

On the basis of the experimental temperature data presented in Table III.1, the above temperature criteria were met at the following locations and times:

Criterion	Location	Time (sec)	[hr:min:sec]
E 119 avg. unexposed surf. temp. (163°C) [325°F]		8400	[2:20:00]
E 119 peak unexposed surf. temp. (205°C) [401°F]	TC 33	11520	[3:12:00]
NRC unexposed surf. temp., 1st occurrence (162.8°C) [325°F]	TC 33	7300	[2:01:40]

Concerning E 119 criteria, the average temperature was the controlling factor and the E 119 fire-endurance period was 8400 seconds (2:20:00). Since the period was greater than 1/2 hour, a correction was required to account for deviations of the actual average furnace temperature from the standard temperature-time curve (see ASTM E 119-88, Par. 7.4). This correction was +32 s and **the corrected fire-endurance period was 8432 s (2 hours and 20.5 minutes).**

Neither glowing nor flame passage through the unexposed surface were observed during the test. The E 119 cotton-waste test was not conducted. The constrained wire mesh on the exposed face and char layer above it were intact at the end of the test.

TABLE III.1 Temperatures, test 3-1.

NRC TEST 3-1

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
-110	24	24	24	24	24	24	24	24	24	24	-0.0
-100	24	24	24	24	24	24	24	24	24	24	-0.0
-90	24	24	24	24	24	24	24	24	24	24	-0.0
-80	24	24	24	24	24	24	24	24	24	24	-0.0
-70	24	24	24	24	24	24	24	24	24	24	-0.0
-60	24	24	24	24	24	24	24	24	25	24	-0.0
-50	24	24	24	24	24	24	24	24	24	24	0.0
-40	24	24	24	24	24	24	24	24	24	24	0.0
-30	24	24	24	24	24	24	24	24	24	24	0.0
-20	24	24	24	24	24	24	24	24	24	24	0.0
-10	24	24	24	24	24	24	24	24	24	24	0.0
-1	24	24	24	24	24	24	24	24	24	24	0.0
0	24	24	24	24	24	24	24	24	25	24	0.0
10	24	24	24	24	24	24	24	24	25	24	0.2
20	24	25	24	24	24	24	24	24	25	24	0.6
30	27	28	28	27	24	25	24	24	25	24	1.2
40	34	32	34	33	24	25	24	24	25	24	1.4
50	43	39	43	42	[illegible]	24	24	24	25	24	1.6
60	57	49	56	53	[illegible]	25	24	24	25	25	1.6
70	74	61	72	68	24	24	24	24	25	24	1.6
80	93	76	90	86	25	25	24	24	25	25	1.5
90	115	93	110	106	24	24	24	24	25	24	1.5
100	139	113	133	128	25	25	24	24	25	25	1.4
110	163	136	156	151	25	25	24	24	25	25	1.4
120	190	161	181	177	25	25	24	25	25	25	1.3
130	218	187	208	204	25	24	24	24	25	24	1.3
140	246	214	236	232	25	25	24	24	25	25	1.3
150	276	243	265	261	25	25	24	25	25	25	1.3
160	306	271	295	290	25	25	24	24	25	25	1.3
170	335	299	323	319	25	25	24	25	25	25	1.3
180	365	327	352	347	25	25	24	24	25	25	1.4
190	393	354	378	374	25	25	24	25	25	25	1.4
200	419	378	402	400	25	25	24	25	25	25	1.4
210	443	401	424	422	25	25	24	24	25	25	1.5
220	464	422	445	444	25	25	24	25	25	25	1.5
230	484	442	465	463	25	25	25	25	25	25	1.6
240	502	460	482	481	25	25	24	25	25	25	1.6
250	519	477	498	498	25	25	24	25	25	25	1.6
260	534	493	514	513	25	25	24	25	25	25	1.7
270	548	508	528	527	25	25	25	25	25	25	1.7
280	561	522	540	541	25	25	24	25	25	25	1.8
290	573	536	552	553	25	25	25	25	25	25	1.8
300	584	548	563	564	25	25	25	25	25	25	1.8

TABLE III.1 Temperatures, test 3-1 (cont.).

NRC TEST 3-1

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
360	634	605	614	617	25	25	25	25	25	25	2.1
420	667	641	647	651	25	25	25	25	25	25	2.2
480	691	665	669	675	25	26	25	25	26	26	2.4
540	707	683	685	691	26	26	26	26	27	26	2.5
600	721	697	698	705	27	27	27	26	28	27	2.6
660	734	712	711	719	27	28	28	27	29	28	2.7
720	748	725	725	733	28	29	29	28	30	29	2.8
780	762	739	739	746	29	30	30	29	31	30	2.9
840	774	752	752	759	30	31	31	30	32	31	3.0
900	786	765	765	771	31	33	32	31	34	32	3.1
960	797	777	776	783	32	34	34	32	35	34	3.2
1020	808	788	787	794	34	36	35	34	37	35	3.3
1080	817	797	798	803	35	37	37	35	38	36	3.3
1140	823	806	806	811	36	39	38	36	40	38	3.4
1200	830	814	814	818	38	40	40	38	42	40	3.5
1260	836	820	821	825	40	42	41	39	44	41	3.5
1320	843	828	828	832	41	44	43	41	46	43	3.6
1380	850	835	835	839	43	45	45	42	48	45	3.7
1440	856	842	842	846	44	47	46	44	49	46	3.7
1500	860	848	848	852	46	49	48	46	51	48	3.7
1560	866	854	853	857	48	51	50	47	53	50	3.7
1620	869	859	858	862	50	52	52	49	55	52	3.7
1680	871	862	861	865	51	54	53	51	57	53	3.7
1740	874	866	864	868	53	56	55	52	59	55	3.6
1800	876	872	871	872	55	58	57	54	60	57	3.6
1860	875	873	873	873	56	59	59	56	62	58	3.5
1920	874	875	874	873	58	61	60	57	64	60	3.4
1980	875	875	874	874	60	63	62	59	66	62	3.4
2040	877	878	877	877	61	65	64	61	67	64	3.3
2100	874	878	876	876	63	66	66	62	69	65	3.1
2160	866	873	871	870	65	68	67	64	71	67	3.0
2220	864	871	869	867	66	70	69	66	73	69	3.1
2280	864	872	870	868	68	71	71	67	74	70	3.2
2340	866	874	872	870	69	73	72	69	76	72	3.3
2400	868	876	873	872	71	74	74	70	78	73	3.3
2460	872	879	877	876	72	76	76	72	79	75	3.5
2520	878	884	881	880	74	78	77	73	81	76	3.7
2580	881	887	884	884	75	79	79	75	82	78	3.9
2640	884	889	887	886	77	81	80	76	84	79	4.2
2700	886	892	889	888	78	82	82	77	85	81	4.3

TABLE III.1 Temperatures, test 3-1 (cont.).

NRC TEST 3-1

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
2760	889	894	892	891	80	84	83	79	87	82	4.5
2820	893	897	895	894	81	85	85	80	88	84	4.7
2880	896	900	898	897	82	87	86	82	90	85	4.9
2940	899	902	901	900	84	88	87	83	91	87	5.1
3000	904	904	905	903	85	90	89	84	93	88	5.4
3060	904	906	906	905	86	91	90	86	94	89	5.6
3120	907	908	909	908	88	92	91	87	96	91	5.8
3180	910	911	912	911	89	94	93	88	97	92	6.1
3240	913	914	915	913	90	95	94	89	98	93	6.3
3300	916	916	918	916	91	96	95	90	100	95	6.6
3360	920	919	920	919	92	98	97	92	101	96	6.8
3420	921	920	922	921	94	99	98	93	102	97	7.0
3480	922	922	924	923	95	100	100	94	104	98	7.2
3540	926	925	927	925	96	101	101	95	105	100	7.4
3600	928	927	929	927	97	102	102	96	106	101	7.6
3660	930	929	931	929	98	103	103	97	107	102	7.8
3720	932	931	932	931	99	104	105	98	108	103	8.3
3780	934	933	935	933	101	105	106	99	110	104	8.3
3840	934	935	936	935	102	106	107	100	111	105	8.8
3900	936	936	938	936	103	107	109	101	112	106	8.8
3960	937	937	939	938	104	108	110	103	113	107	8.9
4020	939	939	941	940	105	109	111	104	114	109	9.0
4080	942	941	944	941	106	110	112	105	115	110	9.2
4140	943	943	945	943	107	111	114	106	116	111	9.7
4200	945	944	947	945	108	112	115	107	117	112	9.9
4260	946	946	949	946	109	112	116	108	118	113	9.9
4320	948	948	950	948	110	113	118	109	119	114	10.0
4380	949	949	952	949	111	114	119	110	120	115	10.1
4440	951	951	953	951	112	115	120	111	121	116	10.2
4500	952	952	954	952	113	116	121	112	122	117	10.3
4560	953	953	955	953	114	116	123	113	123	118	10.4
4620	954	954	957	955	115	117	124	114	124	119	10.5
4680	956	955	958	956	116	118	125	115	125	120	10.6
4740	957	957	960	958	117	119	126	116	126	121	10.7
4800	959	959	962	959	118	120	127	117	127	122	10.8
4860	961	960	963	961	119	120	128	118	128	123	10.9
4920	962	961	965	962	120	121	130	119	128	124	11.4
4980	964	964	966	964	121	122	131	120	129	125	11.2
5040	966	966	968	966	122	123	132	121	130	126	11.6
5100	967	967	968	967	123	124	133	122	131	127	11.4

TABLE III.1 Temperatures, test 3-1 (cont.).

NRC TEST 3-1

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
5160	968	968	971	969	124	125	134	123	132	128	11.4
5220	969	969	972	969	125	125	135	124	133	128	11.5
5280	970	971	973	971	125	126	136	125	134	129	11.5
5340	972	972	974	972	126	127	137	126	134	130	11.6
5400	973	974	976	974	127	128	138	127	135	131	11.7
5460	976	975	978	976	128	128	139	128	136	132	12.3
5520	977	976	979	977	129	129	140	129	137	133	12.2
5580	978	978	980	978	130	130	141	129	138	134	12.3
5640	979	979	981	979	131	131	142	130	139	135	12.3
5700	981	980	983	981	131	132	143	131	139	135	12.3
5760	984	983	985	984	132	132	144	132	140	136	12.4
5820	985	985	987	985	133	133	145	133	141	137	12.5
5880	988	987	989	988	134	134	146	133	142	138	12.7
5940	989	989	991	989	135	135	147	134	142	139	12.8
6000	990	990	992	990	135	135	148	135	143	139	12.7
6060	991	991	993	991	136	136	149	135	144	140	13.1
6120	993	993	994	993	137	137	149	136	145	141	13.0
6180	994	994	996	994	138	137	150	137	145	142	13.0
6240	995	994	997	995	138	138	151	137	146	142	13.1
6300	996	996	999	997	139	139	152	138	147	143	13.1
6360	998	998	1000	998	140	139	153	139	147	144	13.1
6420	999	999	1001	1000	141	140	154	139	148	144	13.2
6480	1000	1000	1002	1000	141	141	154	140	149	145	13.3
6540	1001	1001	1004	1002	142	141	155	140	149	146	13.3
6600	1002	1002	1005	1002	143	142	156	141	150	146	13.4
6660	1003	1004	1005	1004	143	143	156	142	151	147	13.4
6720	1005	1005	1007	1005	144	143	157	142	152	148	13.5
6780	1006	1006	1008	1006	145	144	158	143	153	148	13.5
6840	1007	1007	1009	1007	145	145	158	143	153	149	13.5
6900	1008	1008	1010	1008	146	145	159	144	154	150	13.6
6960	1009	1009	1011	1010	146	146	159	145	154	150	13.7
7020	1011	1010	1013	1011	147	146	160	145	155	151	13.9
7080	1011	1011	1014	1011	148	147	160	146	156	151	14.0
7140	1012	1012	1014	1012	148	148	161	146	156	152	13.9
7200	1013	1013	1015	1013	149	148	162	147	157	152	14.0
7260	1014	1014	1016	1014	150	149	162	147	158	153	14.0
7320	1015	1015	1017	1015	150	149	163	148	158	154	13.9
7380	1015	1015	1018	1016	151	150	163	148	159	154	14.0
7440	1016	1016	1018	1016	151	150	164	149	159	155	14.0
7500	1016	1016	1019	1016	152	151	164	149	160	155	14.0

TABLE III.1 Temperatures, test 3-1 (cont.).

NRC TEST 3-1

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
7560	1017	1016	1019	1017	152	151	165	150	160	156	14.1
7620	1018	1017	1020	1018	153	152	165	150	161	156	14.1
7680	1018	1018	1021	1018	153	152	166	151	161	157	14.2
7740	1019	1019	1022	1019	154	153	167	152	162	157	14.5
7800	1020	1020	1022	1020	154	153	167	152	162	158	14.3
7860	1019	1019	1022	1019	155	154	167	153	163	158	14.6
7920	1018	1018	1021	1019	155	155	168	153	163	159	14.4
7980	1019	1018	1021	1019	156	155	168	154	164	159	14.6
8040	1019	1019	1021	1019	156	156	169	154	164	160	14.6
8100	1019	1019	1022	1019	157	156	169	155	165	160	14.5
8160	1020	1019	1022	1020	157	157	170	155	166	161	14.5
8220	1021	1021	1023	1021	158	157	170	156	166	161	14.6
8280	1021	1021	1024	1021	158	158	170	157	167	162	14.7
8340	1022	1021	1024	1022	159	158	171	157	167	162	14.7
8400	1022	1022	1025	1023	159	158	171	158	167	163	14.8
8460	1023	1023	1025	1023	160	159	172	158	168	163	14.8
8520	1023	1023	1026	1024	160	159	172	159	169	164	14.8
8580	1024	1023	1026	1024	161	160	173	159	169	164	14.9
8640	1024	1024	1027	1024	161	160	173	160	170	165	15.0
8700	1025	1024	1027	1025	162	161	174	161	170	165	14.9
8760	1025	1025	1028	1026	162	161	174	161	171	166	15.0
8820	1026	1026	1028	1026	163	162	175	162	171	166	15.0
8880	1026	1026	1029	1027	163	162	175	162	172	167	15.1
8940	1026	1026	1029	1027	164	163	176	163	172	167	15.2
9000	1028	1027	1030	1028	164	163	176	163	173	168	15.2
9060	1029	1028	1031	1029	165	164	177	164	174	169	15.3
9120	1030	1030	1032	1030	165	164	177	164	174	169	15.4
9180	1031	1031	1033	1031	166	165	178	165	175	170	15.4
9240	1032	1031	1034	1032	166	165	179	165	175	170	15.5
9300	1032	1032	1034	1032	167	166	179	166	176	171	15.7
9360	1033	1032	1035	1033	167	166	180	166	177	171	15.7
9420	1034	1033	1037	1034	168	167	180	167	177	172	15.7
9480	1036	1035	1038	1036	169	168	181	167	178	172	15.7
9540	1037	1037	1039	1038	169	168	181	168	178	173	15.8
9600	1039	1039	1041	1039	170	169	182	168	179	173	15.8
9660	1040	1039	1042	1040	170	169	182	168	180	174	15.9
9720	1040	1040	1042	1040	171	170	183	169	180	174	16.1
9780	1041	1041	1043	1041	171	170	184	169	181	175	16.1
9840	1042	1041	1044	1041	172	171	184	169	181	176	16.2
9900	1043	1042	1045	1043	172	171	185	170	182	176	16.2

TABLE III.1 Temperatures, test 3-1 (cont.).

NRC TEST 3-1

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
9960	1044	1043	1045	1044	173	172	185	170	183	177	16.4
10020	1044	1044	1046	1044	173	172	186	171	183	177	16.4
10080	1045	1044	1047	1045	174	173	187	171	184	178	16.5
10140	1046	1045	1047	1046	174	173	187	172	184	178	16.5
10200	1047	1046	1048	1046	175	174	188	172	185	179	16.5
10260	1047	1047	1049	1047	175	175	189	172	186	179	16.6
10320	1048	1048	1049	1048	176	175	189	173	187	180	16.6
10380	1048	1047	1050	1048	176	176	190	173	187	180	16.7
10440	1049	1049	1050	1049	177	176	191	174	188	181	16.7
10500	1050	1049	1051	1049	177	177	191	174	189	181	16.9
10560	1050	1049	1051	1050	177	177	192	175	189	182	16.9
10620	1051	1050	1052	1050	178	178	193	175	190	183	17.0
10680	1052	1050	1052	1051	179	178	193	175	191	183	17.1
10740	1052	1051	1053	1052	179	179	194	176	192	184	17.2
10800	1052	1052	1054	1052	179	179	195	176	192	184	17.3
10860	1053	1052	1055	1053	180	180	196	177	193	185	17.4
10920	1054	1053	1056	1054	180	181	197	177	194	186	17.5
10980	1055	1054	1056	1054	181	181	197	177	195	186	17.6
11040	1055	1054	1057	1055	182	182	198	178	195	187	17.7
11100	1056	1055	1058	1055	182	182	199	178	196	188	17.7
11160	1056	1055	1058	1055	183	183	200	179	197	188	17.8
11220	1057	1056	1058	1057	183	184	201	179	198	189	17.9
11280	1057	1057	1059	1057	183	184	202	180	199	190	18.0
11340	1058	1056	1059	1057	184	185	202	180	200	190	18.1
11400	1058	1057	1059	1058	185	185	203	180	200	191	18.1
11460	1058	1057	1060	1058	185	186	204	181	201	192	18.1
11520	1059	1058	1061	1059	186	187	205	181	202	192	18.3
11580	1061	1059	1062	1060	186	188	206	182	203	193	18.3
11640	1061	1060	1063	1061	187	188	207	182	204	194	18.5
11700	1062	1061	1064	1061	187	189	208	183	205	194	18.4
11760	1062	1061	1064	1062	188	190	208	183	206	195	18.6
11820	1063	1062	1065	1063	189	190	209	184	207	196	18.7
11880	1064	1062	1065	1063	189	191	210	185	208	197	18.7
11940	1065	1064	1067	1065	190	192	211	185	208	197	18.7
12000	1066	1064	1067	1065	190	193	212	186	209	198	18.7
12060	1066	1065	1068	1065	191	193	213	186	210	199	18.9
12120	1067	1066	1069	1067	191	194	214	187	211	199	18.9
12180	1069	1067	1070	1068	192	195	215	187	212	200	19.0
12240	1070	1069	1071	1069	193	196	216	188	212	201	19.1
12300	1071	1069	1072	1071	193	196	216	188	213	202	19.1

TABLE III.1 Temperatures, test 3-1 (cont.).

NRC TEST 3-1

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
12360	1072	1070	1073	1071	194	197	217	189	214	202	19.2
12420	1072	1070	1073	1071	195	198	218	190	215	203	19.3
12480	1073	1071	1074	1072	195	198	219	190	216	204	19.4
12540	1073	1072	1075	1073	196	199	220	191	217	205	19.4
12600	1074	1072	1075	1073	196	200	221	192	218	205	19.5
12660	1049	1049	1049	1048	197	201	222	192	219	206	20.2

TABLE III.2. Observations, test 3-1.

The following observations were made during and after the test:

(Note: MTC indicates surface temperature measured with movable thermocouple)

Time	
1:00:00	No obvious changes to unexposed surface up to this time.
1:02:	65°C (149°F) measured with movable TC (MTC) at mid-point between pads 34 and 35.
1:22:	85°C (185°F)(MTC) at mid-point between 34 and 35.
1:24:	87°C (189°F)(MTC) at point East of 33 & just West of N/S centerline (CL).
1:30:00	Still no change.
1:31:30	Some outgassing (near center?).
1:39:	97°C (207°F)(MTC) between 33 and 34 & E. of N/S CL.
1:45:00	Still no discoloration of surface.
1:58:	104°C (219°F)(MTC) between 33 and 34.
2:00:00	Still no hot spots or browning.
	102°C (216°F)(MTC) between 34 and 35.
2:03:30	Outgassing increasing.
2:06:00	See some "sparkling" (crystals) in white portion of material in S.E. corner.
2:10:	111°C (232°F)(MTC) between 33 and 34.
2:12:	110°C (230°F)(MTC) between 34 and 35.
2:13:	116°C (241°F)(MTC) between 32 and 35.
2:20:	Light browning in S.E. corner.
2:25:00	Might be some browning on low rill that runs E.-W. just N. of 33 and 34.
2:31:	135°C (275°F)(MTC) in S.E. corner.
2:33:30	Browning in rill E. of 33.
2:36:45	Some bubbling (looks like small water droplets) along N. edge of 34.
2:40:45	Browning continues in area of rill E. of 33 and in S.E. corner.
2:43:	116°C (241°F)(MTC) between 32 and 35.
2:44:	150°C (302°F) and 158°C (316°F)(MTC) in S.E. corner.
2:50:00	Some browning N. of 32 into N.E. corner.
2:57:00	Browning in S.E. corner; N. of 32 extending W. to a point beyond the centerline.
3:07:	163 to 167°C (325 to 333°F)(MTC) on brown spot in S.E. corner.
3:16:00	Browning around pad 31 and E. of 31 near fire brick.
3:17:15	Water droplets vaporizing on W. edge of 33.
3:30:00	Shutdown
3:32:10	Attempted unsuccessfully to lift W. edge of sample.
3:43:00	Successfully lifted and propped W.edge of sample. Flame which emerged upon opening quickly self extinguished. Flame on E. edge (pivot edge) continued to burn due to radiation from furnace.

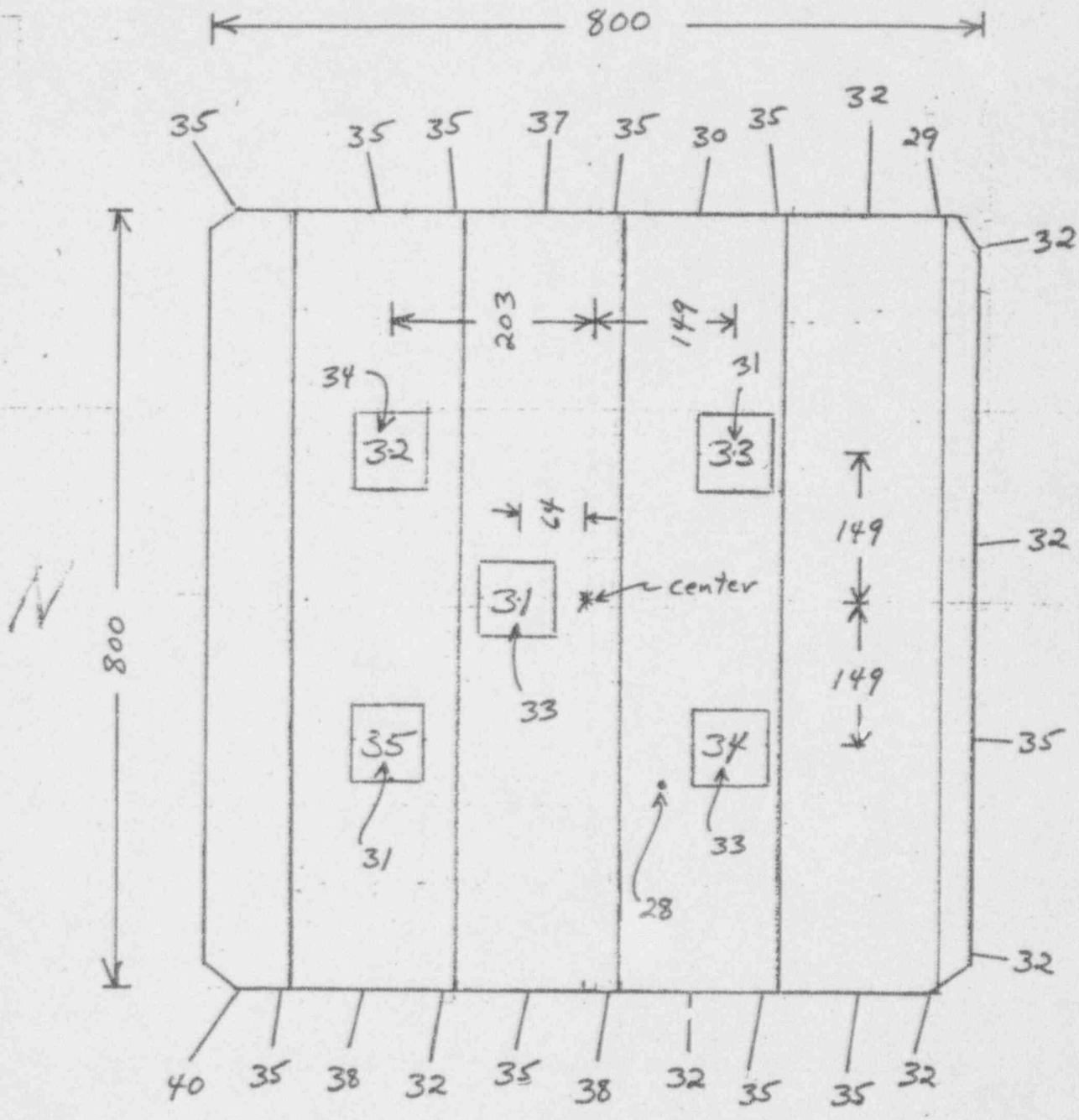

Fig. III.1. Dimensions, sample 3-1. All dimensions in millimeters. Numbered squares denote unexposed-surface thermocouple pads. Other numbers not between arrows indicate thickness.

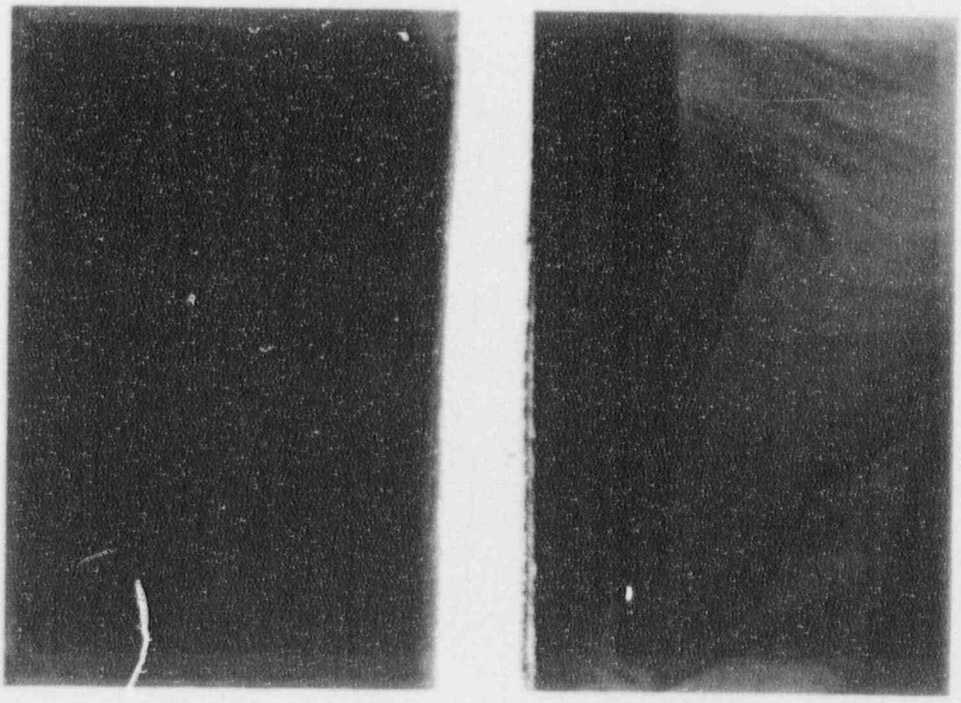

Fig. III.2. Edge view of sample 3-1 showing two distinct layers.

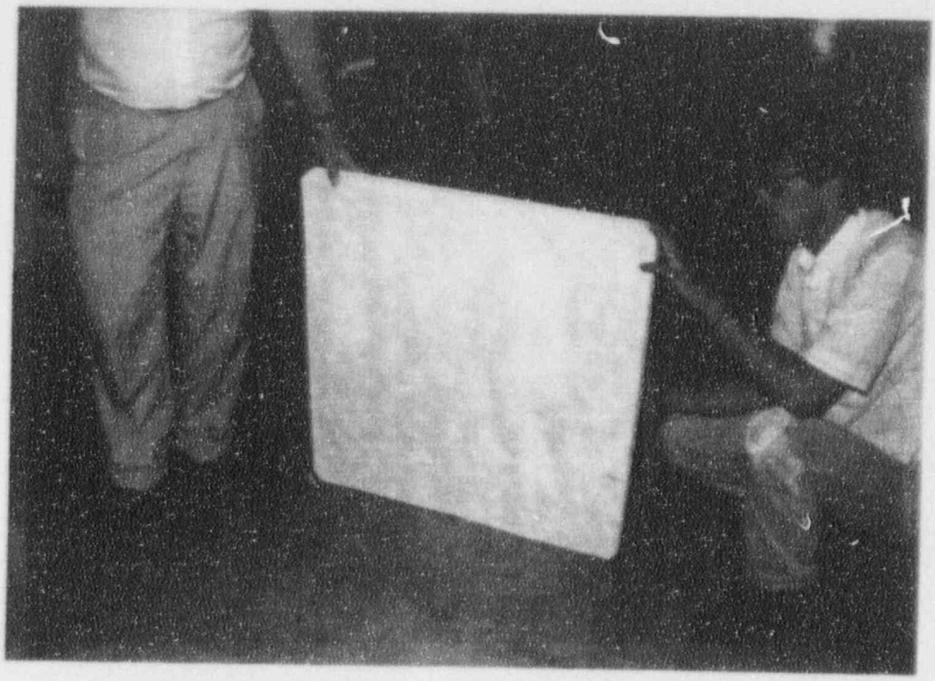

Fig. III.3. Pre-test exposed surface, sample 3-1.

Fig. III.4. Pre-test unexposed surface, sample 3-1.

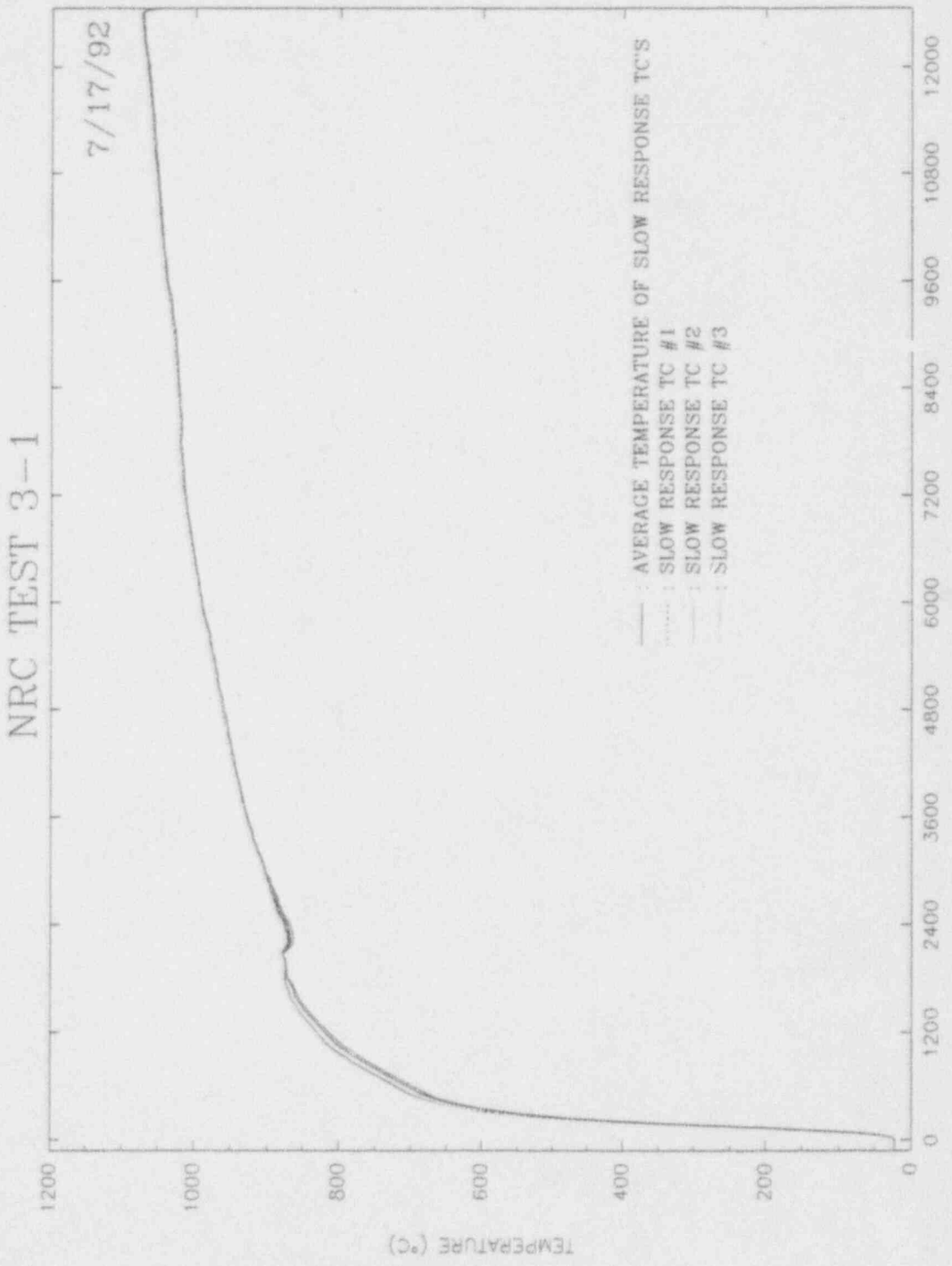

Fig. III.5. Furnace temperatures, test 3-1.

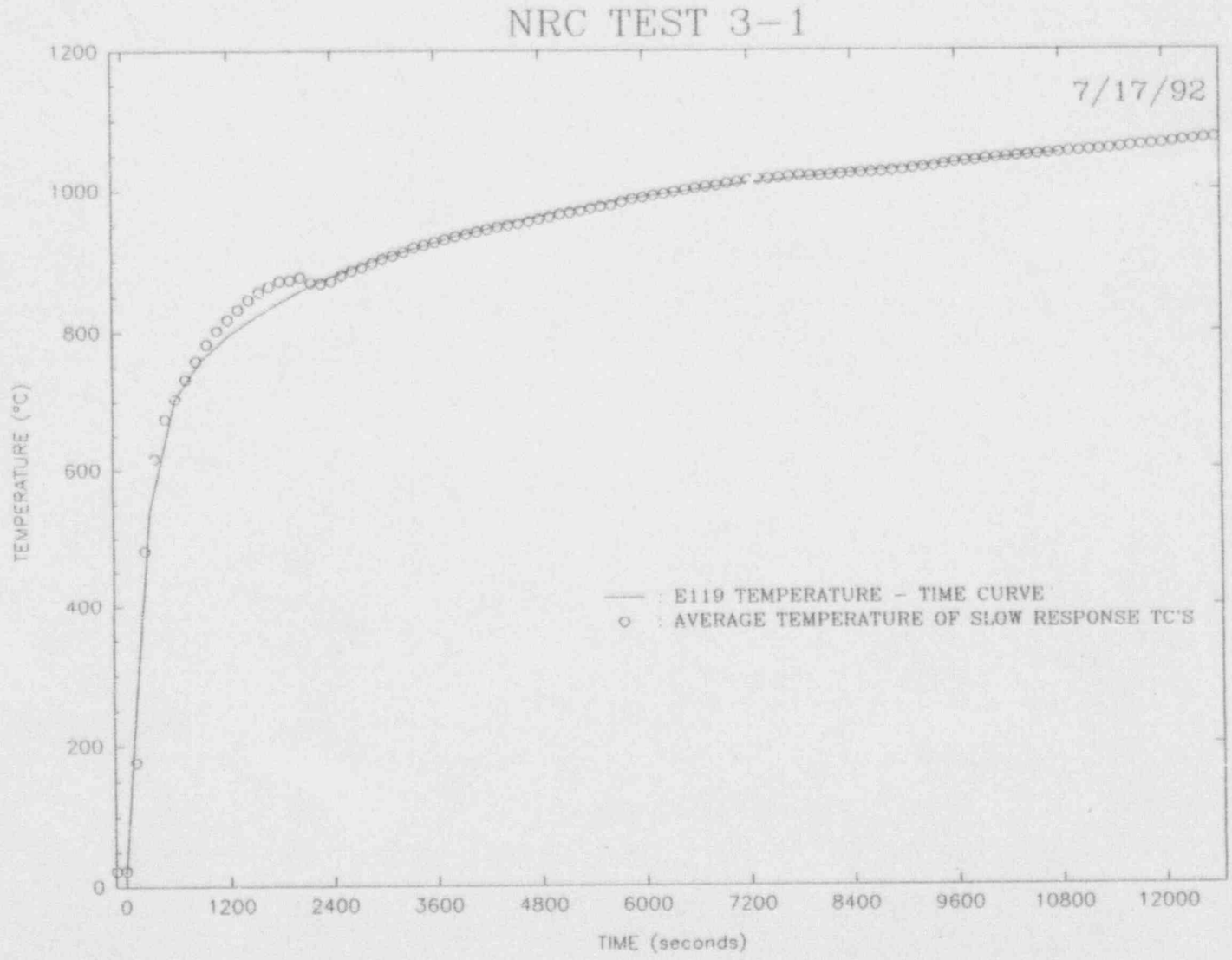

Fig. III.6. Furnace temperatures, test 3-1.

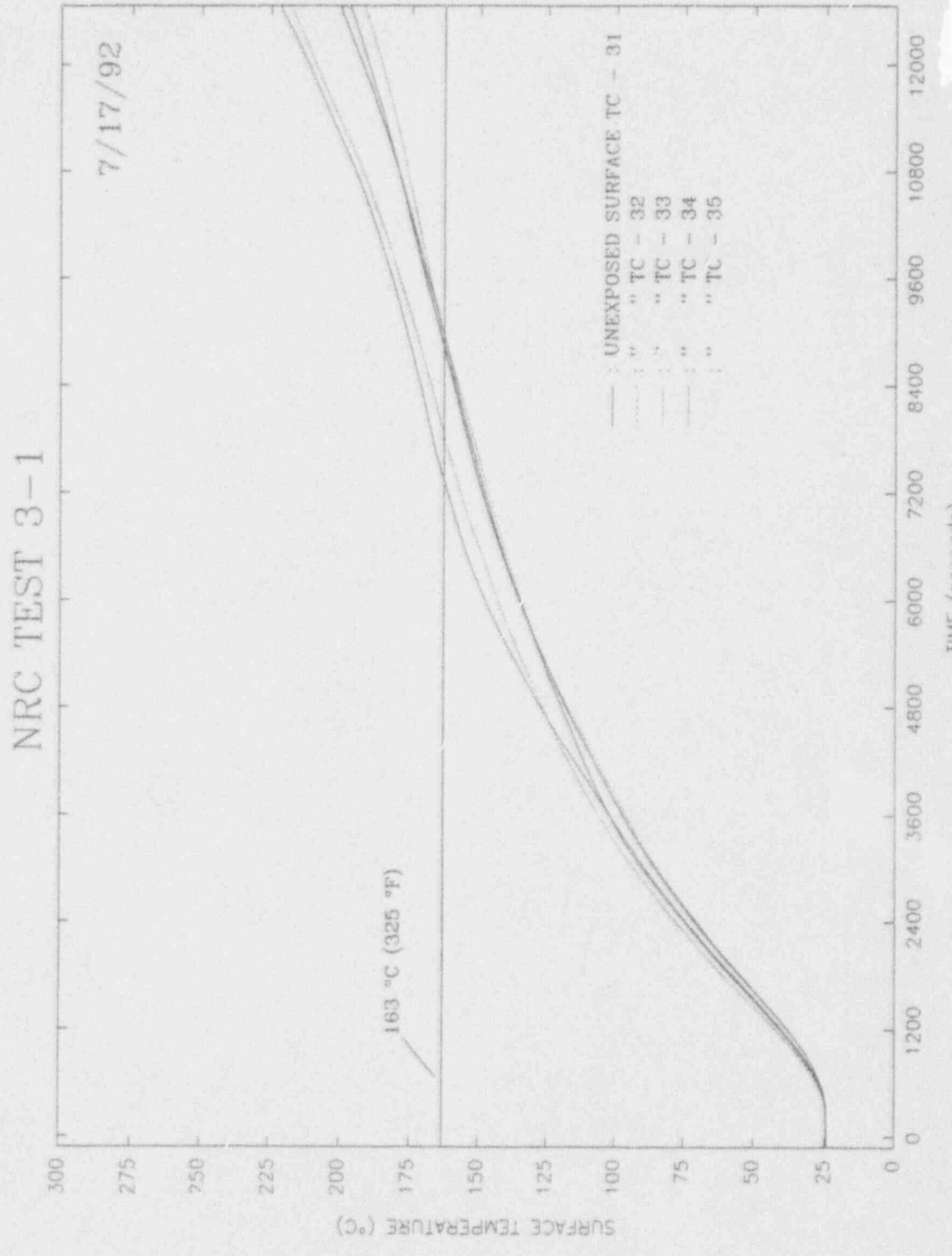

Fig. III.7. Unexposed-surface temperature, test 3-1.

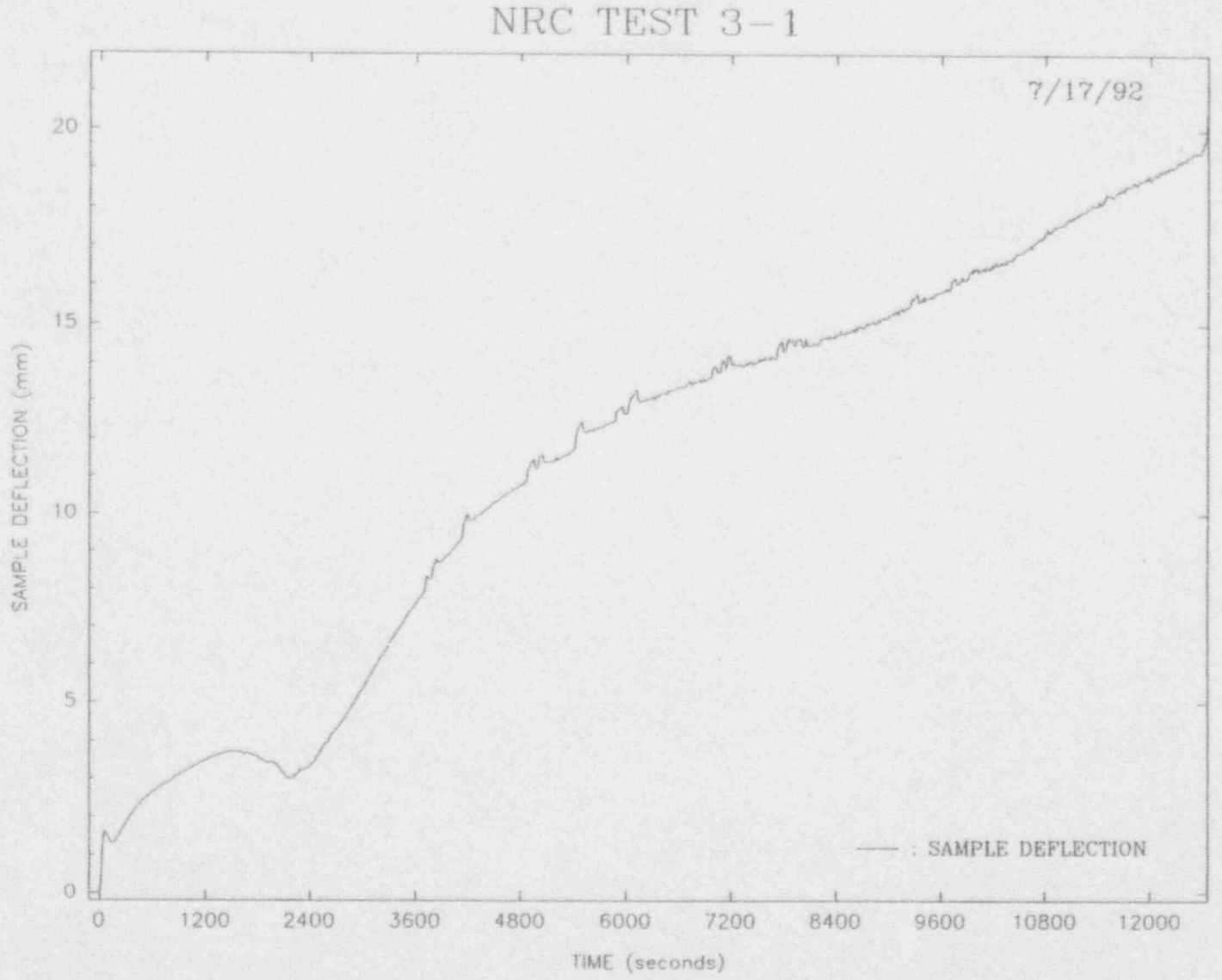

Fig. III.8. Deflection at center of specimen, test 3-1.

Fig. III.9. Photograph of unexposed surface during test 3-1.

Fig. III.10. Photograph of unexposed surface during test 3-1.

Fig. III.11. Photograph of unexposed surface during test 3-1.

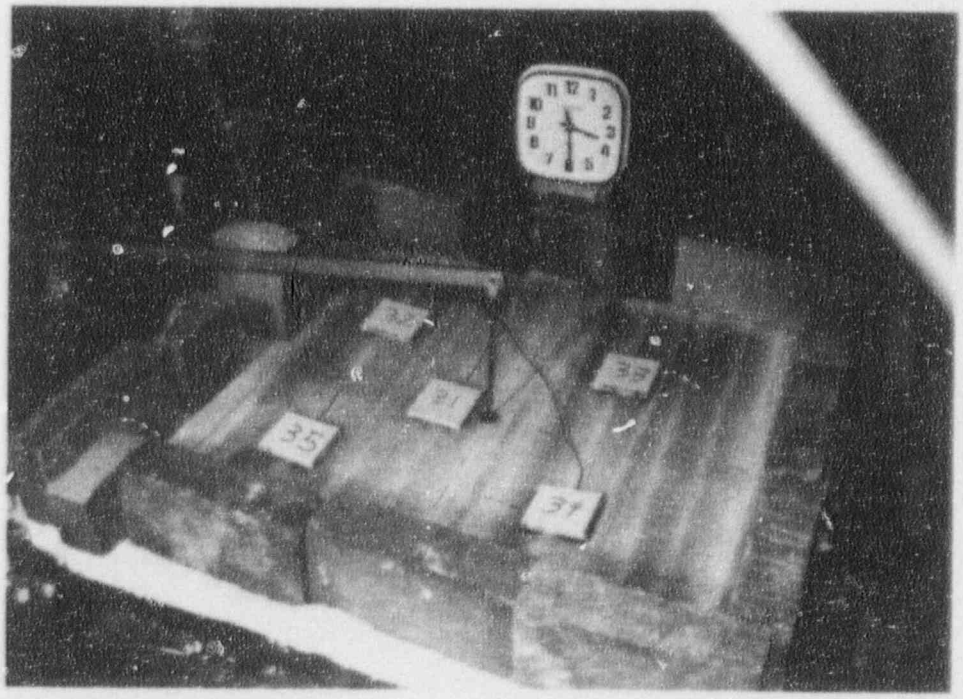

Fig. III.12 Photograph of unexposed surface during test 3-1.

Fig. III.13 Post-test exposed surface, test 3-1.

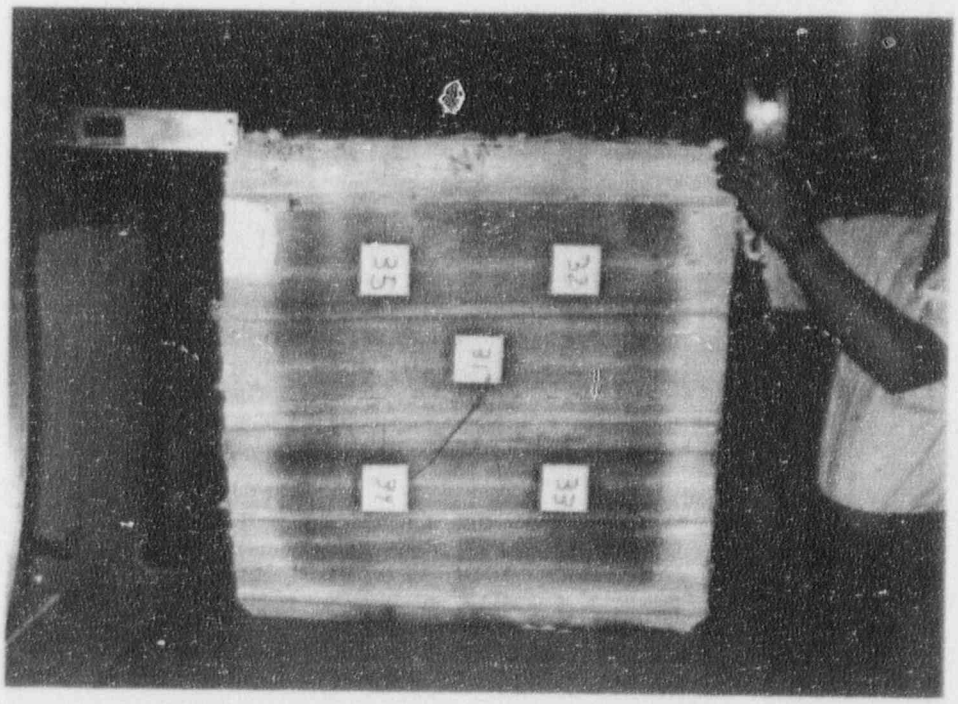

Fig. III.14 Post-test unexposed surface, test 3-1.

IV. Test 3-2

A. Description of Test Assembly

The test assembly consisted of a single sheet of NRC-supplied 3-hour subliming fire-barrier panel. This panel is manufactured with a "flat" face, a ribbed face, and a wire mesh covering both faces. The specimen was tested with its ribbed surface as the unexposed surface. Wire mesh covered the entire area of the ribbed face but was removed from the perimeter of the flat face.

The fire barrier specimen, designated sample 3-2, was cut to the dimensions shown in Fig. IV.1 from a panel labeled by the manufacturer as F-9109032 and F031491.

The wire mesh was removed from the flat side of the panel in the region outside the dot-dash line in Fig. IV.1 This region lies above the sample-support lip of the furnace and is not directly exposed to the furnace. Panel thicknesses measured on either side but close to the dot-dash demarcation are shown in the figure along with the thicknesses beneath the surface-temperature measurement points. The 13 measurements made inside the demarcation can be summarized as follows:

Off-Rib Thickness (mm [in])			
avg.	std. dev.	max.	min.
30.7 [1.21]	2.6 [0.10]	35.6 [1.40]	25.9 [1.02]

Thicknesses at ribs interior to the demarcation varied from 38 to 41 mm (1.5 to 1.6 in). Outside the demarcation some subliming material was stripped during the removal of the wire mesh (Figs. IV.2 and IV.3) with the result that panel thicknesses in this region were reduced 1.6 to 4.8 mm (0.063 to 0.19 in). No marks indicating manufacturer's measurement points were found on the specimen.

Figure IV.4 shows an edge view of the sample and its two distinct layers (shown separated). These layers separated along the perimeter of the sample when staples were removed as part of the wire-mesh removal process. Wood screws were installed at the corners and mid-points on the edges of the sample to hold the layers together. Also, the wire mesh and a thin layer of attached subliming material separated along the northern edge of the demarcation (Fig. IV.2). This was re-attached with 9 staples (similar in size to those used by the manufacturer) at the points indicated by arrows in this figure.

The pre-test mass of the specimen was 19.1 kg (42.1 lb) (20.0 kg [44.1 lb] before removal of wire mesh as described above). Pre-test photographs of exposed and unexposed surfaces of the specimen are shown in Figs. IV.2 and IV.5, respectively.

The specimen was tested with its ribbed surface as the unexposed surface (facing upward). The upper wire mesh was constrained by the vertical load of the bricks which were placed along the perimeter of the specimen. Since the wire mesh was removed from the lip region of the lower face, the remaining resh covering the actual exposed area of the lower face was not constrained by the bricks or any other edge constraints.

B. Fire Test Procedures and Results

The test was conducted on August 5, 1992 and was witnessed by the following official observers: M. Widmann (NRC), I. Moghissi (NRC).

The specimen was subjected to a 3-hour fire exposure controlled by the ASTM E 119-88 standard temperature-time curve. Plots of the furnace temperatures recorded by the furnace thermocouples and their average values are presented in Fig. IV.6 and tabulated in Table IV.1. The average furnace temperatures and the standard temperature-time curve are shown in Fig. IV.7

Unexposed-surface thermocouples measured surface temperatures underneath insulation pads at 5 locations designated 31 to 35 in Fig. IV.1. The thermocouples at these locations are designated TC31 to TC35, respectively, and their outputs are plotted in Fig. IV.8 and tabulated in Table IV.1. Included in the table are the averages of the unexposed-surface temperatures as a function of time. Note that 3 of the 5 unexposed-surface thermocouples eventually exceeded the furnace temperature by up to approximately 70°C and all 5 thermocouples eventually cooled while the furnace temperature continued to increase. Comments concerning these apparent anomalies have been presented in section II.C.

The deflection at the center of the specimen was measured throughout the test and is plotted in Fig. IV.9 and tabulated in Table IV.1. Positive deflection indicates downward deflection or sag. The maximum recorded deflection of 56.9 mm (2.24 in) occurred at 10860 seconds (3:01:00) (hr:min:s), when the test was terminated. Note there is a small error (+3 mm) [0.12 in] associated with these data owing to the use of a 3 mm (0.12 in) thick spacer between the unexposed surface and the "foot" of the deflection gauge. This spacer, which was thought to be an inorganic insulator, was in fact bakelite, which melted at some point during the experiment.

Figures IV.10 to IV.15 show the appearance of the unexposed surface during the test. A sudden change in the furnace control at 0:17:00 suggests that at least some of the char layer fell from the exposed surface. Outgassing of the unexposed surface began at 0:32:30, and browning at 0:41:25. A black spot appeared at 0:46:25 and glowing pin holes between pads 31 and 32 at 1:16:00. At 1:25:30 the pin-hole area extended to the center of the unexposed surface. The

east burner port in the furnace could be seen through a burnthrough area of the specimen at 2:05:20. At 2:46:00 the burnthrough area covered 75 to 80 percent of the exposed area. No flame passage was observed during the test -- presumably a consequence of having maintained the furnace at negative pressure. A log of observations and temperatures measured with the movable thermocouple are presented in Table IV.2.

The exposed and unexposed surfaces after the test are shown in Figs. IV.16 and IV.17, respectively. Essentially no material was left on 75 percent of the exposed area. A gray char, from 38 to 46 mm (1.5 to 1.8 in) thick, covered the remaining exposed area of the exposed surface. The unexposed surface was burned through or blackened over its entire exposed area. Very little solid material (1 to 2 mm) [0.04 to 0.08 in] remained beneath the blackened area. Areas underneath all thermocouple pads were burned through.

The post-test mass of the specimen was 8.36 kg (18.4 lb). A light blue glassy residue (Fig. IV.18) was found at the bottom of the furnace.

C. Analysis of Test Results

The ASTM E 119-88 thermal transmission acceptance criteria are that the average temperature rise of the unexposed-surface thermocouples shall not exceed 139°C (250°F) above its initial temperature (in this test, 25°C [77°F]) and the temperature rise of any of these thermocouples shall not exceed 181°C (325°F) above the initial temperature. Another criterion is that at no time during the test should hot gases or flame pass through the assembly so as to ignite cotton waste held against the unexposed surface. In addition to these criteria, NRC requirements include monitoring the time at which any of the unexposed-surface thermocouples reaches 162.8°C (325°F).

On the basis of the experimental temperature data presented in Table IV.1, the above temperature criteria were met at the following locations and times:

Criterion	Location	Time (sec)	Time [hr:min:sec]
E 119 avg. unexposed surf. temp. (164°C) [327°F]		2520	[0:42:00]
E 119 peak unexposed surf. temp. (206°C) [403°F]	TC 31	2708	[0:45:08]
NRC unexposed surf. temp., 1st occurrence (162.8°C) [325°F]	TC 31	2302	[0:38:22]

Concerning E 119 criteria, the average temperature was the controlling factor and the E 119 fire-endurance period was 2520 seconds (0:42:00). Since the period is greater than 1/2 hour, a correction was required to account for deviations of the actual average furnace temperature from the standard temperature-time curve (see ASTM E 119-88, Par. 7.4). This correction was -1 s and **the corrected fire-endurance period was 2519 s (42.0 minutes).**

Although glowing was observed through a large area of the unexposed face of the specimen during the test, the E 119 cotton-waste test was not conducted. Flame passage through the unexposed surface was not observed during the test, apparently the result of the furnace operating at negative pressure. Post-test inspection, however, revealed that about 75 percent of the exposed area was burned through; that is, there was essentially no material left attached to the upper wire mesh over this area.

TABLE IV.1. Temperatures, test 3-2.

NRC TEST 3-2

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
-110	24	24	24	23	25	24	25	25	25	25	0.0
-100	24	23	23	23	24	24	24	25	25	24	0.0
-90	24	24	24	23	25	24	25	25	25	25	-0.0
-80	24	24	24	23	25	24	25	25	25	25	-0.0
-70	24	24	24	23	25	24	24	25	25	24	0.0
-60	24	24	24	23	25	24	25	25	25	25	-0.0
-50	24	24	24	23	25	24	24	25	25	25	-0.0
-40	24	24	24	23	25	24	25	25	25	25	0.0
-30	24	23	23	23	24	24	24	25	25	24	0.0
-20	24	24	24	23	25	24	25	25	25	25	-0.0
-10	24	24	24	23	25	24	25	25	25	25	0.0
-1	24	24	24	23	25	24	25	25	25	25	-0.0
0	24	24	24	23	25	24	25	25	25	25	0.0
10	24	24	24	23	25	25	25	25	25	25	0.2
20	24	24	24	24	25	24	25	25	25	25	0.7
30	27	27	27	26	25	24	25	25	25	25	1.1
40	34	31	32	32	25	24	25	25	25	25	1.3
50	45	38	41	41	25	25	25	25	25	25	1.4
60	60	47	52	53	25	24	25	25	25	25	1.5
70	79	59	66	67	25	24	25	25	25	25	1.5
80	101	73	83	85	25	24	25	25	25	25	1.6
90	125	89	101	105	25	24	25	25	25	25	1.6
100	151	107	122	126	25	24	25	25	25	25	1.6
110	179	128	143	150	25	24	25	25	25	25	1.6
120	207	151	166	175	25	24	25	25	25	25	1.6
130	236	175	190	200	25	25	25	25	25	25	1.6
140	266	201	216	227	25	24	25	25	25	25	1.6
150	296	228	242	255	25	24	25	25	25	25	1.6
160	326	256	269	283	25	24	25	25	25	25	1.7
170	355	285	297	312	25	24	25	25	25	25	1.7
180	383	313	324	340	25	24	25	25	25	25	1.7
190	410	341	351	367	25	24	25	25	25	25	1.8
200	434	367	376	392	25	24	25	25	25	25	1.8
210	457	391	399	415	25	24	25	25	25	25	1.8
220	478	414	421	437	25	25	25	25	25	25	1.9
230	497	435	442	457	25	25	25	25	25	25	1.9
240	515	455	461	477	25	25	25	25	25	25	2.0
250	532	474	479	495	25	25	25	25	25	25	2.0
260	547	492	497	512	25	25	25	25	25	25	2.0
270	561	509	513	527	25	25	25	25	25	25	2.1
280	574	525	529	542	25	25	25	25	25	25	2.1
290	586	540	543	556	25	25	25	25	25	25	2.2
300	597	554	557	569	25	25	25	25	25	25	2.2

TABLE IV.1. Temperatures, test 3-2. (Cont.)

NRC TEST 3-2

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
360	648	616	617	627	25	25	25	25	25	25	2.6
420	678	649	651	659	25	25	25	25	26	25	2.9
480	689	667	669	674	25	26	26	26	26	26	3.1
540	684	673	674	676	26	26	26	26	27	26	3.3
600	680	669	660	669	27	27	27	27	28	27	3.6
660	690	669	663	673	28	28	28	28	29	28	3.7
720	714	688	687	696	29	29	29	29	31	29	3.9
780	737	709	709	717	30	31	31	30	32	31	4.1
840	750	724	725	733	31	32	32	31	34	32	4.3
900	767	743	746	751	32	34	33	33	35	33	4.5
960	769	743	748	753	34	36	35	34	37	35	5.1
1020	751	723	730	734	35	37	36	35	38	37	5.6
1080	765	740	749	751	38	40	38	37	41	39	6.0
1140	786	763	773	774	42	45	40	39	45	42	6.5
1200	807	783	792	794	47	51	43	43	50	47	7.0
1260	806	790	799	798	54	57	47	47	56	52	7.5
1320	817	805	816	812	60	64	51	51	63	58	8.1
1380	831	823	834	829	67	70	56	56	70	64	8.8
1440	835	824	828	828	73	77	61	61	76	70	9.2
1500	839	825	831	832	80	83	66	66	83	76	9.7
1560	846	835	840	840	86	89	71	72	89	81	10.2
1620	849	836	839	840	92	95	75	77	94	87	10.5
1680	851	834	837	840	98	102	80	82	100	92	10.9
1740	856	844	846	848	104	107	85	87	105	97	11.1
1800	866	860	861	862	110	112	89	91	111	102	11.4
1860	875	871	871	872	116	117	93	96	116	108	11.7
1920	857	848	848	850	122	123	97	100	122	113	11.9
1980	859	849	848	851	129	129	100	105	127	118	12.1
2040	872	862	862	865	136	135	104	109	132	123	12.5
2100	882	873	873	875	142	141	107	114	138	126	12.7
2160	856	847	846	849	149	147	111	119	143	134	12.6
2220	863	854	853	856	155	153	115	123	148	139	12.8
2280	877	869	868	870	161	158	119	128	153	144	13.0
2340	889	881	880	883	166	163	124	132	158	149	13.0
2400	870	865	863	865	171	168	130	137	162	154	13.0
2460	873	867	866	868	177	174	135	142	166	159	13.4
2520	886	879	878	880	183	180	141	146	171	164	13.6
2580	894	886	884	888	189	187	147	150	177	170	13.7
2640	876	869	868	871	196	194	153	155	183	176	14.2
2700	884	878	877	879	205	203	158	159	188	183	14.3
2760	898	892	891	893	213	213	164	163	194	189	14.3
2820	895	888	887	890	221	223	170	168	201	197	13.9
2880	885	879	878	880	234	241	177	174	209	207	14.5
2940	900	894	892	894	252	263	186	179	217	220	15.1

TABLE IV.1. Temperatures, test 3-2. (Cont.)

NRC TEST 3-2

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
3000	915	908	907	910	274	288	195	185	225	233	15.6
3060	927	920	918	921	298	319	203	190	233	249	16.1
3120	935	928	927	930	327	353	212	196	242	266	16.7
3180	938	934	933	934	352	383	218	202	253	282	17.1
3240	939	936	935	936	375	413	225	208	264	297	17.6
3300	937	935	933	935	397	448	232	214	275	313	18.0
3360	938	932	932	934	418	487	241	219	285	330	18.5
3420	933	930	931	930	441	521	251	224	299	347	18.8
3480	928	926	927	927	476	549	262	229	316	366	18.8
3540	925	923	924	924	506	572	273	235	334	384	19.1
3600	923	920	921	921	535	591	284	241	354	401	19.3
3660	922	918	919	919	558	606	295	247	370	415	19.4
3720	921	917	918	919	576	620	307	253	385	428	19.6
3780	921	917	918	918	587	628	319	259	396	438	19.7
3840	922	918	919	919	615	629	332	265	412	451	19.9
3900	928	926	927	927	662	627	344	272	430	467	20.0
3960	932	932	933	932	678	624	357	279	442	476	20.8
4020	936	935	937	935	695	623	371	287	455	486	20.4
4080	938	937	938	937	691	623	385	295	468	492	20.4
4140	941	940	941	940	689	624	400	302	485	500	20.6
4200	943	943	944	942	695	628	413	308	506	510	20.6
4260	945	944	946	944	692	633	427	315	514	516	20.7
4320	948	946	948	947	709	640	439	320	519	526	20.9
4380	951	949	950	950	707	650	451	328	523	533	21.0
4440	953	951	952	952	714	663	464	336	538	543	21.2
4500	954	952	954	953	719	679	480	344	545	553	21.5
4560	956	955	956	956	756	700	494	350	551	570	21.9
4620	961	958	959	958	781	727	507	357	554	585	22.0
4680	963	960	961	960	812	763	521	365	556	604	22.4
4740	964	962	962	962	929	816	539	373	557	643	22.9
4800	966	964	964	964	981	857	564	380	556	668	23.5
4860	967	964	966	965	932	881	596	387	556	670	24.0
4920	968	965	966	966	924	892	636	394	555	680	24.5
4980	969	965	967	966	916	904	674	400	554	689	25.2
5040	970	966	968	967	919	912	709	405	555	700	25.7
5100	974	970	972	972	923	928	740	411	556	712	26.3
5160	977	974	976	975	923	939	765	418	559	721	26.9
5220	979	977	979	978	922	947	804	425	563	732	27.4
5280	980	978	980	978	916	947	844	432	569	741	27.9
5340	979	978	979	978	911	944	935	442	576	762	28.2
5400	979	978	979	978	899	943	981	452	584	772	28.3
5460	979	977	979	978	895	942	964	460	593	771	28.8
5520	979	978	980	978	881	939	945	466	603	767	29.0
5580	982	979	982	981	883	940	930	473	614	768	29.2

TABLE IV.1. Temperatures, test 3-2. (Cont.)

NRC TEST 3-2

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
5640	985	981	984	983	883	940	921	479	626	770	29.4
5700	986	982	985	984	885	938	908	483	641	771	29.7
5760	987	983	986	985	889	934	886	487	660	771	30.0
5820	987	984	986	985	894	930	875	491	687	775	30.2
5880	990	985	988	987	904	934	868	494	705	781	30.7
5940	994	989	992	991	906	933	868	497	726	786	31.0
6000	996	991	994	993	914	931	870	501	747	793	31.3
6060	997	991	994	994	913	924	868	505	933	828	31.6
6120	996	992	995	994	919	920	869	509	1000	843	32.0
6180	997	992	995	994	923	920	874	512	927	831	32.3
6240	997	992	995	994	920	917	884	515	845	816	32.4
6300	998	992	995	995	923	918	887	519	801	809	33.0
6360	999	993	996	995	923	916	885	522	782	806	33.4
6420	999	993	996	996	923	916	879	525	769	802	33.7
6480	1001	994	998	997	925	915	881	528	769	804	34.1
6540	1002	996	999	998	927	916	883	532	762	804	34.4
6600	1003	997	1000	999	929	912	886	536	763	805	34.7
6660	1004	998	1001	1000	934	915	891	540	771	810	35.1
6720	1005	999	1002	1002	936	912	894	545	772	812	35.4
6780	1007	1000	1003	1003	943	918	897	552	774	817	35.9
6840	1009	1002	1005	1005	947	919	903	558	786	822	36.3
6900	1009	1002	1006	1005	944	918	909	566	771	821	36.7
6960	1009	1003	1006	1006	942	916	911	575	768	822	36.9
7020	1010	1004	1007	1006	947	917	915	584	761	825	37.4
7080	1011	1005	1008	1007	946	910	918	593	753	824	37.6
7140	1012	1006	1008	1008	948	913	920	603	741	825	38.1
7200	1013	1006	1009	1009	949	916	921	613	712	822	38.4
7260	1013	1006	1009	1009	945	915	920	623	679	816	38.5
7320	1013	1006	1009	1008	948	917	918	631	679	818	38.9
7380	1014	1006	1009	1009	952	915	917	638	688	822	39.3
7440	1014	1007	1010	1010	955	921	916	647	673	822	39.6
7500	1015	1008	1010	1010	956	921	913	656	666	822	39.9
7560	1019	1011	1013	1014	970	939	921	667	716	843	40.8
7620	1023	1014	1016	1017	973	937	924	682	706	844	41.0
7680	1024	1017	1018	1019	979	941	928	700	705	851	41.7
7740	1026	1018	1020	1021	982	942	930	721	707	856	42.2
7800	1025	1017	1019	1020	981	941	928	746	705	859	42.4
7860	1024	1016	1018	1019	980	939	927	770	689	861	42.7
7920	1022	1016	1017	1018	979	935	926	793	683	863	42.9
7980	1021	1014	1016	1017	979	937	923	813	713	873	43.3
8040	1022	1014	1016	1017	981	941	924	835	737	883	43.7
8100	1023	1015	1017	1018	985	947	926	860	751	894	44.1
8160	1025	1017	1018	1020	987	949	930	897	756	904	44.4
8220	1025	1017	1018	1020	988	951	930	961	784	923	44.9

TABLE IV.1. Temperatures, test 3-2. (Cont.)

NRC TEST 3-2

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
8280	1025	1017	1018	1019	987	951	932	1039	786	939	45.1
8340	1026	1017	1018	1020	990	957	934	1040	808	946	45.5
8400	1026	1018	1018	1020	989	959	934	1015	811	942	45.7
8460	1027	1019	1019	1021	994	969	939	991	842	947	46.3
8520	1030	1022	1023	1024	997	981	945	979	861	952	46.7
8580	1032	1022	1023	1025	997	977	943	965	858	948	46.9
8640	1032	1023	1024	1025	999	981	946	958	863	949	47.3
8700	1033	1023	1024	1026	1000	984	948	950	878	952	47.8
8760	1034	1024	1025	1028	1002	988	951	947	885	954	48.0
8820	1034	1025	1026	1027	1002	984	952	928	884	950	48.3
8880	1034	1024	1025	1027	1001	984	953	915	877	946	48.6
8940	1035	1025	1027	1028	1003	986	955	911	890	949	48.9
9000	1035	1026	1029	1030	1003	991	957	907	896	951	49.2
9060	1036	1027	1029	1030	1004	993	973	900	898	954	49.5
9120	1036	1027	1029	1030	1005	993	962	905	905	954	49.8
9180	1035	1026	1028	1030	1003	992	959	893	900	949	50.0
9240	1037	1027	1029	1031	1007	997	962	908	915	958	50.4
9300	1038	1030	1032	1033	1008	999	965	909	915	959	50.5
9360	1040	1031	1033	1035	1010	1001	970	921	922	965	50.9
9420	1041	1032	1034	1035	1010	1001	971	925	925	967	51.2
9480	1042	1033	1035	1036	1011	1002	973	929	925	968	51.3
9540	1042	1034	1035	1036	1010	1002	974	938	925	970	51.6
9600	1041	1033	1035	1036	1010	1002	976	945	925	972	51.9
9660	1041	1033	1034	1035	1010	1003	976	943	924	971	52.1
9720	1040	1032	1034	1035	1009	1002	976	951	927	973	52.4
9780	1041	1033	1035	1036	1012	1004	979	963	938	979	52.8
9840	1045	1036	1038	1040	1015	1007	983	972	945	984	53.1
9900	1046	1037	1041	1041	1016	1008	986	979	950	988	53.3
9960	1047	1039	1042	1042	1017	1009	988	985	952	990	53.5
10020	1049	1041	1044	1044	1019	1012	989	988	959	993	53.8
10080	1050	1042	1045	1045	1020	1013	991	989	961	995	54.1
10140	1050	1042	1045	1045	1021	1013	992	993	957	995	54.2
10200	1050	1042	1045	1045	1020	1012	992	994	959	996	54.4
10260	1049	1042	1045	1045	1020	1012	993	995	961	996	54.6
10320	1049	1042	1045	1045	1020	1012	992	996	963	997	54.8
10380	1049	1042	1045	1044	1020	1012	992	997	962	997	55.0
10440	1049	1043	1045	1045	1020	1013	993	998	967	998	55.3
10500	1051	1045	1048	1047	1024	1015	996	1002	975	1002	55.6
10560	1052	1046	1049	1049	1025	1016	997	1003	977	1003	55.9

TABLE IV.1. Temperatures, test 3-2. (Cont.)

NRC TEST 3-2

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
10620	1053	1046	1050	1049	1024	1016	997	1005	977	1004	56.1
10680	1053	1047	1051	1049	1026	1017	999	1006	983	1006	56.3
10740	1054	1048	1052	1051	1028	1019	1000	1007	982	1007	56.6
10800	1054	1048	1052	1051	1026	1018	1000	1007	984	1007	56.8
10860	1054	1048	1052	1051	1027	1018	1000	1008	984	1007	56.9
10920	1053	1048	1051	1050	1025	1017	999	1007	983	1006	-20.3
10980	1052	1047	1051	1049	1024	1016	998	1007	980	1005	-20.3

TABLE IV.2 Observations, test 3-2.

The following observations were made during and after the test:

(Note: MTC indicates surface temperature measured with movable thermocouple)

Time	
0:17:00	Furnace control suddenly changed -- More energy is required to follow temp.-time curve (char may have fallen on TCs ?)
0:23:45	No visible changes on unexposed surface.
0:32:30	Outgassing of unexposed surface has begun.
0:38:00	Strong outgassing, no browning.
0:41:25	Browning on both sides of ridge between pads 31 and 32. Crystals appearing between 32 and 35. 230°C (446°F) measured with MTC between 32 and 35.
0:46:15	No glowing so far.
0:46:45	Strong outgassing and black spot appearing in area between 32 and 35. Bubbling on both sides along much of the ridge between 31 and 32, and 31 and 35.
0:52:00	Black area extending S. of 31 and on both sides of ridge between 31 and 32, and 31 and 35. Brown area continues to expand; black/brown over most of N.E. quadrant of exposed area.
0:56:30	Area between 31 and 32 "cooking out".
0:58:00	Darkening around 35.
1:04:30	Still no glowing.
1:06:	500 - 618°C (932 - 1144°F) (MTC) between 32 and 35.
1:09:00	Tar-like bubbles on both sides of ridge immediately S. of 35.
1:09:30	No glowing so far.
1:15:30	60 to 70 percent of the exposed area is black. 85 to 90 percent of the exposed area is brown or black.
1:16:00	Glowing pin holes W. of 32 and on both sides of ridge between 31 and 32.
1:17:45	Glowing on S. side and S.W. corner of pad 32.
1:20:30	TC31 has exceeded the furnace temp. (due to local burning of specimen ?).
1:22:00	Glowing pin-hole region expanding toward 31.
1:25:30	Pin-hole region has extended to center of specimen.
1:28:00	Glowing throughout the region between 31 and 32.
1:33:30	Glowing on W. edge of 31.
1:41:00	Glowing at along S. edge of 35.
1:53:00	Glowing on diagonal between 31 and 33.
2:05:20	Can see E. burner port through pin holes.
2:46:00	Burnedthrough area covers 75 to 80 percent of the exposed area. Only the wire mesh (upper) and a small amount of char remains in this area.
3:01:00	Shutdown.
4:13:00	W. edge of specimen lifted and propped.

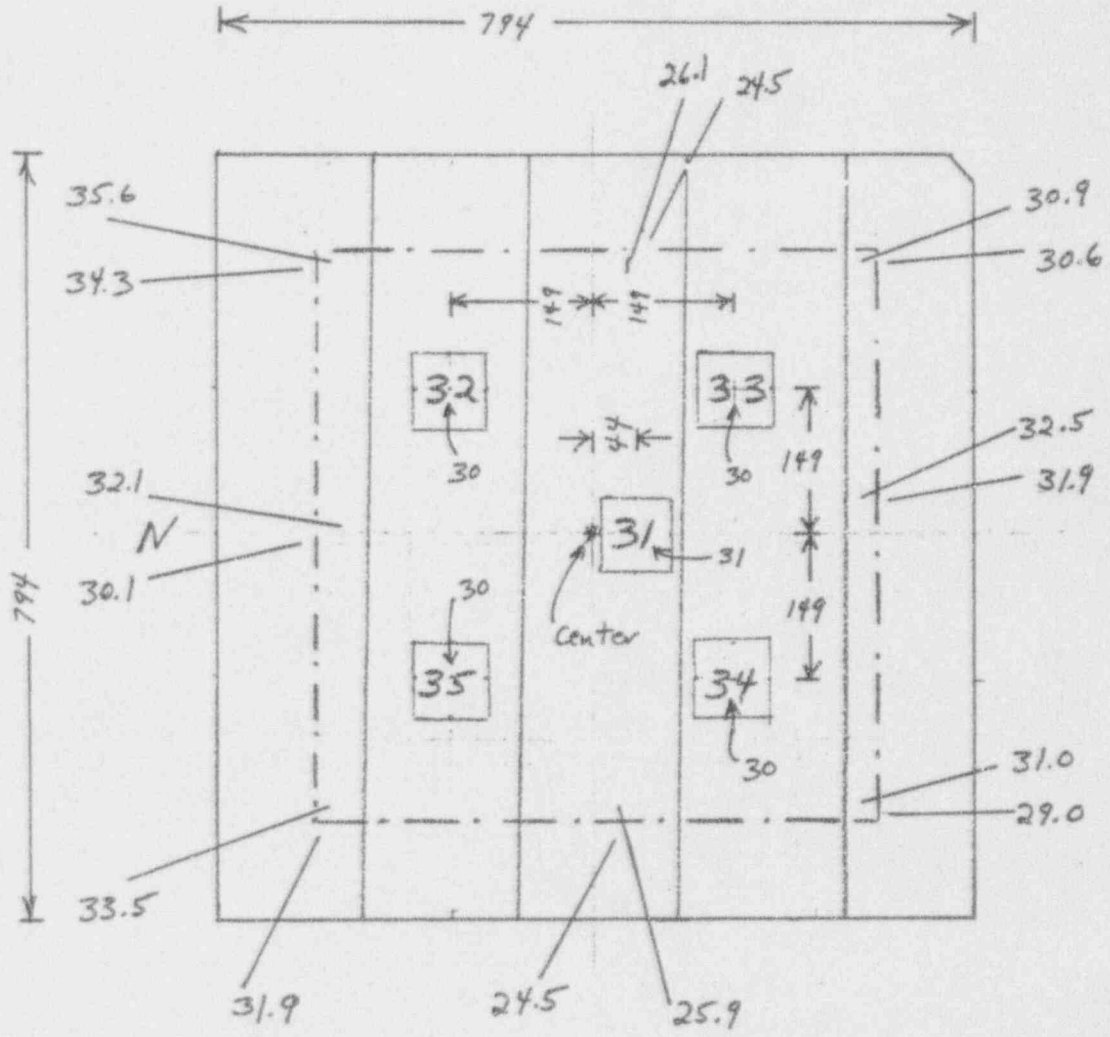

Fig. IV.1. Dimensions, sample 3-2. All dimensions in millimeters. Numbered squares denote unexposed-surface thermocouple pads. Other numbers not between arrows indicate thickness.

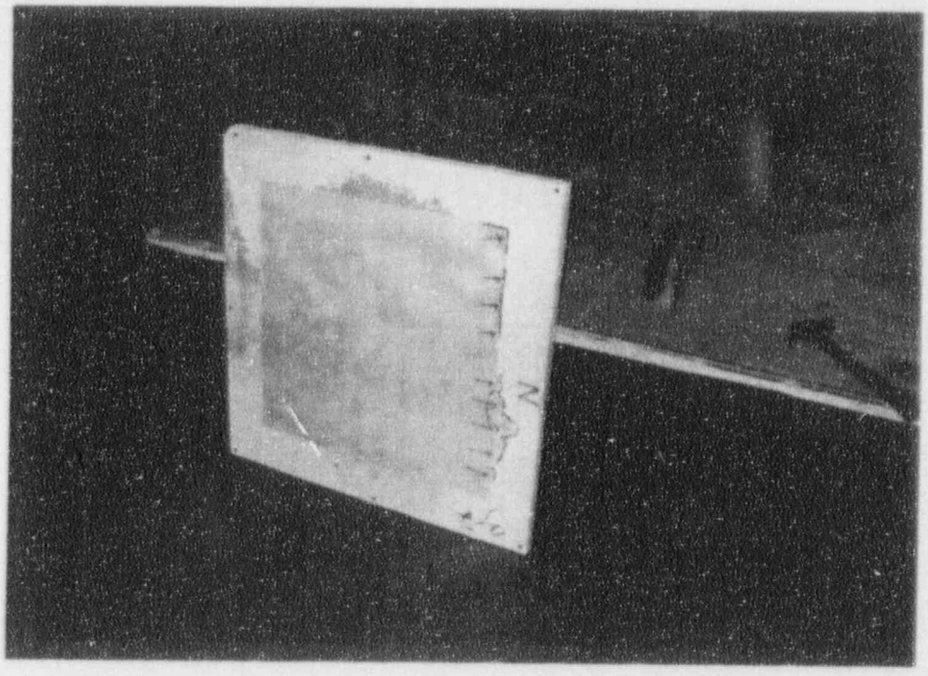

Fig. IV.2. Pre-test exposed surface, sample 3-2.

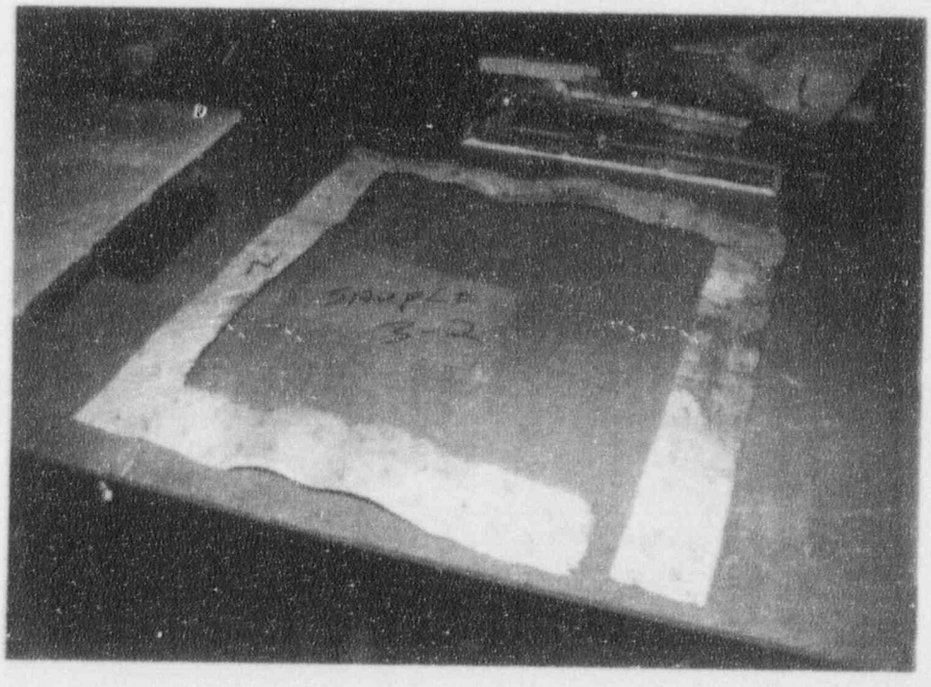

Fig. IV.3. Wire removed from exposed surface, sample 3-2.

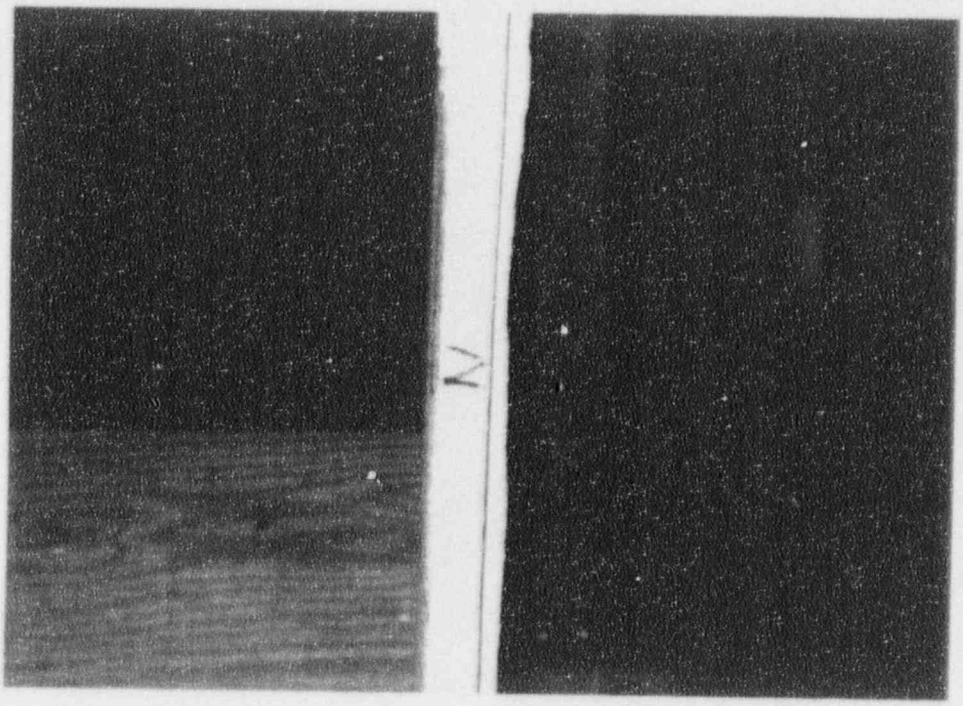

Fig. IV.4. Pre-test edge view of sample 3-2.

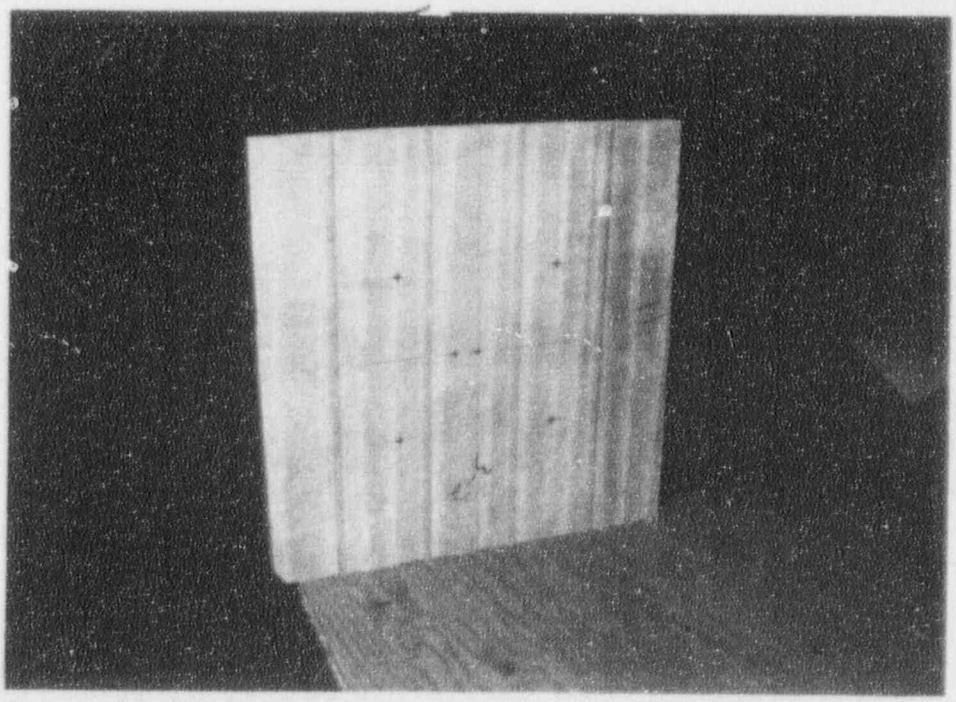

Fig. IV.5. Pre-test unexposed surface of sample 3-2.

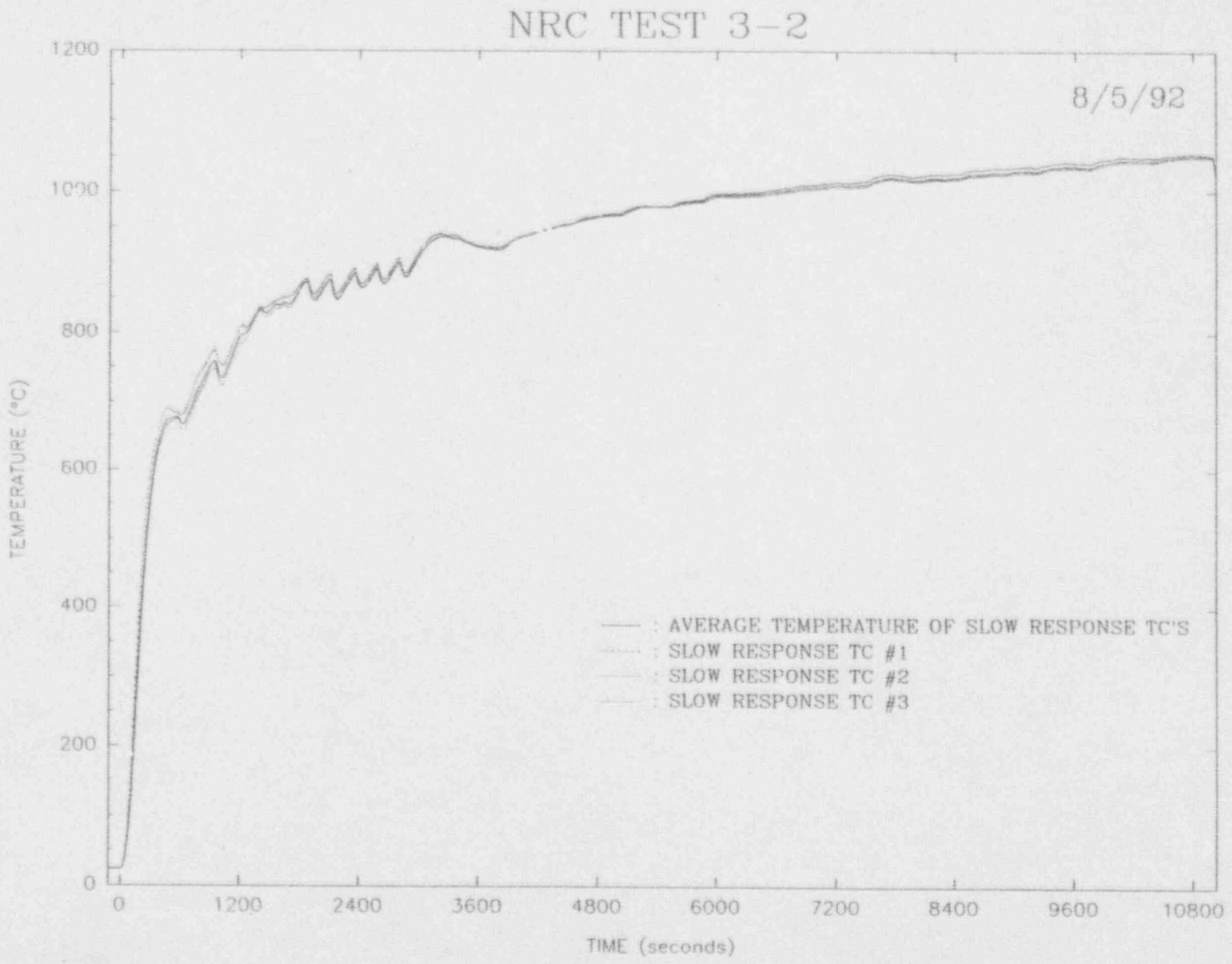

Fig. IV.6. Furnace temperatures, test 3-2.

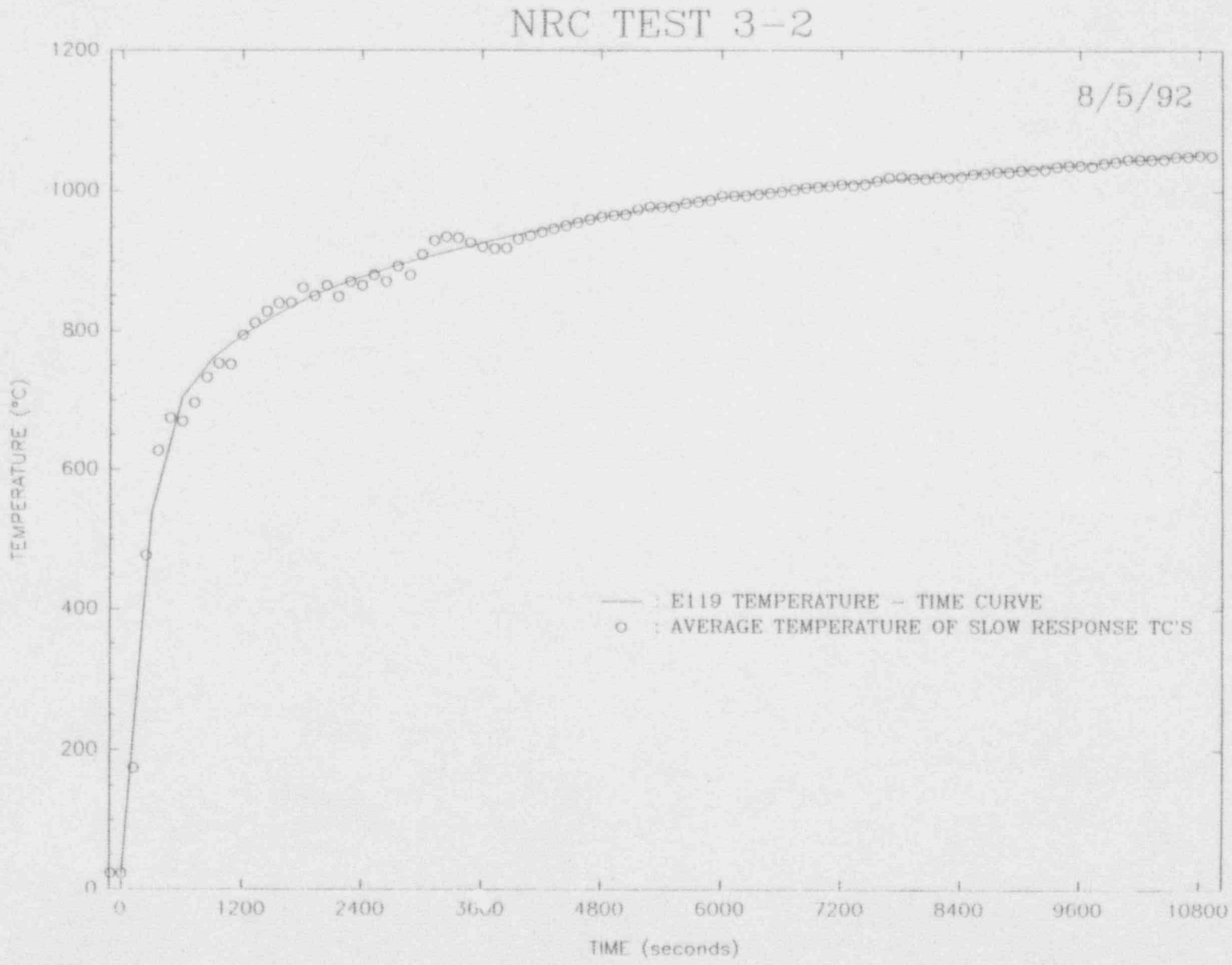

Fig. IV.7. Furnace temperatures, test 3-2.

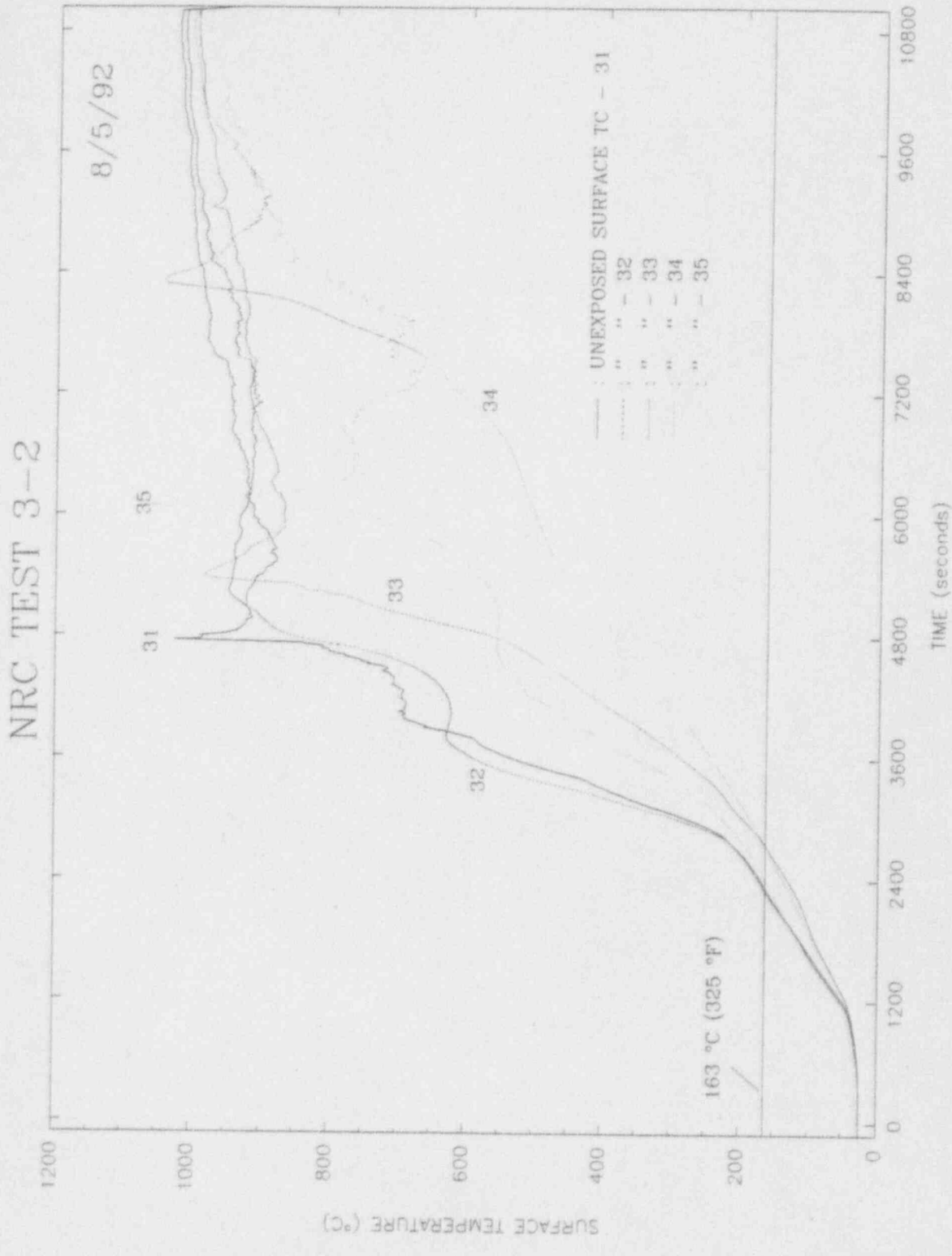

Fig. IV.8. Unexposed-surface temperature, sample 3-2.

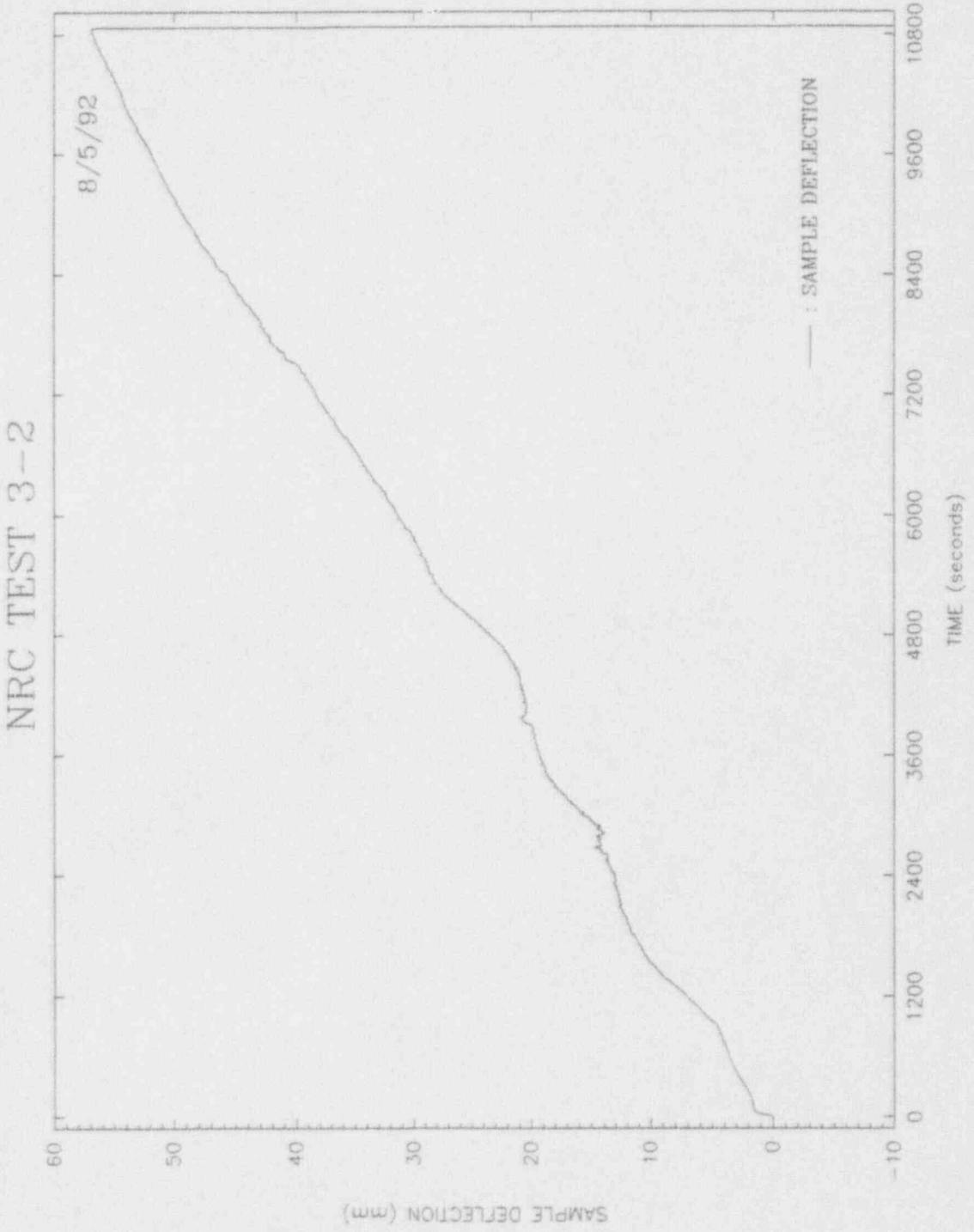

Fig. IV.9. Deflection at center of specimen, test 3-2.

Fig. IV.10. Photograph of unexposed surface during test.

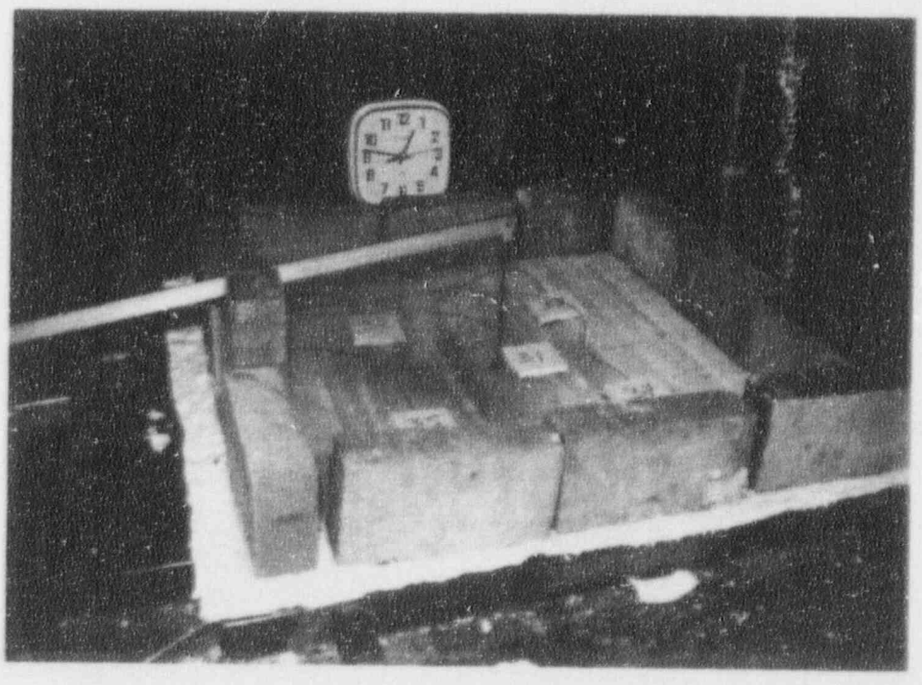

Fig. IV.11. Photograph of unexposed surface during test.

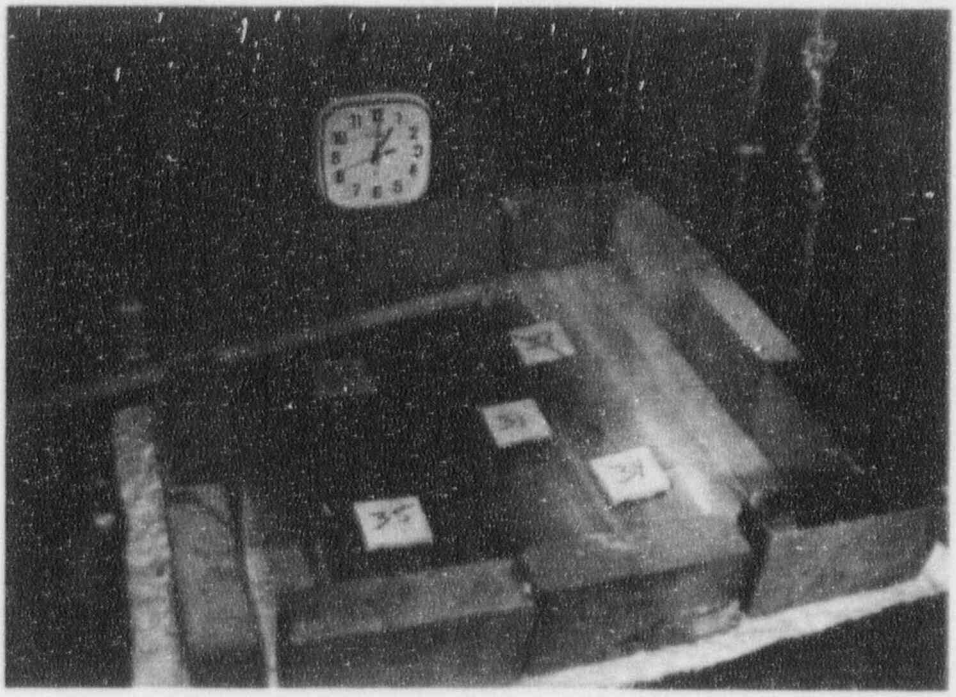

Fig. IV.12. Photograph of unexposed surface during test.

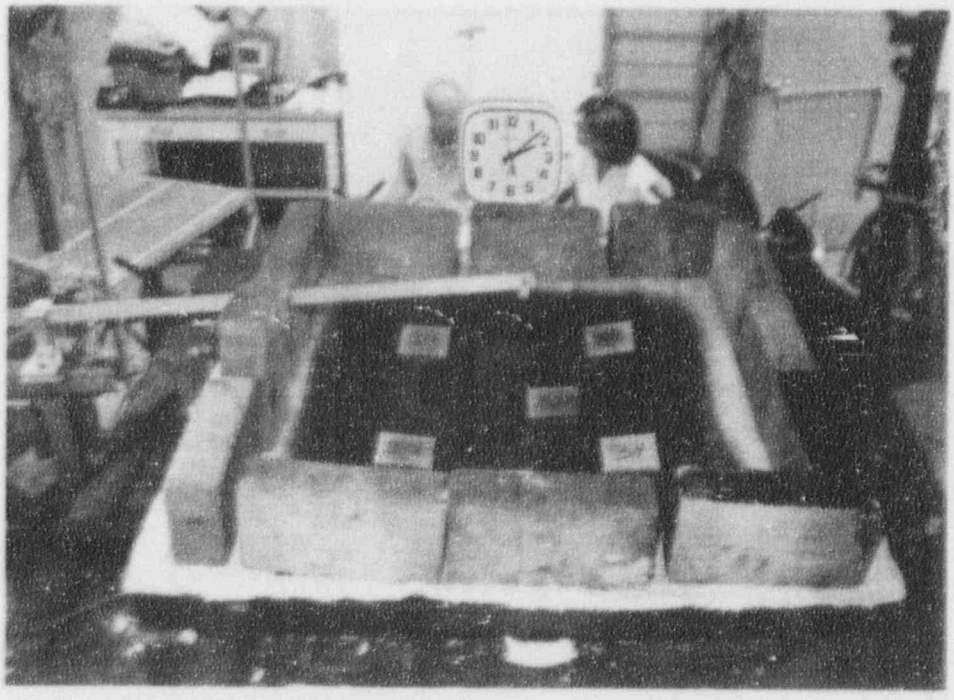

Fig. IV.13. Photograph of unexposed surface during test.

Fig. IV.14. Photograph of unexposed surface during test.

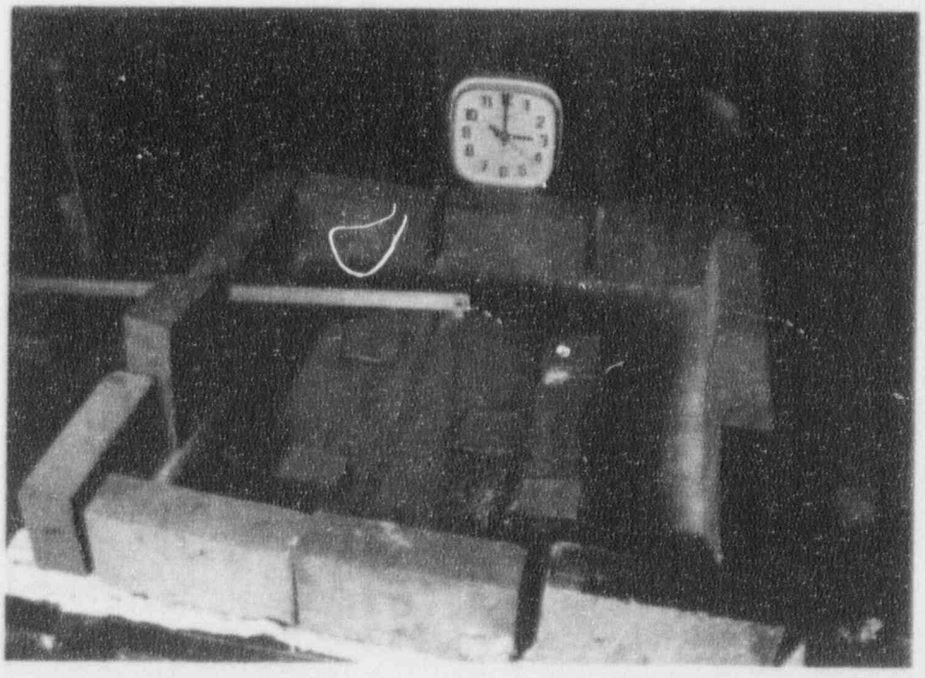

Fig. IV.15. Photograph of unexposed surface during test.

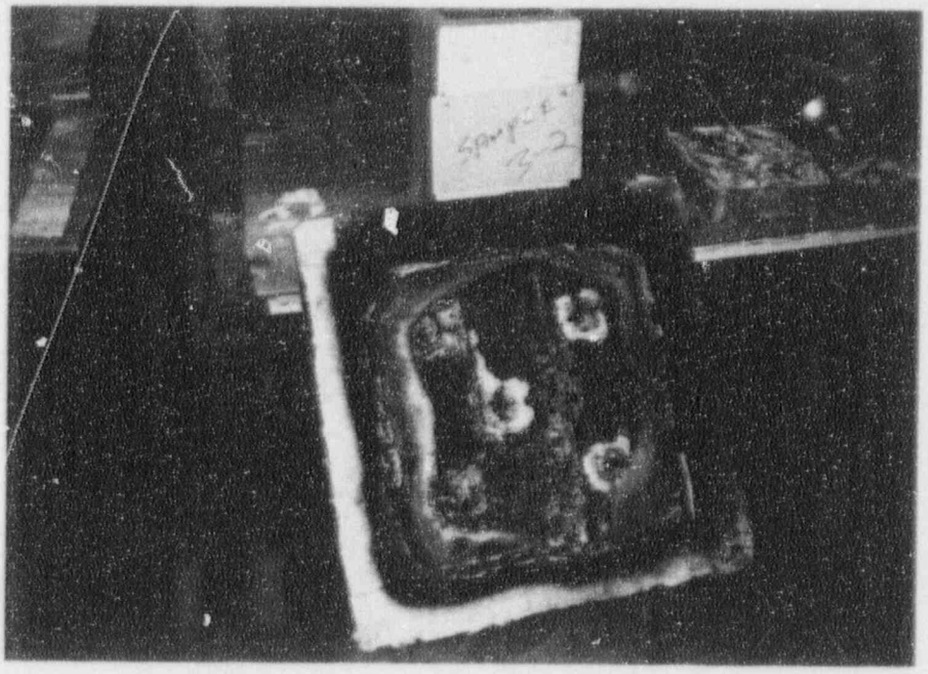

Fig. IV.16. Post-test exposed surface, sample 3-2.

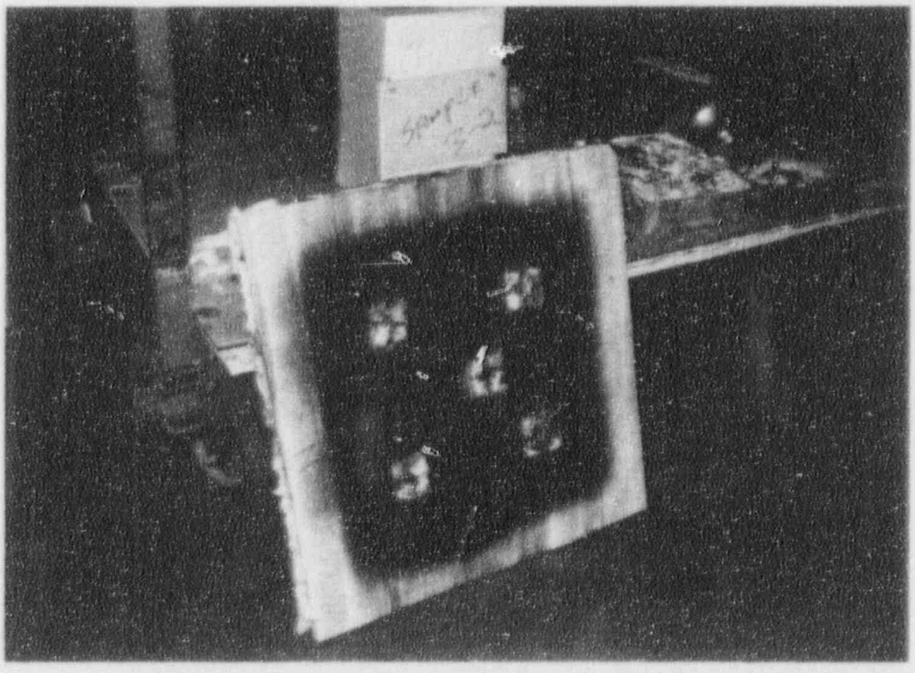

Fig. IV.17. Post-test unexposed surface, sample 3-2.

Fig. IV.18. Post-test residue.

V. Test 1-3

A. Description of Test Assembly

The test assembly consisted of a single sheet of NRC-supplied 1-hour subliming fire-barrier panel. This panel is manufactured with a "flat" face, a ribbed face, and wire mesh covering only the ribbed face. The specimen was tested with its ribbed surface as the exposed surface and with the wire mesh covering the entire ribbed face.

The fire barrier specimen, designated sample 1-3, was cut to the dimensions shown in Fig. V.1 from a panel labeled by the manufacturer as F9-203001 and F080891. The panel consisted of two distinct layers; a thick "white" layer and a 0 to 3 mm (0.12 in) cream layer on the flat side of the panel.

Figure V.1 shows a total of 20 off-rib thicknesses of the specimen along the perimeter and beneath the surface-temperature pads. In addition, measurements were made at another 5 off-rib locations marked as quality control measurement points by the manufacturer but not identified in this figure. These measurements can be summarized as follows:

	Off-Rib Thickness (mm [in])			
	avg.	std. dev.	max.	min.
perimeter & below pads	18 [0.72]	1.9 [0.075]	22 [0.87]	15 [0.59]
Mfrs. QC pts.	16 [0.64]	1.3 [0.051]	17 [0.67]	14 [0.55]

Thicknesses at ribs were about 25 mm (0.98 in). The pre-test mass of the specimen was 12.0 kg (26.4 lb). Pre-test photographs of the exposed and unexposed surfaces of the specimen are shown in Figs. V.2 and V.3.

The specimen was tested with its ribbed surface as the exposed surface (facing downward) and with the wire mesh covering unaltered; i.e., the entire lower face was covered by the wire mesh. Consequently, the lower (and only) wire mesh was constrained by the vertical load of the bricks located along the perimeter of the specimen.

B. Fire Test Procedures and Results

The test was conducted on August 6, 1992 and was witnessed by the following official observers: P. Madden (NRC), S. West (NRC), M. Widmann (NRC), I. Moghissi (NRC), M. Streibich (NRC), and B. Bradley, Nuclear Management and Resources Council (NUMARC).

The specimen was subjected to a 1-hour fire exposure controlled by the ASTM E 119-88 standard temperature-time curve. Plots of the furnace temperatures recorded by the individual furnace thermocouples and their average values are presented in Fig. V.4 and tabulated in Table V.1. The average furnace temperatures and the standard temperature-time curve are shown in Fig. V.5.

Unexposed-surface thermocouples measured surface temperatures underneath insulation pads at 5 locations designated 31 to 35 in Fig. V.1. The thermocouples at these locations are designated TC31 to TC35, respectively, and their outputs are plotted in Fig. V.6 and tabulated in Table V.1. Included in the table are the averages of the unexposed-surface temperatures as a function of time. It is unclear why TC31 closely tracks TC34 up to about 2900 s, then cools for about 100 s, and then slowly re-approaches TC34.

The deflection at the center of the specimen was measured throughout the test and is plotted in Fig. V.7 and tabulated in Table V.1. Positive deflection indicates sag into the furnace. The maximum recorded deflection of 41.1 mm (1.62 in) occurred at 3660 seconds (1:01:00) (hr:min:s), which was 1 minute after shutdown was initiated.

Figures V.8 to V.11 show the appearance of the unexposed surface during the test. Outgassing from the unexposed surface was observed at 0:17:00 and the specimen was sagging at 0:25:00. Light brown discoloration was evident in the area north of thermocouple pad 31 and a large bubble began forming northwest of pad 33. At 0:57:15 no glowing was visible and the light brown discoloration covered about 75 percent of the exposed area. No flame passage occurred. A log of observations and temperatures measured with the movable thermocouple are presented in Table V.2.

The exposed and unexposed surfaces after the test are shown in Figs. V.12 and V.13, respectively. Char covered the entire exposed area of the exposed surface. Char thickness tapered from 38 mm (1.5 in) at the center to 19 mm (0.75 in) in the corners. The wire mesh on the exposed surface was intact, albeit very brittle, and embedded in the char layer. It appeared that some softened material pushed through the wire mesh and then formed a char layer on the fire-side of the mesh.

The thermocouple pads remained attached to the specimen and had to be pried off to complete the inspection of the unexposed surface. There was some black area underneath each of the thermocouple pads. The areas underneath three of the pads were heavily charred but not burned through. Several large unbroken bubbles were formed on the unexposed surface. About 13 mm (0.51 in) of "virgin" material remained at the center of the specimen.

The post-test mass of the specimen was 9.9 kg (21.9 lb). No residue was found at the bottom of the furnace.

C. Analysis of Test Results

The ASTM E 119-88 thermal transmission acceptance criteria are that the average temperature rise of the unexposed-surface thermocouples shall not exceed 139°C (250°F) above its initial temperature (in this test, 26°C [79°F]) and the temperature rise of any of these thermocouples shall not exceed 181°C (325°F) above the initial temperature. Another criterion is that at no time during the test should hot gases or flame pass through the assembly so as to ignite cotton waste held against the unexposed surface. In addition to these criteria, NRC requirements include the time at which any of the unexposed-surface thermocouples reaches 162.8°C (325°F).

On the basis of the experimental temperature data presented in Table V.1, the above temperature criteria were met at the following locations and times:

Criterion	Location	Time (sec)	Time [hr:min:sec]
E 119 avg. unexposed surf. temp. (165°C) [329°F]		1980	[0:33:00]
E 119 peak unexposed surf. temp. (207°C) [405°F]	TC 32	2760	[0:46:00]
NRC unexposed surf. temp., 1st occurrence (162.8°C) [325°F]	TC 35	1587	[0:26:27]

Concerning E 119 criteria, the average temperature was the controlling factor and the E 119 fire-endurance period was 1980 seconds (0:33:00). Since the period is greater than 1/2 hour, a correction was required to account for deviations of the actual average furnace temperature from the standard temperature-time curve (see ASTM E 119-88, Par. 7.4). This correction was -5 s and **the corrected fire-endurance period was 1975 s (32.9 minutes).**

Neither glowing nor flame passage were observed during the test. The E 119 cotton-waste test was not conducted at any time during the test. Post-test inspection revealed no burnedthrough areas but areas underneath three of the thermocouple pads were heavily charred[11]. Char layer on exposed face remained in place throughout the test.

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[11]Maximum temperatures are expected to occur beneath pads (see section I.C).

TABLE V.1. Temperatures, test 1-3.

NRC TEST 1-3

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
-110	26	26	26	26	25	25	25	26	26	26	0.0
-100	26	26	26	26	25	25	25	26	26	25	0.0
-90	26	26	26	26	25	25	25	26	26	25	-0.0
-80	26	26	26	26	25	25	25	26	26	25	-0.0
-70	26	26	26	26	25	25	25	26	26	25	-0.0
-60	26	26	26	26	25	25	25	26	26	25	-0.0
-50	26	26	26	26	25	25	25	26	26	26	-0.0
-40	26	26	26	26	25	25	25	26	26	25	-0.0
-30	26	26	26	26	25	25	25	26	26	25	0.0
-20	26	26	26	26	25	26	25	26	26	26	-0.0
-10	26	26	26	26	25	25	25	26	26	26	-0.0
-1	26	26	26	26	25	25	25	26	26	26	0.0
0	26	26	26	26	25	25	25	26	26	25	0.1
10	26	26	26	26	25	25	25	26	26	25	0.3
20	26	26	26	26	25	25	25	26	26	25	1.0
30	28	29	29	28	25	25	25	26	26	25	2.5
40	33	33	33	32	25	25	25	26	26	25	3.6
50	40	39	41	39	25	25	25	26	26	25	4.5
60	50	46	51	49	25	25	25	25	26	25	5.3
70	64	56	63	60	25	25	25	26	26	26	5.9
80	80	67	76	74	25	26	25	26	26	26	6.5
90	99	80	92	90	25	26	25	26	26	26	7.0
100	121	95	108	108	25	26	25	26	26	26	7.4
110	145	112	126	127	26	26	25	26	26	26	7.7
120	170	130	145	148	26	26	25	26	27	26	7.8
130	197	150	165	170	26	27	26	26	27	26	7.9
140	225	170	185	193	26	28	26	26	28	27	7.8
150	254	191	206	217	27	28	26	26	29	27	7.6
160	284	214	228	241	27	29	26	27	29	28	7.6
170	313	237	252	266	28	30	26	27	30	28	7.6
180	342	262	276	293	28	31	27	28	31	29	7.6
190	371	287	301	319	29	32	27	28	33	30	7.7
200	398	313	326	345	30	33	27	29	34	31	7.8
210	424	339	351	371	31	35	28	30	35	32	7.9
220	449	364	375	395	32	36	28	30	36	33	8.1
230	472	389	398	420	32	37	29	31	38	34	8.2
240	494	413	421	442	33	39	30	32	39	35	8.4
250	515	436	444	464	34	40	30	33	41	36	8.6
260	534	458	465	485	35	42	31	34	42	37	8.8
270	551	479	485	504	37	43	32	35	44	38	9.0
280	566	497	503	522	38	45	33	36	45	39	9.2
290	581	515	520	538	39	46	33	37	47	40	9.5
300	594	531	535	553	40	48	34	38	49	42	9.8

TABLE V.1. Temperatures, test 1-3. (cont.)

NRC TEST 1-3

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
360	647	600	603	616	47	57	40	44	58	49	11.8
420	669	631	635	644	54	66	46	51	67	57	13.9
480	675	647	650	657	61	74	52	58	76	64	16.1
540	679	655	659	663	68	82	58	65	84	71	18.0
600	687	670	674	676	74	89	64	71	91	78	19.7
660	710	690	695	697	80	96	70	77	98	84	21.3
720	736	714	719	723	86	102	75	82	104	90	22.8
780	759	737	741	745	91	108	80	88	110	95	24.1
840	774	755	758	762	95	113	85	93	115	100	25.4
900	783	766	770	772	100	118	90	98	122	105	26.4
960	790	775	779	780	104	123	95	102	126	110	27.3
1020	786	777	781	781	109	127	99	106	129	114	28.0
1080	780	777	778	778	113	131	103	110	133	118	28.5
1140	783	780	783	782	117	135	106	114	137	122	29.0
1200	796	791	794	793	121	140	110	118	141	126	29.4
1260	809	799	802	803	125	144	113	122	145	130	29.8
1320	816	806	809	810	127	147	115	126	148	133	30.2
1380	816	811	814	814	130	151	117	130	152	136	30.5
1440	817	816	818	816	134	154	119	133	155	139	30.8
1500	820	821	823	820	137	157	121	137	158	142	31.0
1560	824	824	826	824	140	160	124	140	161	145	31.3
1620	829	829	832	830	144	164	127	143	165	148	31.6
1680	833	835	837	834	147	167	130	146	169	152	31.8
1740	837	840	842	840	149	171	133	149	172	155	32.1
1800	843	844	845	843	152	174	136	151	175	158	32.4
1860	848	848	850	848	155	177	139	153	177	160	32.7
1920	852	853	854	853	157	179	142	156	180	163	32.9
1980	855	859	860	857	160	182	145	158	182	165	33.2
2040	855	861	861	859	162	184	147	160	184	168	33.5
2100	859	863	865	862	165	186	150	163	185	170	33.8
2160	861	866	867	864	168	188	152	165	187	172	34.0
2220	865	869	870	867	170	190	154	168	189	174	34.4
2280	868	873	874	871	173	192	156	171	191	177	34.6
2340	872	877	878	875	175	194	158	174	193	179	34.9
2400	874	879	880	877	178	195	160	177	195	181	35.2
2460	878	883	883	881	179	198	162	179	196	183	35.5
2520	881	885	887	884	181	200	164	181	198	185	35.8
2580	885	889	890	888	183	202	166	183	199	187	36.1
2640	887	891	892	889	185	204	167	185	201	188	36.4
2700	889	894	895	892	187	206	169	187	202	190	36.7
2760	892	896	896	894	188	207	170	189	204	192	37.0
2820	894	898	899	896	190	209	171	191	206	193	37.4

TABLE V.1. Temperatures, test 1-3. (cont.)

NRC TEST 1-3

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
2880	897	901	902	900	191	211	172	192	207	195	37.6
2940	901	904	905	903	192	213	173	194	209	196	37.9
3000	902	906	907	905	191	215	175	195	210	197	38.1
3060	905	909	910	908	189	217	176	197	212	198	38.7
3120	909	913	914	911	189	220	177	198	214	199	38.9
3180	913	914	915	913	190	222	178	199	216	201	39.2
3240	913	916	917	915	191	224	179	201	218	203	39.4
3300	914	918	918	916	193	227	180	202	220	204	39.7
3360	916	919	920	918	195	229	181	204	222	206	39.9
3420	919	921	922	920	197	232	182	205	225	208	40.1
3480	921	924	924	922	199	234	183	207	226	210	40.4
3540	925	925	926	925	202	235	183	208	228	211	40.7
3600	927	927	928	926	205	237	184	210	231	213	40.9
3660	927	927	927	926	208	239	185	212	231	215	41.1

TABLE V.2. Observations, test 1-3.

The following observations were made during and after the test:

(Note: MTC indicates surface temperature measured with movable thermocouple)

Time	
0:10:00	No obvious changes to unexposed surface.
0:14:	82°C (180°F) (MTC) between pads 34 and 35.
0:17:00	Outgassing begins on unexposed surface. No discoloration.
0:21:00	No browning.
0:25:00	Still no browning. Sag is obvious.
0:27:00	Light brown discoloration N. of 31.
0:29:30	Bubble may be forming N.W. of 33.
0:30:30	Bubble seems to be growing.
0:31:30	Significant increase of outgassing.
0:34:	122°C (252°F) (MTC) between 34 and 35.
0:37:45	Crystals appearing N.E. of 32.
0:40:30	Browning E. of 35.
0:46:30	Crystals throughout central region bounded by 32,33,34,35.
0:51:	138°C (280°F) (MTC) measured between 34 and 35.
0:52:30	153°C (307°F) (MTC) between 32 and 35.
0:57:15	Turned off floodlight. No glowing seen. Bubble forming E. of 31.
0:59:00	Increasing smoke from beneath pad 31.
1:00:00	Shutdown.
1:04:30	Central area easily penetrated with putty knife.
1:08:	Sample lifted and propped.

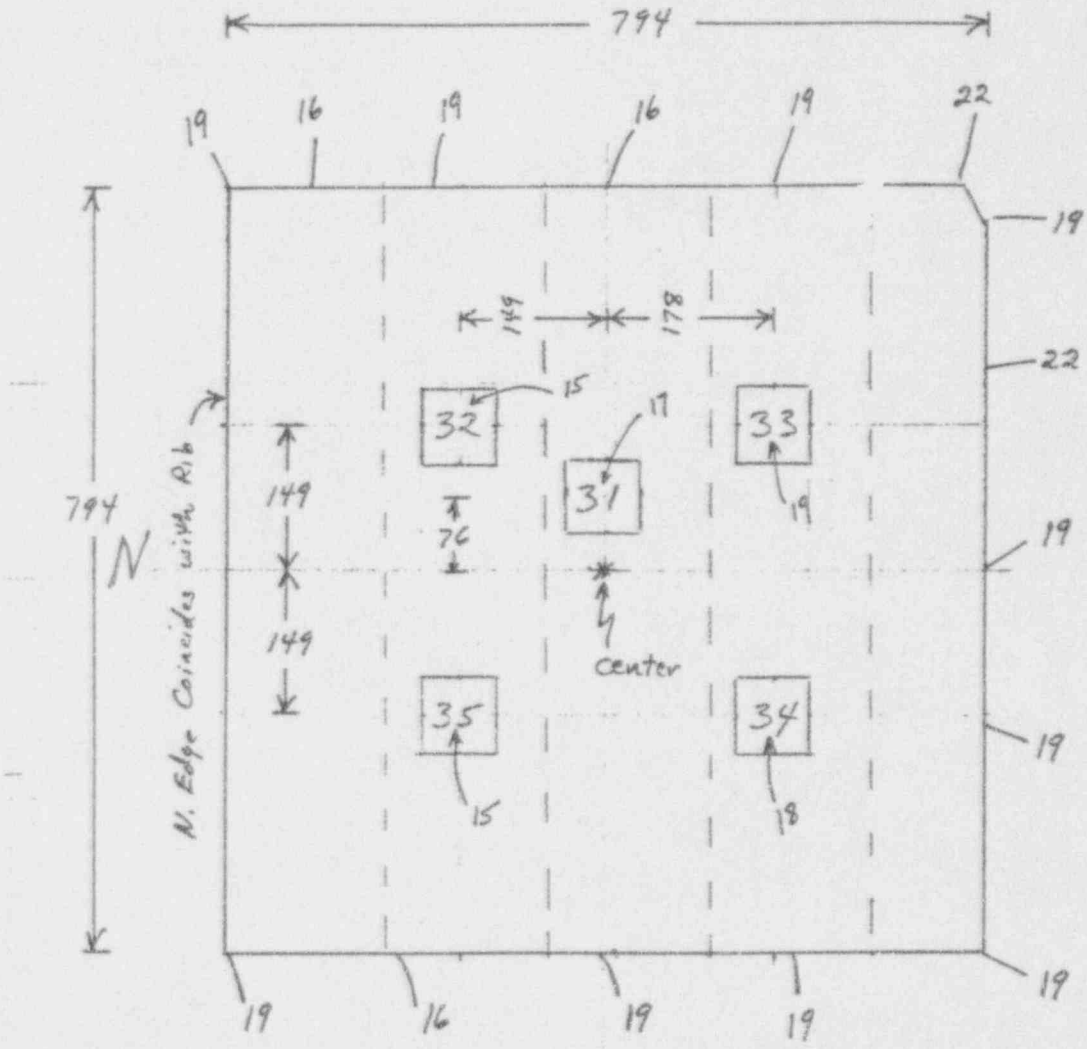

Fig. V.1. Dimensions, sample 1-3. All dimensions in millimeters. Numbered squares denote unexposed-surface thermocouple pads. Other numbers not between arrows indicate thickness.

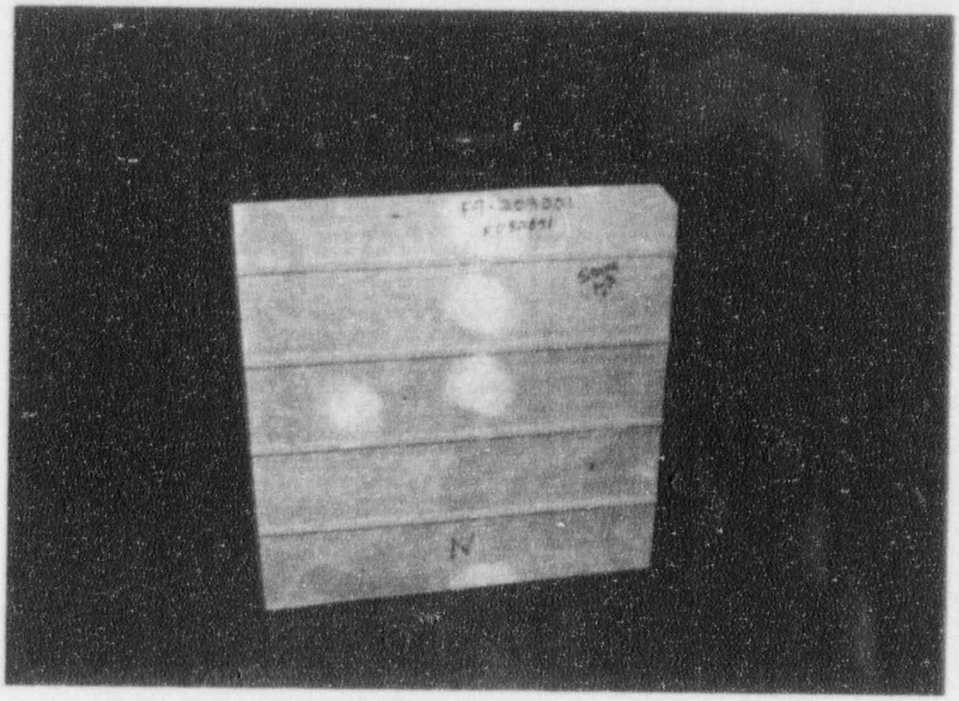

Fig. V.2. Pre-test exposed surface, sample 1-3.

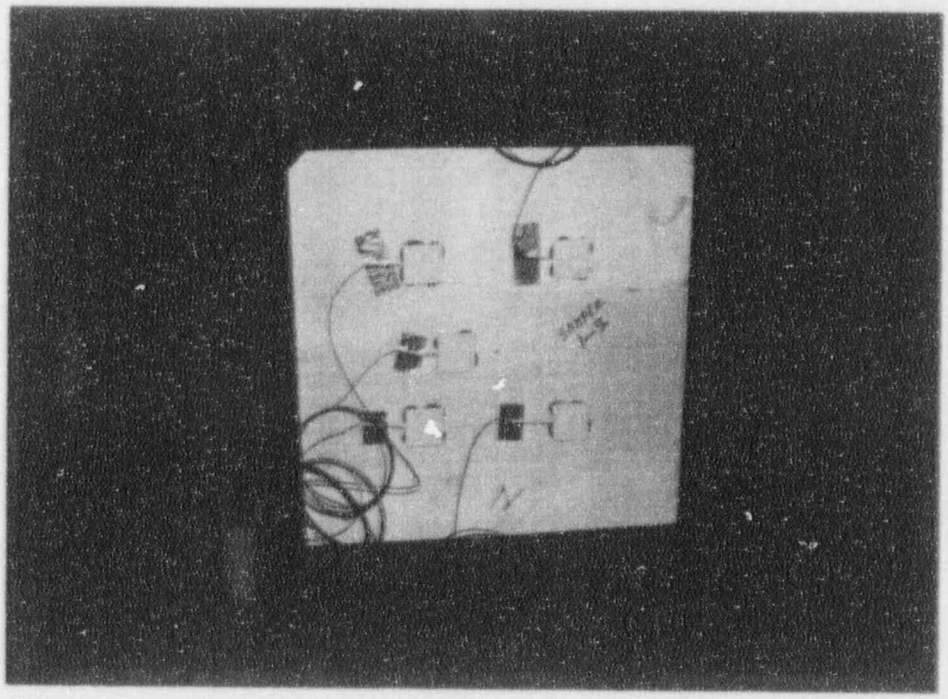

Fig. V.3. Pre-test unexposed surface, sample 1-3.

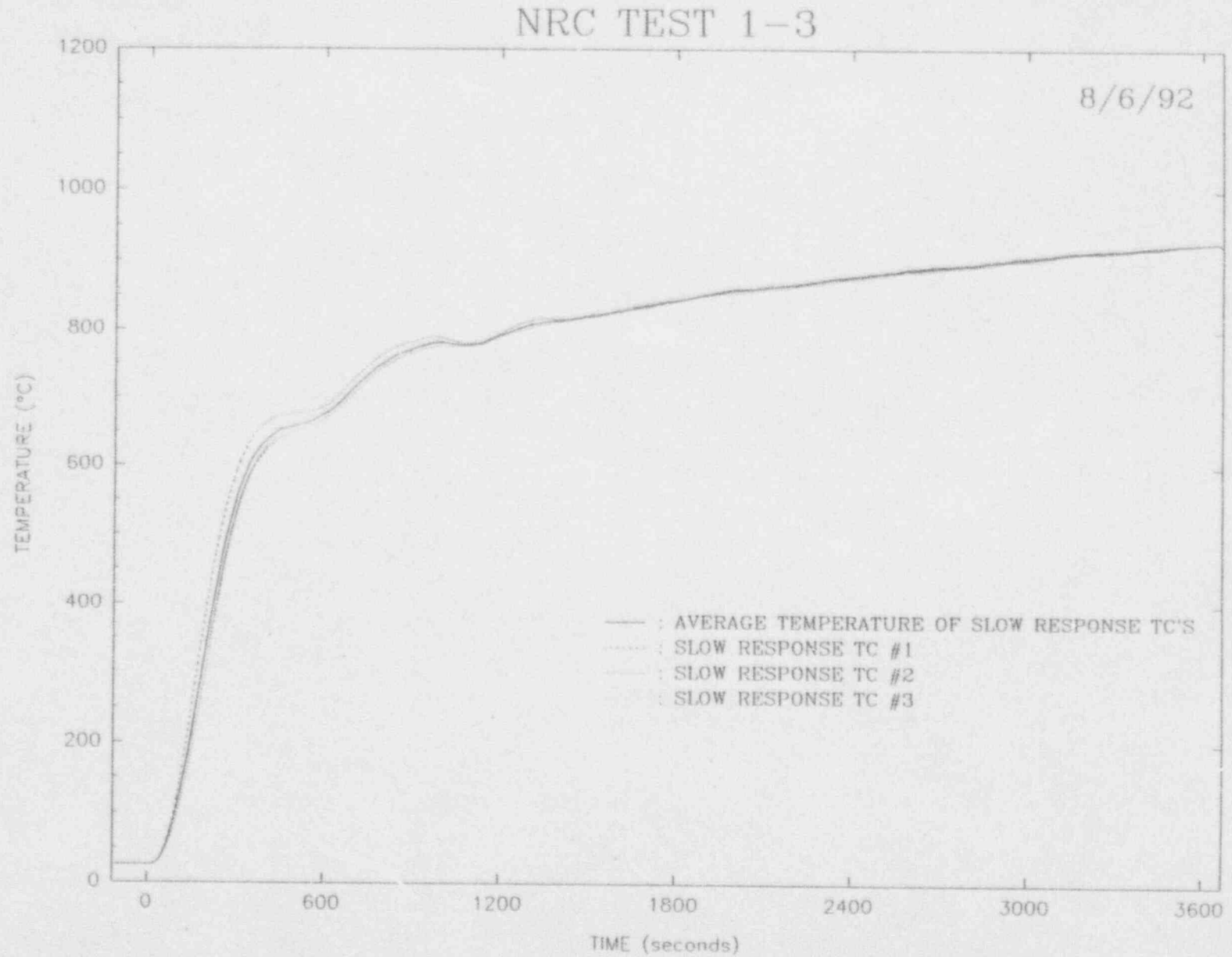

Fig. V.4. Furnace temperatures, test 1-3.

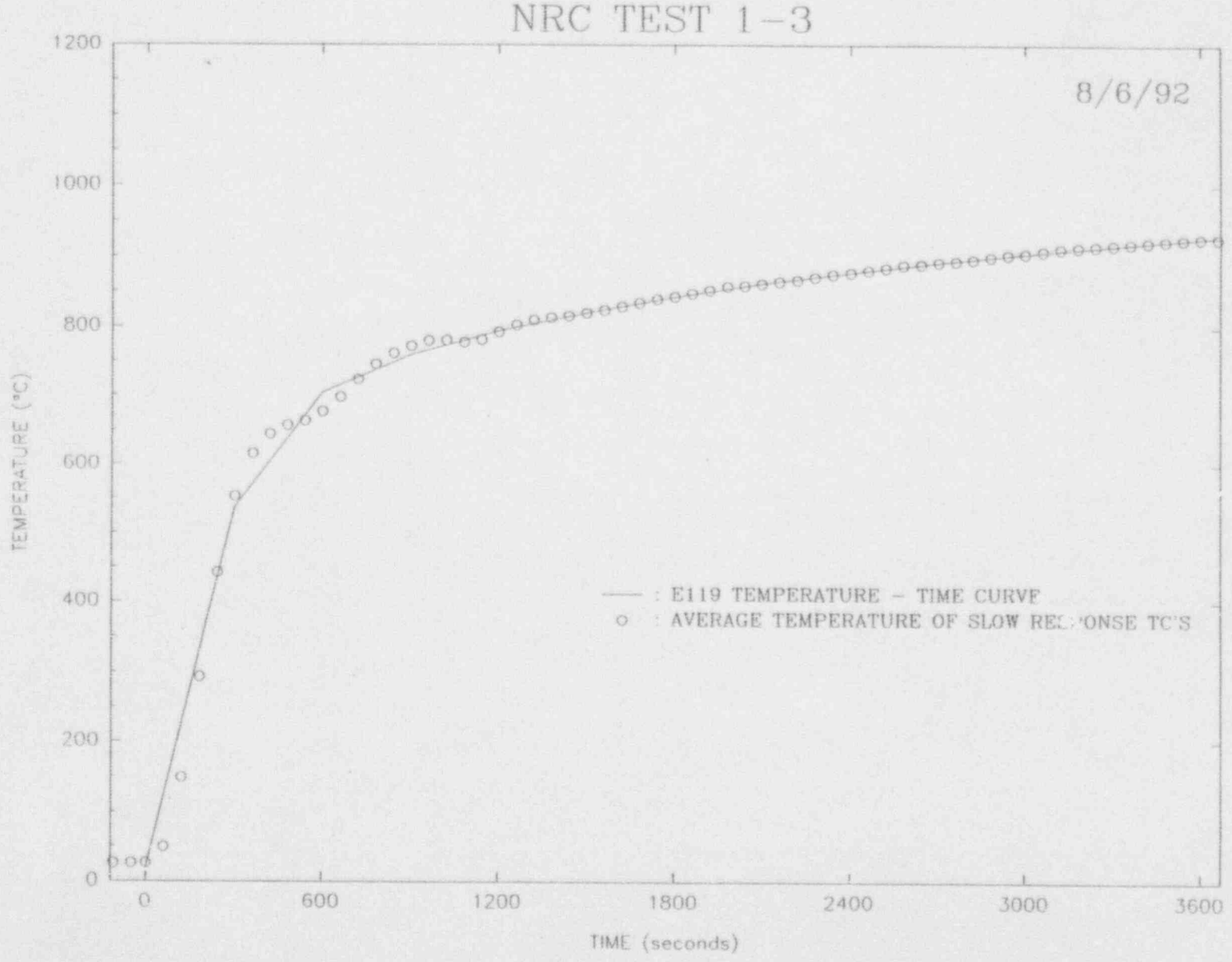

Fig. V.5. Furnace temperatures, test 1-3.

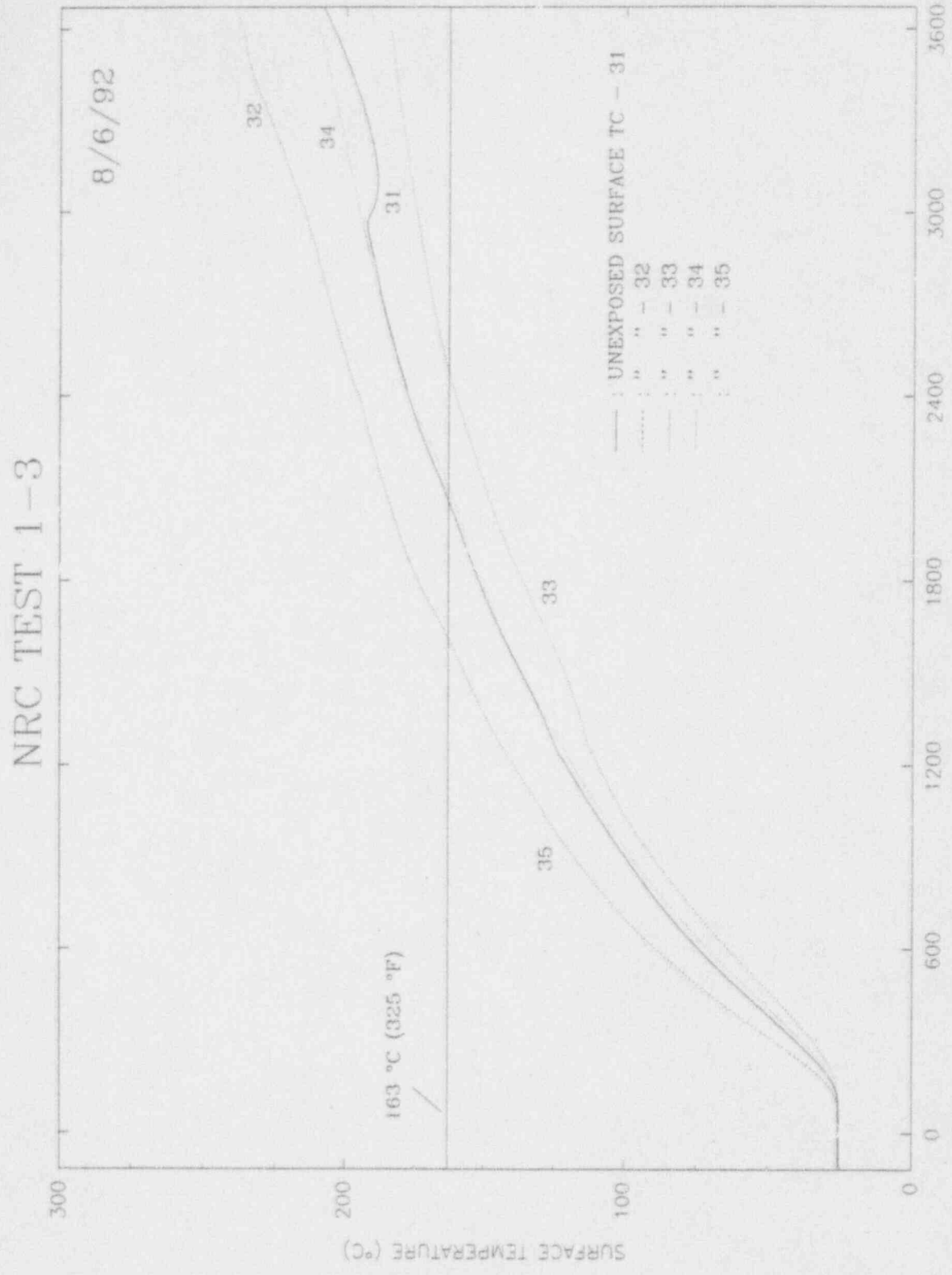

Fig. V.6. Unexposed-surface temperatures, test 1-3.

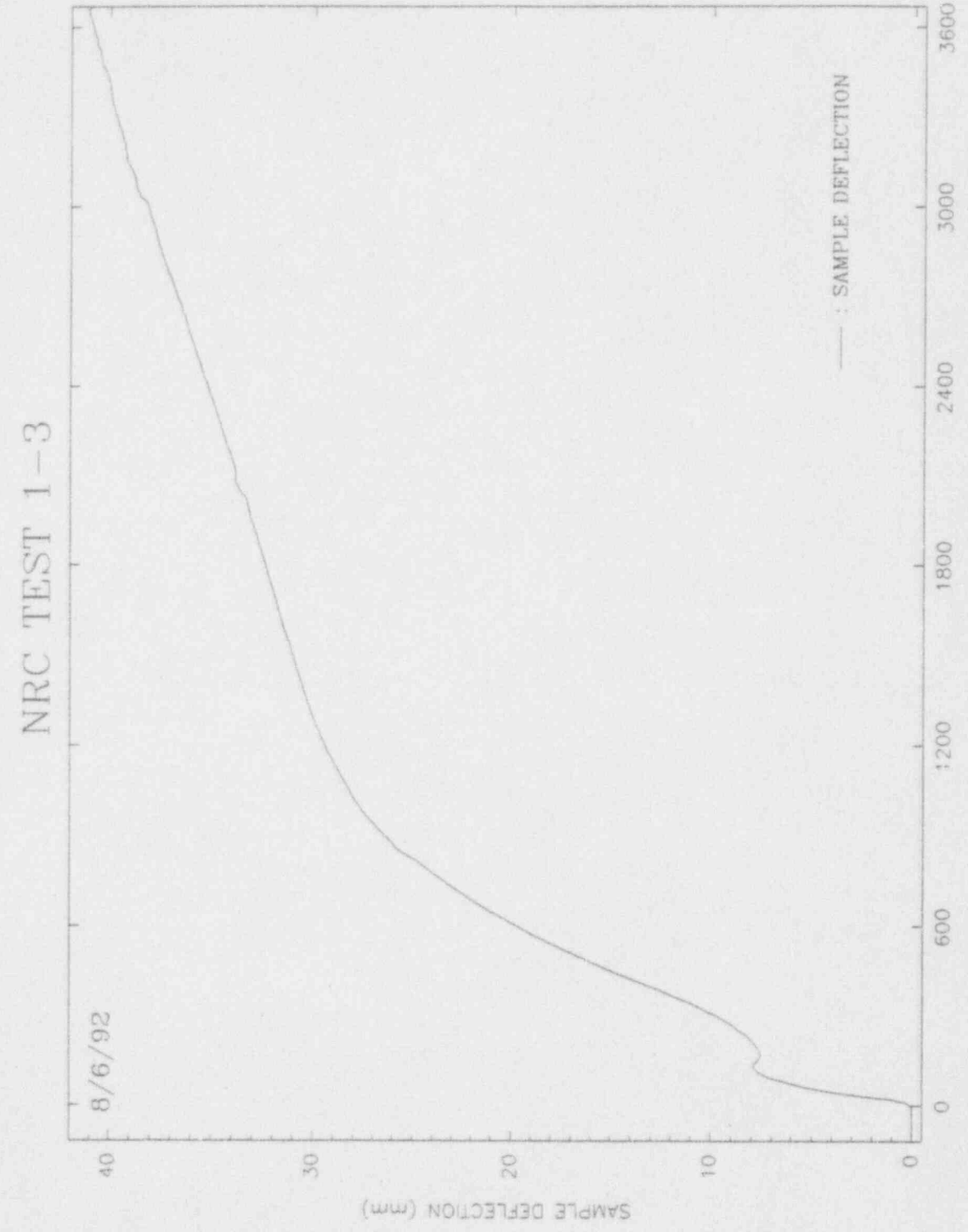

Fig. V.7. Deflection at center of specimen, test 1-3.

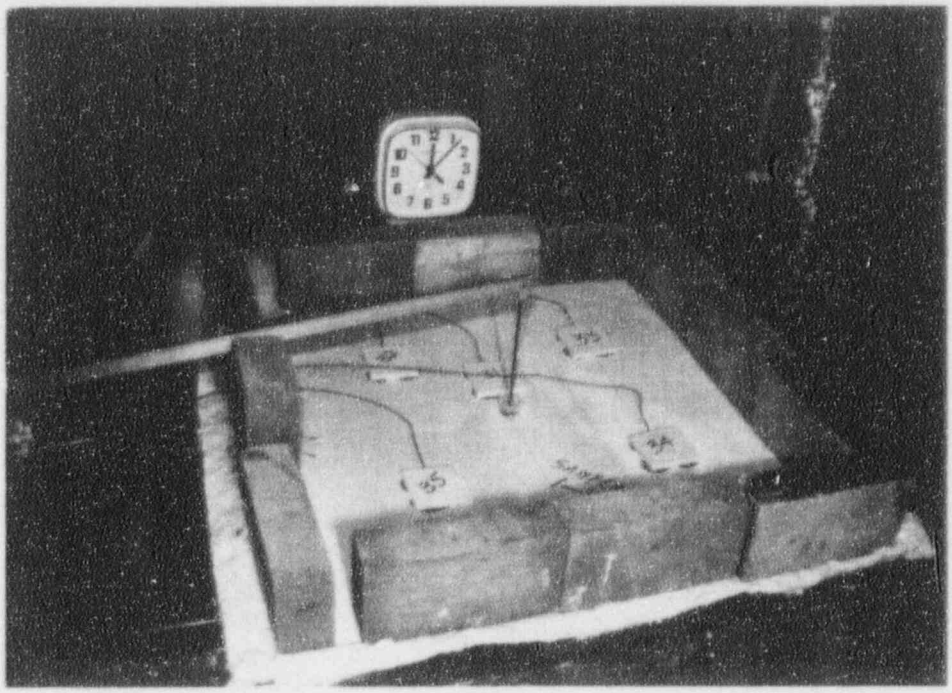

Fig. V.8. Photograph of unexposed surface during test.

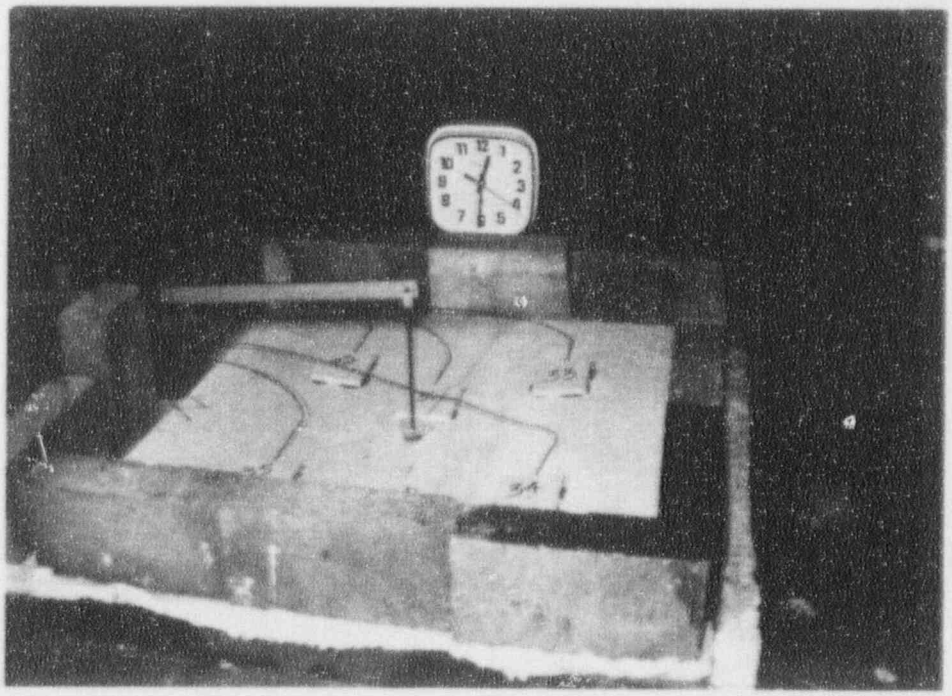

Fig. V.9. Photograph of unexposed surface during test.

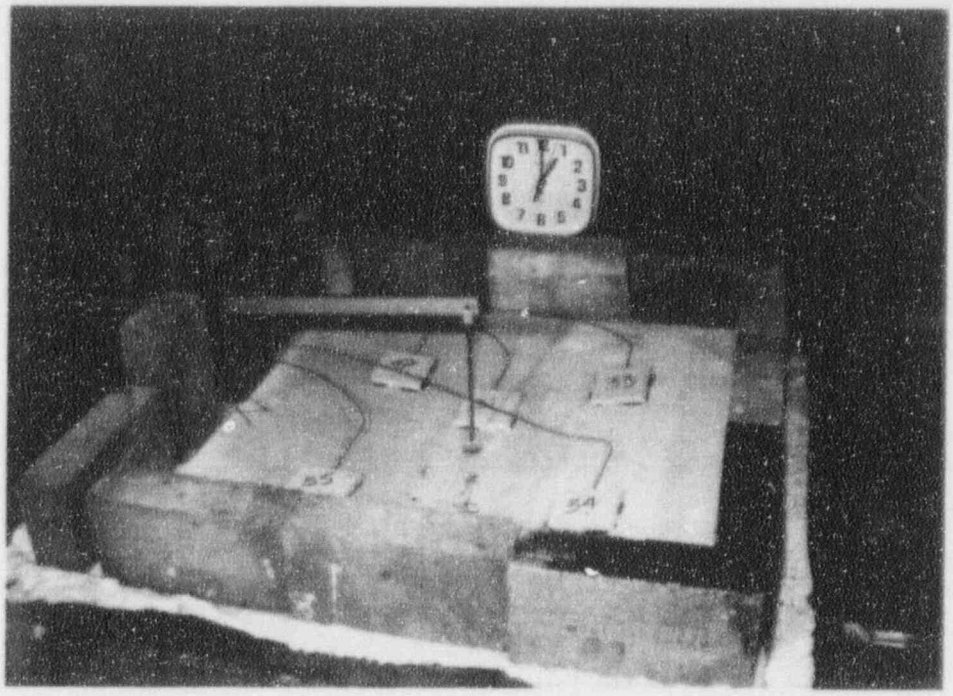

Fig. V.10. Photograph of unexposed surface during test.

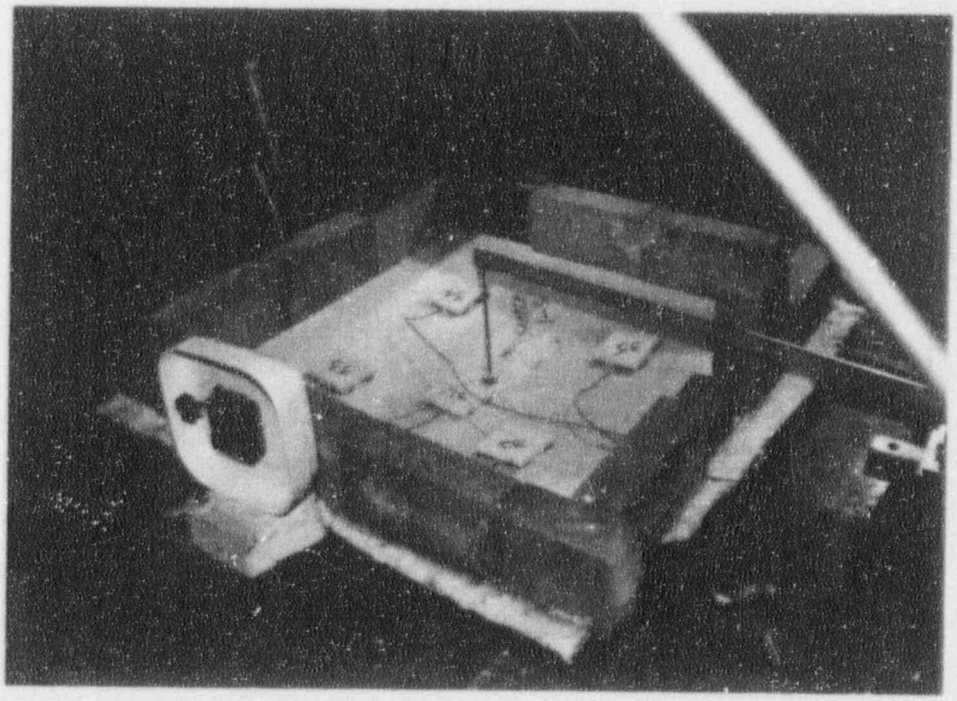

Fig. V.11. Photograph of unexposed surface during test.

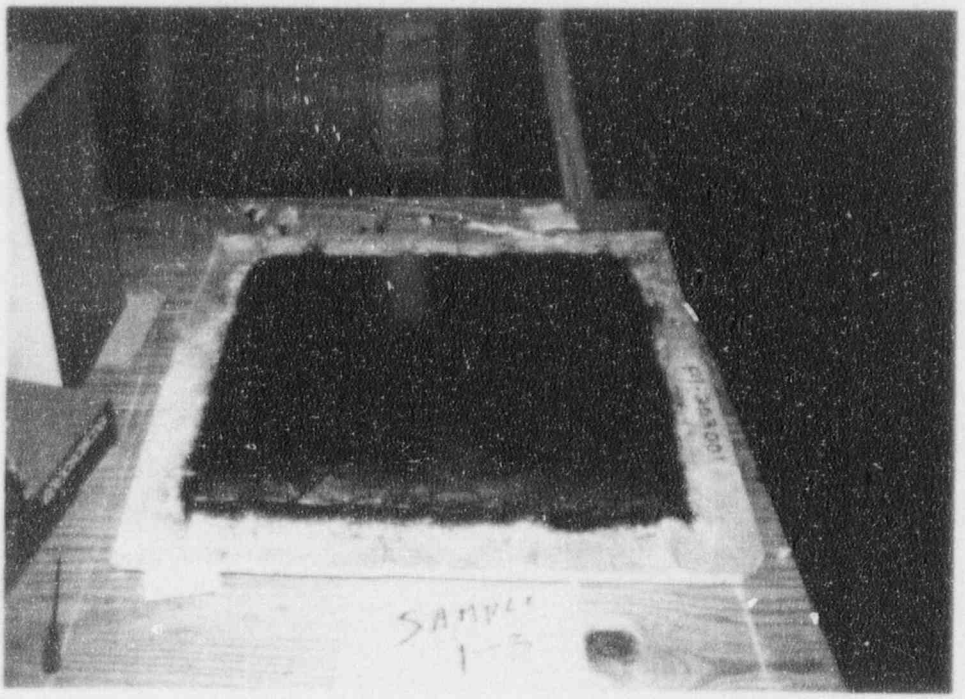

Fig. V.12. Post-test exposed surface, test 1-3.

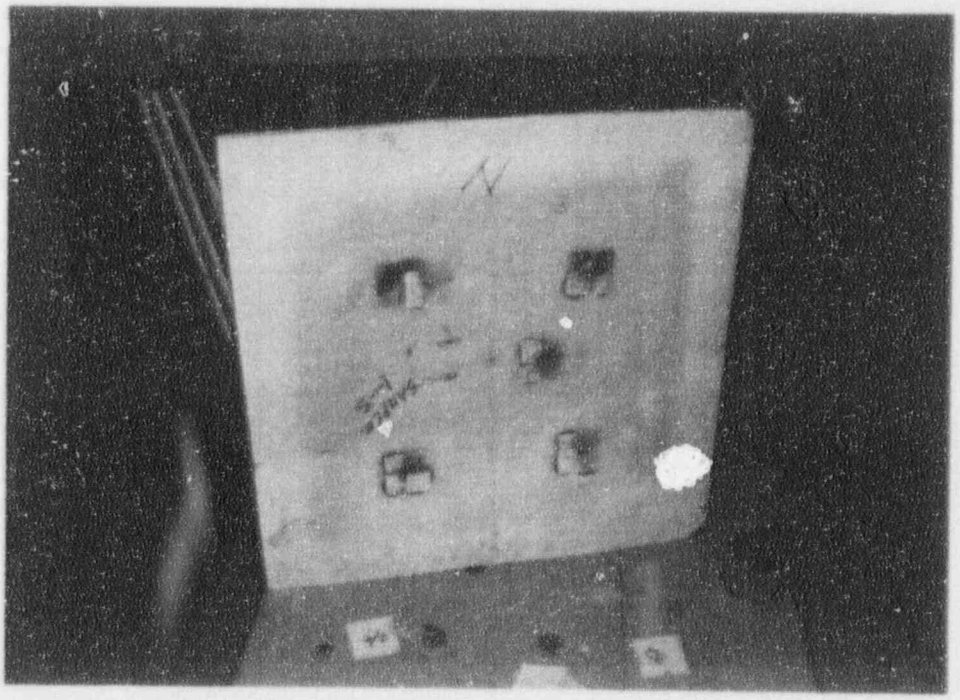

Fig. V.13. Post-test unexposed surface, test 1-3.

VI. Test 1-4/5

A. Description of Test Assembly

The test assembly consisted of two sheets of NRC-supplied 1-hour subliming fire-barrier panel. This panel is manufactured with a "flat" face, a ribbed face, and wire mesh covering only the ribbed face. The two sheets (specimens) were tested with their flat faces back-to-back. Consequently, both the exposed and unexposed surfaces of the assembly were ribbed faces with wire-mesh coverings. The mesh covered the entire area of the unexposed face but was removed from the perimeter of the exposed face.

The fire barrier specimens, designated sample 1-4 and sample 1-5, were cut to the dimensions shown in Fig. VI.1 and VI.2, respectively. Sample 1-4, which became the lower sheet in the assembly, was cut from a panel labeled by the manufacturer as F92-02037 and F080891. Sample 1-5, the upper sheet, was cut from a panel labeled F9-203001 and F080891. Edge views (Fig. VI.3 and VI.4) reveal that these samples had two distinct layers.

The wire mesh was removed from sample 1-4 in the region outside the dot-dash line in Fig. VI.1. This region lies above the sample-support lip of the furnace and is not directly exposed to the furnace. Included in Fig. VI.1 are off-rib thicknesses of the specimen along the perimeter and beneath the five surface-temperature-measurement points. **Note that all thickness measurements were made before the wire mesh was removed. Thicknesses in the perimeter region were not re-measured after the mesh was removed.** Measurements were made at an additional 5 off-rib locations marked as quality control measurement points by the manufacturer. These locations are not identified in Fig. VI.1. The thickness data can be summarized as follows:

	Sample 1-4: Off-Rib Thickness (mm [in])			
	avg.	std. dev.	max.	min.
perimeter & below pads	18 [0.71]	2.1 [0.083]	22 [0.87]	15 [0.59]
Mfrs. QC pts.	17 [0.65]	1.8 [0.071]	18 [0.71]	15 [0.59]

Thicknesses at ribs (prior to removal of wire mesh) varied from 25 to 28 mm (0.98 to 1.1 in). The pre-test mass of the sample 1-4 was 11.5 kg (25.3 lb) (11.8 kg [26.0 lb] before removal of wire mesh).

Figure VI.2 shows thicknesses measured at various off-rib locations on sample 1-5. Measurements were made at an additional 5 off-rib locations marked as quality control measurement points by the manufacturer but are not identified in the figure. These

measurements can be summarized as follows:

	Sample 1-5: Off-Rib Thickness (mm [in])			
	avg.	std. dev.	max.	min.
perimeter & below pads	18 [0.72]	2.4 [0.094]	25 [0.98]	15 [0.59]
Mfrs. QC pts.	17 [0.66]	2.0 [0.079]	20 [0.79]	15 [0.59]

Thicknesses at ribs (prior to removal of wire mesh) varied from 25 to 28 mm (0.98 to 1.1 in). The pre-test mass of sample 1-5 was 12.5 kg (27.5 lb).

Pre-test photographs of the faces of samples 1-4 and 1-5 are shown in Figs. VI.5 and VI.8.

The test assembly consisted of sample 1-5 atop sample 1-4 with their "flat" faces back-to back. No trowel-grade subliming material or adhesive was inserted at their interface. Since the adjoining faces were not truly flat, uneven interstitial air gaps were formed between them (Fig. VI.9). The larger of the gaps along the perimeter of the assembly were filled with a few millimeters of ceramic fiber insulation and then the edge perimeter wrapped with nominal 25.4 mm (1 in) thick ceramic fiber insulation.

The upper wire mesh (on the top ribbed face of sample 1-5) was constrained by the vertical load of the bricks which were placed along its perimeter. Since the mesh was removed from the lip region of the lower face of the assembly (the bottom ribbed face of sample 1-4), the remaining mesh covering the actual exposed area of the lower face was not constrained by the bricks or any other edge constraints.

B. Fire Test Procedures and Results

The test was conducted on August 7, 1992 and was witnessed by the following official observers: P. Madden (NRC), R. Paul (NRC), I. Moghissi (NRC), and A. Singh (NRC).

The specimen was subjected to a 3-hour fire exposure controlled by the ASTM E 119-88 standard temperature-time curve. Plots of the furnace temperatures recorded by the furnace thermocouples and their average values are presented in Fig. VI.10 and tabulated in Table VI.1. The sudden drop in temperature at 3240 seconds (0:54:00) (hr:min:s) probably was due to char falling from the exposed surface and exposing cooler virgin material and/or the char landing on and insulating the furnace thermocouples. The average furnace temperatures and the standard temperature-time curve are shown in Fig. VI.11.

Unexposed-surface thermocouples measured surface temperatures beneath insulation pads at 5 locations designated 31 to 35 in Fig. VI.2. The thermocouples at these locations are designated TC31 to TC35, respectively, and their outputs are plotted in Fig. VI.12 and tabulated in Table VI.1. Included in the table are the averages of the unexposed-surface temperatures as a function of time. Note that TC32 exceeded the furnace temperature near the end of the test and other unexposed-surface thermocouples cooled while the furnace temperature increased. Comments concerning these apparent anomalies are presented in section II.C.

The deflection at the center of the specimen was measured throughout the test and is plotted in Fig. VI.13 and tabulated in Table VI.1. Positive deflection indicates sag into the furnace. The maximum recorded deflection of 37.2 mm (1.46 in) occurred at 10,800 seconds (3:00:00), when shutdown was initiated.

Figures VI.14 to VI.19 show the appearance of the unexposed surface during the test. As stated above, it appears that some char fell from the exposed surface at 0:54:00. Outgassing began about 1:15:00 and a brown spot was observed east of thermocouple pad 32 at 1:37:30. A dark brown spot formed west of pad 31 at about 1:45:00. The northeast corner of pad 34 burned through at 2:14:15[12]. The burnthrough area steadily increased to about 50 percent of the exposed area at 3:00:00, when the furnace was shutdown. No flame passage was observed -- presumably a consequence of having maintained the furnace at negative pressure. A log of observations and temperatures measured with the movable thermocouple are presented in Table VI.2.

The exposed and unexposed surfaces after the test are shown in Figs. VI.20 and VI.21, respectively. The central 50 percent of the exposed area of the assembly burned through completely. The remaining 50 percent of the exposed area on the exposed surface was covered with a char layer that was generally from 70 to 90 mm (2.8 to 3.5 in) thick. The remaining 50 percent of the exposed area of the unexposed surface retained about 6 mm (0.2 in) of soft barrier material.

The post-test mass of the assembly was 12.6 kg (27.8 lb). Light blue-gray glassy residue, similar to that found after Test 3-2, was found at the bottom of the furnace.

C. Analysis of Test Results

The ASTM E 119-88 thermal transmission acceptance criteria are that the average temperature rise of the unexposed-surface

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[12]Maximum temperatures are expected to occur beneath pads (see section I.C).

thermocouples shall not exceed 139°C (250°F) above its initial temperature (in this test, 26°C [79°F]) and the temperature rise of any of these thermocouples shall not exceed 181°C (325°F) above the initial temperature. Another criterion is that at no time during the test should hot gases or flame pass through the assembly so as to ignite cotton waste held against the unexposed surface. In addition to these criteria, NRC requirements include monitoring the time at which any of the unexposed-surface thermocouples reaches 162.8°C (325°F).

On the basis of the experimental temperature data presented in Table VI.1, the above temperature criteria were met at the following locations and times:

Criterion	Location	Time (sec)	Time [hr:min:sec]
E 119 avg. unexposed surf. temp. (165°C) [329°F]		5160	[1:26:00]
E 119 peak unexposed surf. temp. (207°C) [405°F]	TC 31	5554	[1:32:34]
NRC unexposed surf. temp., 1st occurrence (162.8°C) [325°F]	TC 32	4916	[1:21:56]

Concerning E 119 criteria, the average temperature was the controlling factor and the E 119 fire-endurance period was 5160 seconds (1:26:00). Since the period is greater than 1/2 hour, a correction was required to account for deviations of the actual average furnace temperature from the standard temperature-time curve (see ASTM E 119-88, Par. 7.4). This correction was -10 s and **the corrected fire-endurance period was 5150 s (1 hr and 25.8 minutes).**

The wire mesh (unconstrained at its perimeter) and char on the exposed face fell away during the test. Although about 50 percent of the unexposed face of the assembly burned through during the test, the E 119 cotton-waste test was not conducted. Flame passage through the unexposed surface was not observed during the test -- presumably a consequence of having maintained the furnace at negative pressure.

TABLE VI.1. Temperatures, test 1-4/5.

NRC TEST 1-4/5

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
-110	25	25	25	25	26	25	26	26	26	26	-0.0
-100	25	25	25	25	26	25	26	26	26	26	-0.0
-90	25	25	25	25	26	25	26	26	26	26	-0.0
-80	25	25	25	25	26	25	25	26	26	26	-0.0
-70	25	25	25	25	26	25	25	26	26	26	-0.0
-60	25	25	25	25	26	25	26	26	26	26	-0.0
-50	25	25	25	25	26	25	26	26	26	26	0.0
-40	25	25	25	25	26	25	25	26	26	26	0.0
-30	25	25	25	25	26	25	25	26	26	26	0.0
-20	25	25	25	25	26	25	25	26	26	26	0.0
-10	25	25	25	25	26	25	25	26	26	26	0.0
-1	25	25	25	25	26	25	25	26	26	26	0.0
0	25	25	25	25	26	25	25	26	26	26	0.1
10	25	25	25	25	26	25	25	26	26	26	0.2
20	26	26	26	25	26	25	25	26	26	26	0.6
30	28	29	29	28	26	25	25	26	26	26	1.1
40	35	33	34	33	26	25	25	26	26	26	1.4
50	45	40	42	42	26	25	25	26	26	26	1.6
60	60	49	54	54	26	25	25	26	26	26	1.8
70	79	60	68	68	26	25	26	26	26	26	1.9
80	102	73	84	86	26	25	26	26	26	26	1.9
90	126	88	102	105	26	25	26	26	26	26	1.9
100	153	107	122	127	26	25	25	26	26	26	2.0
110	182	127	144	150	26	25	26	26	26	26	2.0
120	211	148	166	175	26	25	26	26	26	26	2.0
130	242	170	190	200	26	25	26	26	26	26	2.0
140	272	194	214	226	26	25	26	26	26	26	2.0
150	302	219	239	253	26	25	26	26	26	26	2.0
160	332	244	265	280	26	25	26	26	26	26	2.1
170	361	270	291	307	26	25	25	26	26	26	2.1
180	389	296	317	334	26	25	25	26	26	26	2.1
190	415	322	343	360	26	25	26	26	26	26	2.1
200	440	350	369	386	26	25	25	26	26	26	2.2
210	463	376	394	410	26	25	26	26	26	26	2.2
220	484	399	418	433	26	25	25	26	26	26	2.2
230	504	419	439	454	26	25	26	26	26	26	2.2
240	522	437	459	472	26	25	26	26	26	26	2.2
250	539	453	476	489	26	25	26	26	26	26	2.3
260	554	468	493	505	26	25	26	26	26	26	2.3
270	568	482	507	518	26	25	26	26	26	26	2.3
280	581	494	521	532	26	25	26	26	26	26	2.3
290	592	506	534	543	26	25	26	26	26	26	2.3
300	602	517	545	554	26	25	26	26	26	26	2.3

TABLE VI.1. Temperatures, test 1-4/5 (cont.).

NRC TEST 1-4/5

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
360	648	571	599	605	26	25	26	27	26	26	2.4
420	670	605	632	636	26	26	26	27	26	26	2.5
480	687	632	659	659	26	26	26	27	26	26	2.6
540	692	650	673	671	27	26	27	27	26	27	2.7
600	699	665	687	684	27	27	28	28	26	27	2.8
660	725	685	709	706	27	27	28	28	27	28	2.9
720	757	712	731	733	28	28	29	29	27	28	3.0
780	778	734	750	753	29	29	30	29	28	29	3.2
840	790	750	766	768	30	30	31	30	28	30	3.3
900	792	759	773	774	30	31	33	31	29	31	3.4
960	794	766	778	779	31	32	34	32	29	32	3.5
1020	794	776	783	784	32	33	35	33	30	33	3.7
1080	796	785	788	789	34	34	37	34	31	34	3.8
1140	801	795	794	797	35	35	38	35	32	35	3.9
1200	809	805	802	805	36	36	40	36	33	36	4.1
1260	814	817	807	813	37	38	41	37	34	37	4.2
1320	817	820	810	816	39	39	43	38	35	39	4.3
1380	819	821	811	817	40	41	44	40	36	40	4.4
1440	821	821	813	818	42	42	46	41	37	42	4.6
1500	823	824	815	820	43	43	48	42	38	43	4.7
1560	828	829	821	826	45	45	49	44	39	44	4.8
1620	835	836	827	832	46	46	51	45	41	46	4.9
1680	840	842	833	838	48	48	53	46	42	47	5.0
1740	846	848	838	844	49	49	54	48	43	49	5.2
1800	848	850	842	846	51	51	56	50	45	50	5.3
1860	847	849	841	845	52	52	58	51	46	52	5.5
1920	851	853	845	849	54	54	60	53	47	53	5.6
1980	859	859	853	857	55	55	61	54	49	55	5.8
2040	864	863	859	862	57	57	63	56	50	56	5.9
2100	867	868	862	865	58	58	65	57	51	58	6.1
2160	871	872	866	869	59	60	67	58	53	59	6.3
2220	876	875	869	873	61	61	68	60	54	61	6.4
2280	876	873	869	872	62	63	70	61	55	62	6.6
2340	875	873	868	872	63	64	71	63	57	64	6.8
2400	880	876	873	876	65	66	73	64	58	65	7.0
2460	883	881	877	880	66	67	75	65	59	67	7.2
2520	889	885	882	885	68	68	76	67	60	68	7.4
2580	893	891	887	890	69	70	78	68	62	69	7.6
2640	896	891	891	892	70	71	79	70	63	71	7.8
2700	890	881	888	886	72	73	81	71	64	72	8.0
2760	892	882	891	888	73	74	82	72	65	73	8.2
2820	896	885	894	891	74	75	83	74	66	75	8.3

TABLE VI.1. Temperatures, test 1-4/5 (cont.).

NRC TEST 1-4/5

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
2880	900	888	898	895	75	76	85	75	67	76	8.5
2940	905	890	902	899	77	77	86	76	69	77	8.7
3000	910	887	906	901	78	78	87	78	70	78	8.9
3060	915	886	911	903	79	79	89	79	71	79	9.0
3120	920	886	916	907	80	80	90	80	72	80	9.2
3180	924	883	919	908	81	81	91	81	73	81	9.7
3240	902	783	895	860	82	82	92	82	74	82	10.0
3300	897	755	887	845	84	83	93	83	75	84	10.2
3360	908	764	900	856	86	85	95	84	76	85	10.5
3420	931	790	925	881	89	87	96	85	77	87	10.7
3480	950	810	943	901	92	89	97	87	79	89	11.0
3540	965	832	954	917	95	92	97	89	81	91	11.4
3600	976	851	963	929	99	95	99	91	83	93	11.8
3660	972	855	958	928	103	98	100	94	85	96	12.2
3720	966	850	952	922	106	101	102	96	87	99	12.4
3780	971	870	959	933	110	104	104	99	89	101	12.8
3840	972	884	961	938	113	108	106	102	92	104	13.2
3900	973	895	962	943	114	111	109	105	94	106	12.6
3960	973	899	962	944	111	111	111	108	97	107	13.6
4020	971	905	959	945	110	112	113	111	99	109	13.9
4080	972	915	959	948	111	112	115	114	102	111	14.3
4140	972	915	959	948	113	114	117	114	105	113	14.7
4200	974	917	961	950	115	117	119	115	107	115	14.9
4260	976	920	964	953	118	121	122	117	110	117	14.8
4320	977	923	964	954	121	125	125	120	113	121	15.4
4380	976	932	966	957	125	129	127	123	116	124	15.6
4440	975	937	967	959	129	134	131	126	118	128	15.9
4500	972	942	967	960	133	138	134	130	121	131	16.2
4560	970	947	967	961	137	143	137	133	124	135	16.5
4620	969	948	968	961	141	147	140	137	128	139	16.5
4680	970	950	969	963	145	151	143	140	132	142	16.9
4740	971	952	970	964	149	154	146	144	135	145	17.4
4800	971	951	969	963	152	157	149	147	139	149	17.5
4860	971	950	969	963	154	160	151	150	143	152	17.7
4920	972	951	970	964	157	163	154	153	146	154	17.8
4980	973	954	971	965	159	165	157	155	150	[illegible]	18.0
5040	974	956	972	967	162	168	159	158	153	160	18.2
5100	976	957	974	968	165	170	162	160	155	162	18.4
5160	977	959	975	970	167	172	164	162	159	165	18.5
5220	978	961	976	972	170	174	167	164	162	167	19.0
5280	980	964	977	973	173	176	169	166	165	170	19.2
5340	981	966	979	974	177	178	171	168	168	172	19.1

TABLE VI.1. Temperatures, test 1-4/5 (cont.).

NRC TEST 1-4/5

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
5400	982	967	980	976	183	180	173	170	170	175	19.2
5460	983	969	981	977	190	182	174	171	173	178	19.3
5520	984	971	982	978	199	186	176	173	176	182	19.3
5580	985	972	982	979	213	189	177	174	178	186	19.5
5640	986	974	983	980	230	193	179	175	180	191	19.6
5700	987	975	984	982	246	201	180	177	182	197	19.8
5760	988	979	986	983	260	201	181	178	183	201	20.0
5820	989	980	987	984	271	204	182	180	185	204	20.1
5880	990	982	988	986	284	207	183	181	187	208	20.4
5940	991	984	990	988	296	211	184	183	188	212	20.4
6000	992	987	992	990	308	215	185	184	190	216	21.0
6060	994	989	993	991	320	218	185	186	191	220	20.7
6120	995	990	994	993	332	222	186	187	192	224	20.8
6180	996	991	995	994	343	226	187	189	194	228	20.9
6240	997	993	996	995	353	231	188	191	195	232	21.0
6300	998	994	997	996	363	235	189	192	196	235	21.1
6360	999	995	998	997	371	240	190	194	197	238	21.2
6420	1000	997	999	998	379	244	191	196	198	242	21.3
6480	1001	998	1000	999	386	248	191	199	200	245	21.5
6540	1001	997	1001	999	392	252	193	201	201	248	21.8
6600	1001	1000	1001	1000	401	256	193	204	202	251	22.2
6660	1002	1002	1003	1002	412	262	194	207	203	256	22.2
6720	1003	1004	1004	1003	426	265	196	210	205	260	22.3
6780	1004	1005	1006	1005	439	270	197	214	206	265	22.3
6840	1006	1006	1007	1006	452	274	198	219	207	270	22.5
6900	1007	1007	1008	1007	463	278	199	224	208	274	22.6
6960	1009	1009	1009	1008	475	283	199	229	210	279	22.7
7020	1010	1010	1009	1009	486	287	200	234	211	284	23.6
7080	1011	1011	1010	1010	500	291	201	239	212	289	23.4
7140	1013	1012	1010	1011	513	291	202	245	213	293	23.5
7200	1014	1012	1011	1012	543	292	203	251	214	301	23.7
7260	1016	1012	1011	1013	567	294	204	255	216	307	23.9
7320	1017	1012	1011	1013	609	295	205	259	217	317	24.1
7380	1017	1013	1011	1013	604	298	206	265	218	318	24.4
7440	1018	1013	1011	1014	566	302	207	270	219	313	24.6
7500	1019	1014	1012	1014	527	307	208	274	220	307	24.8
7560	1020	1015	1012	1015	524	315	209	280	221	310	25.0
7620	1020	1016	1012	1016	527	322	210	286	222	313	25.0
7680	1021	1016	1013	1016	530	330	211	289	223	317	25.2
7740	1022	1017	1013	1017	539	337	213	283	224	319	25.4
7800	1023	1018	1014	1018	554	347	214	271	225	322	25.6
7860	1023	1019	1014	1019	572	358	215	266	226	327	25.7

TABLE VI.1. Temperatures, test 1-4/5 (cont.).

NRC TEST 1-4/5

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
7920	1024	1020	1015	1019	584	367	217	268	227	333	25.9
7980	1024	1019	1015	1019	608	380	218	278	228	343	25.9
8040	1024	1018	1016	1019	642	395	220	296	230	357	26.0
8100	1024	1018	1016	1019	657	417	222	626	231	431	26.1
8160	1025	1021	1018	1021	646	479	224	846	233	486	26.2
8220	1030	1027	1024	1026	613	505	227	777	235	471	26.4
8280	1032	1029	1034	1032	578	496	229	783	238	465	26.4
8340	1032	1028	1036	1032	539	491	232	797	240	460	26.7
8400	1031	1026	1039	1032	555	486	235	805	242	464	26.9
8460	1031	1024	1037	1030	591	483	238	803	243	471	27.2
8520	1029	1023	1030	1027	611	480	241	783	246	472	27.5
8580	1028	1023	1026	1025	596	479	244	786	248	471	27.6
8640	1028	1023	1024	1024	577	479	248	792	250	469	27.8
8700	1028	1023	1022	1024	583	479	251	801	252	473	28.0
8760	1029	1024	1021	1024	567	481	254	812	255	474	28.2
8820	1030	1025	1021	1025	562	484	260	833	257	479	28.3
8880	1032	1026	1020	1025	544	486	267	845	260	480	28.6
8940	1033	1028	1019	1026	528	489	270	859	262	482	28.8
9000	1034	1029	1019	1027	502	493	279	869	265	482	29.0
9060	1036	1030	1018	1028	495	499	285	897	269	489	29.2
9120	1037	1031	1019	1029	481	506	288	886	273	487	29.5
9180	1038	1032	1017	1028	485	515	302	883	277	492	29.6
9240	1040	1032	1017	1029	492	523	327	895	280	504	29.8
9300	1042	1034	1019	1031	516	532	346	908	284	517	29.9
9360	1043	1035	1021	1032	530	542	358	905	287	525	30.0
9420	1043	1035	1019	1032	532	553	367	898	291	528	30.1
9480	1044	1038	1021	1034	541	564	374	898	295	534	30.3
9540	1047	1039	1022	1036	559	576	378	896	299	542	30.4
9600	1048	1040	1021	1036	547	589	383	896	303	544	30.5
9660	1048	1040	1022	1036	557	603	390	894	307	550	30.7
9720	1048	1040	1022	1037	578	615	399	896	311	560	30.9
9780	1049	1042	1023	1038	581	628	410	903	314	567	31.2
9840	1051	1044	1024	1039	583	640	423	907	318	574	31.4
9900	1052	1045	1025	1040	607	653	433	914	321	586	31.7
9960	1055	1049	1033	1045	621	669	442	922	323	596	32.0
10020	1057	1050	1034	1046	610	686	456	923	326	600	32.1
10080	1057	1050	1034	1046	619	711	483	925	329	613	32.4
10140	1057	1049	1032	1045	605	790	506	920	331	631	32.6
10200	1056	1048	1032	1045	620	835	529	919	333	647	33.0
10260	1055	1047	1034	1045	621	935	551	921	334	672	33.5
10320	1055	1048	1034	1045	644	784	570	927	335	652	33.8
10380	1056	1049	1036	1046	645	779	585	931	336	655	34.1

TABLE VI.1. Temperatures, test 1-4/5 (cont.).

NRC TEST 1-4/5

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
10440	1055	1048	1033	1045	652	769	599	928	337	657	34.3
10500	1055	1048	1032	1044	673	780	607	929	338	666	34.7
10560	1056	1050	1034	1047	697	839	615	939	339	686	35.5
10620	1061	1055	1039	1051	704	850	623	946	340	693	36.1
10680	1060	1053	1038	1050	688	843	630	941	341	688	36.4
10740	1058	1052	1036	1048	718	847	634	942	342	697	37.0
10800	1060	1054	1039	1051	667	840	636	947	343	687	37.2

TABLE VI.2 Observations, test 1-4/5.

The following observations were made during the test:

(Note: MTC indicates surface temperature measured with movable thermocouple)

Time	
0:08:00	No obvious changes to unexposed surface.
0:45:00	Still no change.
0:54:00	Furnace TC SR2 suddenly cooling. Natural gas flow increased.
0:55:50	Furnace pressure neutral to positive. Smoke emerging from center of E. edge.
1:00:00	Furnace negative again.
1:01:30	Stain on E. side in front of clock is smoke stain, not degradation.
1:07:00	No browning so far.
1:15:00	Outgassing beginning.
1:19:	124°C (255°F) (MTC) between pads 34 and 35.
1:28:	128°C (262°F) (MTC) between pads 32 and 35.
1:29:30	Crystals visible at S.W. corner of 32 and in white area W. of 33.
1:30:30	No obvious browning so far. Slight deflection at center of assembly.
1:37:30	Brown spot forming E. of 32. under TC wire.
1:38:	159°C (318°F) (MTC) between 34 and 35.
1:40:	150°C (302°F) (MTC) between 32 and 35. Brown area N. of 32 is growing.
1:45:	Browning around 31. Dark brown spot developing W. of 31.
1:50:15	157°C (315°F) (MTC) between 32 and 35.
1:54:30	Turned off spotlight -- no glowing seen. New brown spot developing between 32 and 33.
1:57:	164°C (327°F) (MTC) and rising between 32 and 35.
2:05:30	Still no glowing.
2:14:15	Burning through at N.E. corner of 34.
2:17:15	Glowing through pin holes in black spot between 34 and 35.
2:37:45	The density of pin holes in the area between 32 and 33 has increased. Can see flame wafting below this area.
3:00:00	Shutdown.
3:21:	Lifted and propped W. edge of sample.

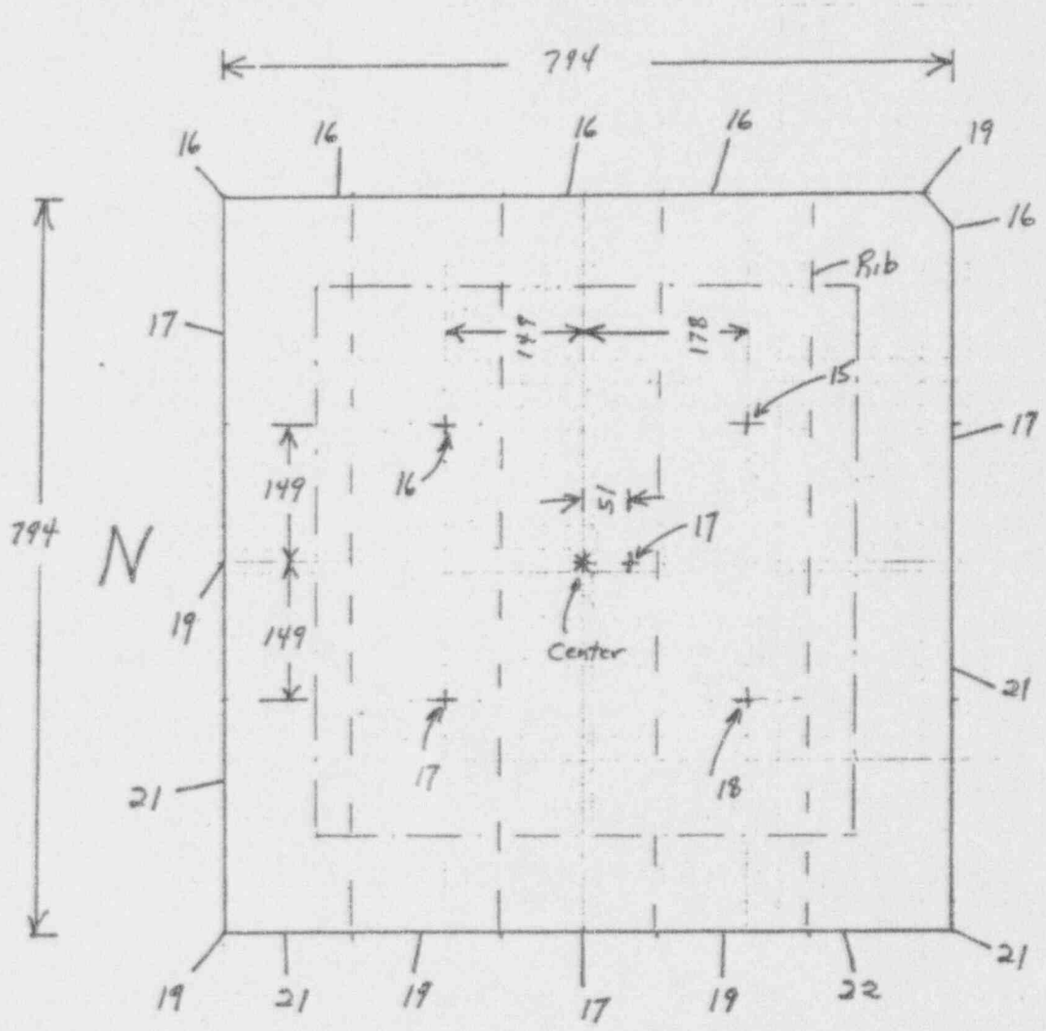

Fig. VI.1. Dimensions, sample 1-4. All dimensions in millimeters. Numbered squares denote unexposed-surface thermocouple pads. Other numbers not between arrows indicate thickness.

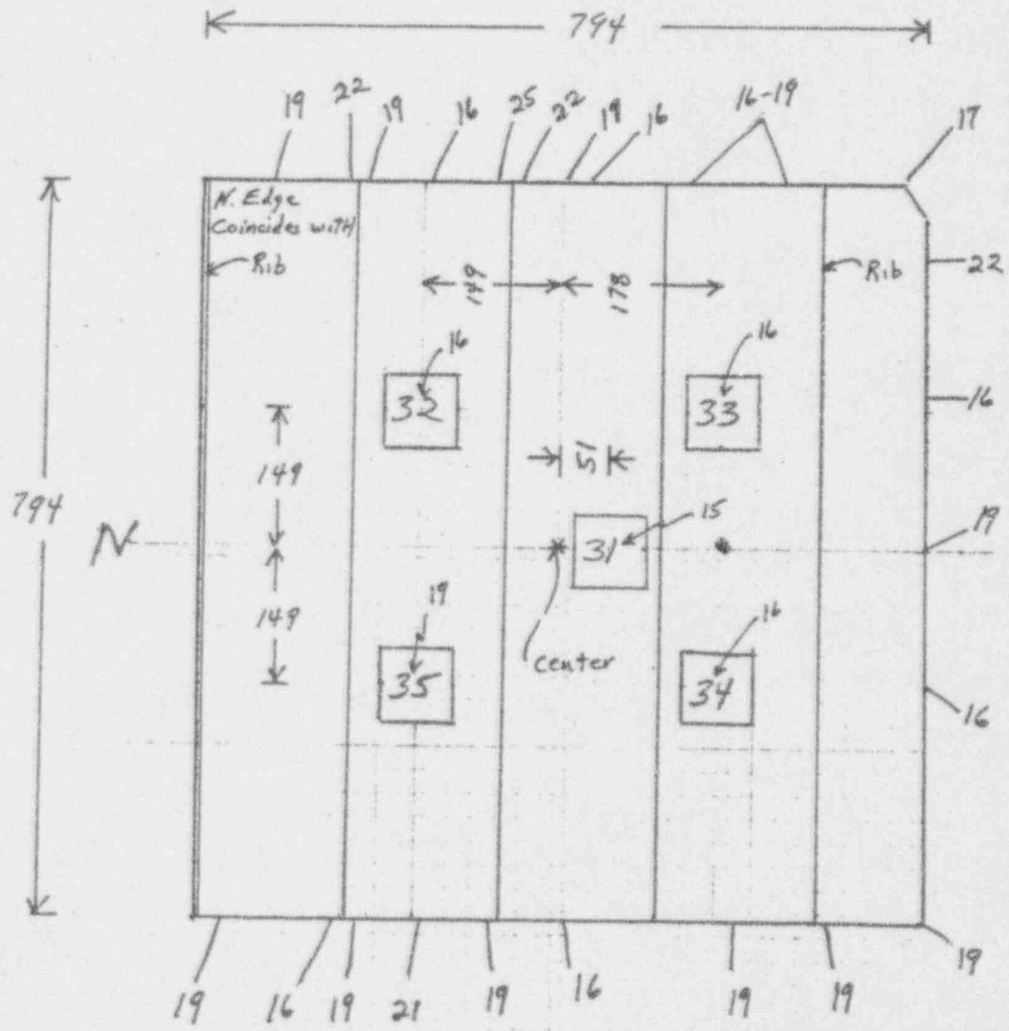

Fig. VI.2. Dimensions, sample 1-5. All dimensions in millimeters.

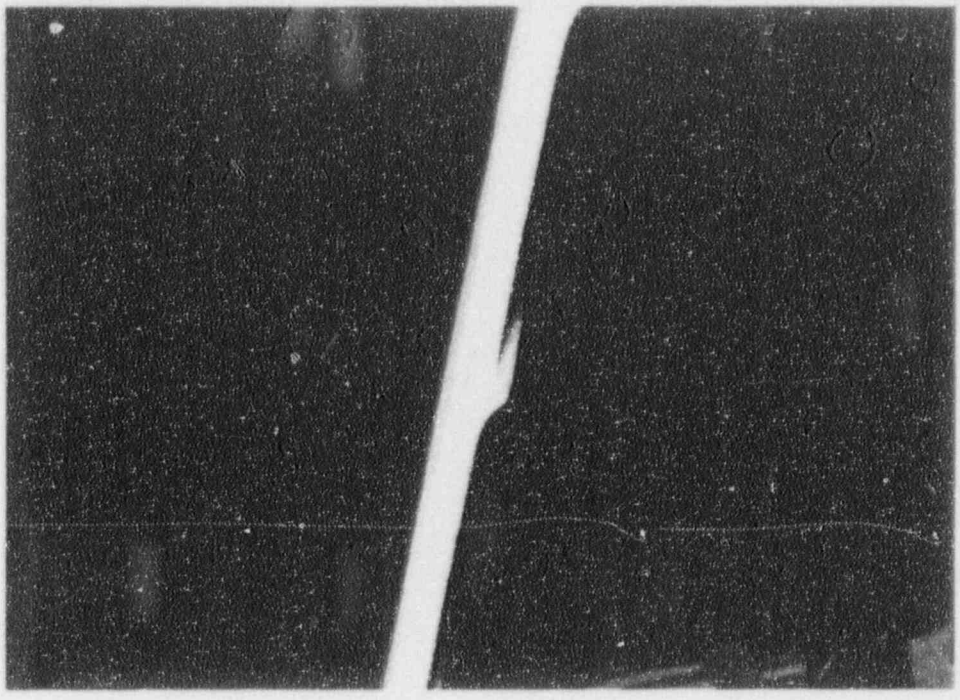

Fig. VI.3. Edge view of sample 1-4.

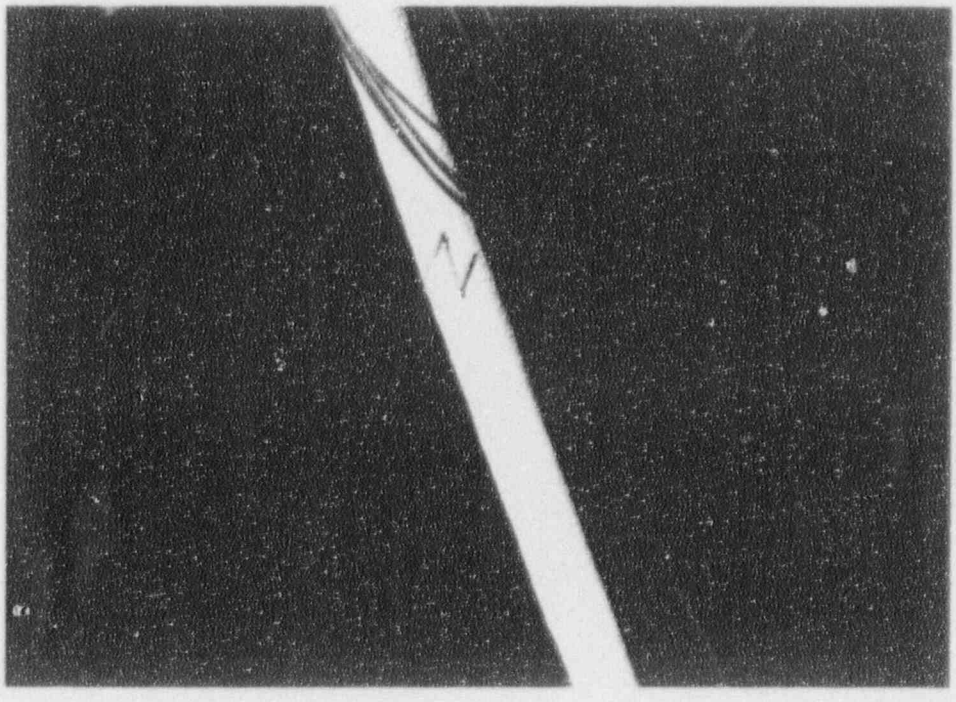

Fig. VI.4. Edge view of sample 1-5.

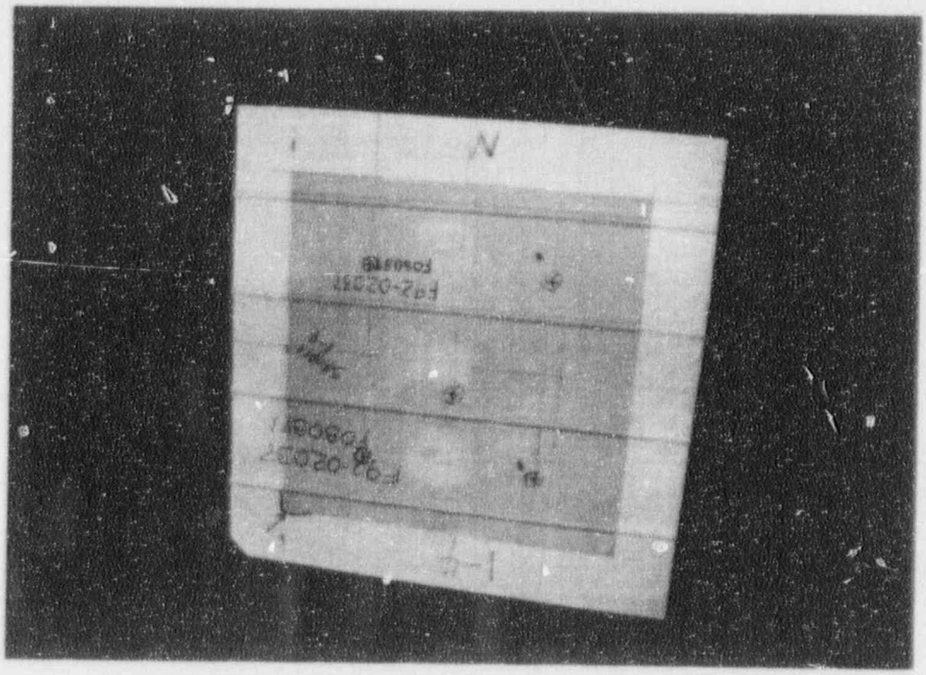

Fig. VI.5. Pre-test exposed surface, sample 1-4.

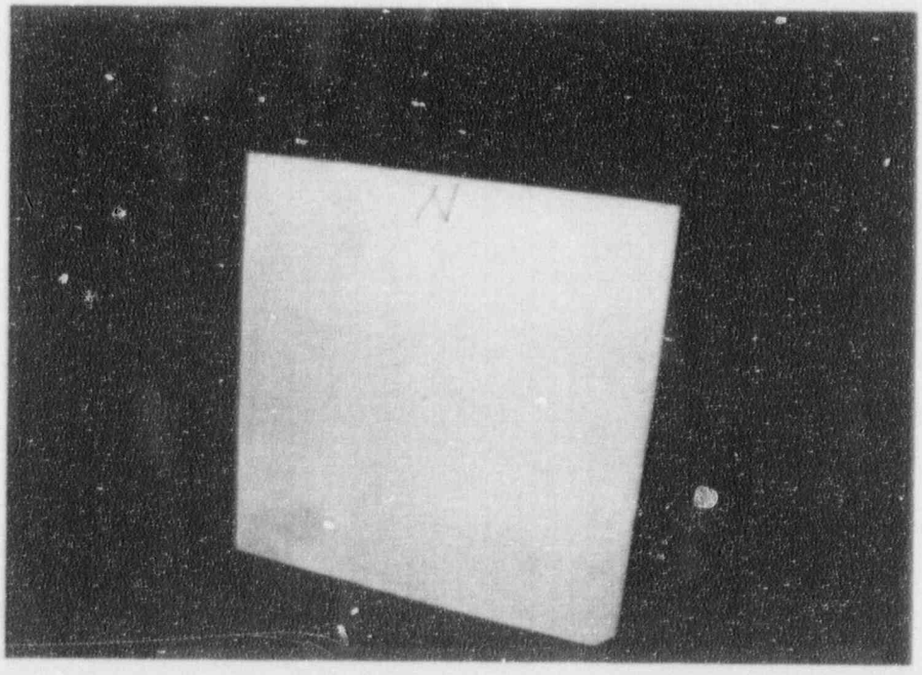

Fig. VI.6. Pre-test upper face of sample 1-4.

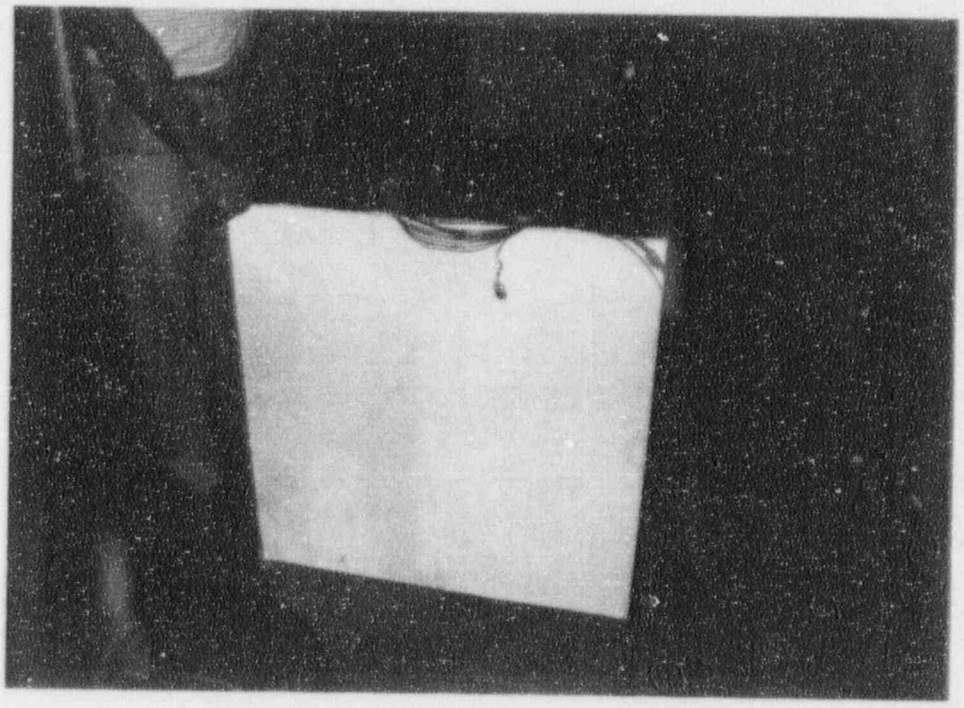

Fig. VI.7. Pre-test lower face of sample 1-5.

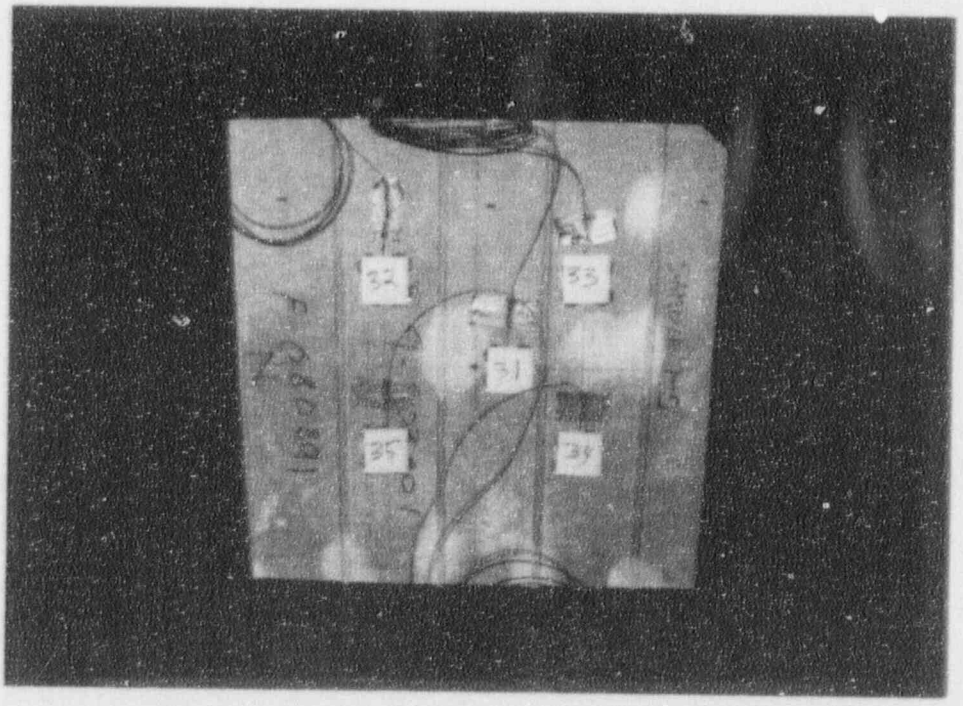

Fig. VI.8. Pre-test unexposed surface, sample 1-5.

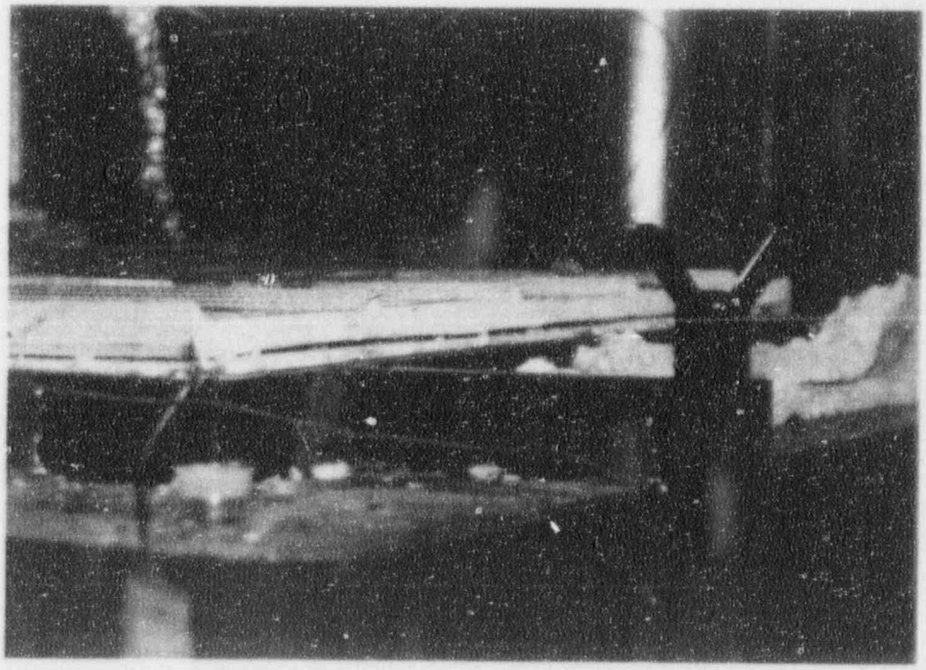

Fig. VI.9. View of air gap at interface between samples.

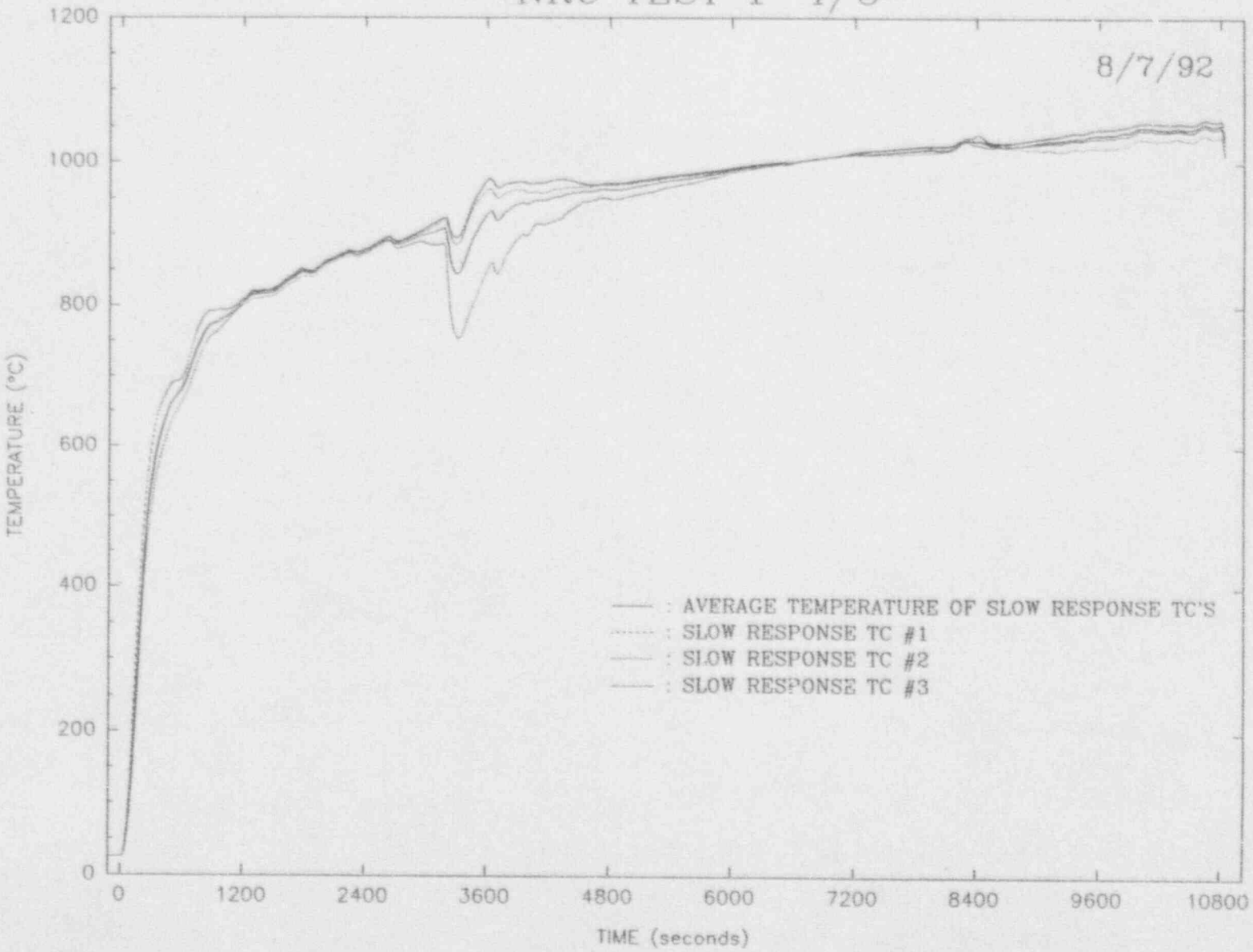

Fig. VI.10. Furnace temperatures, test 1-4/5.

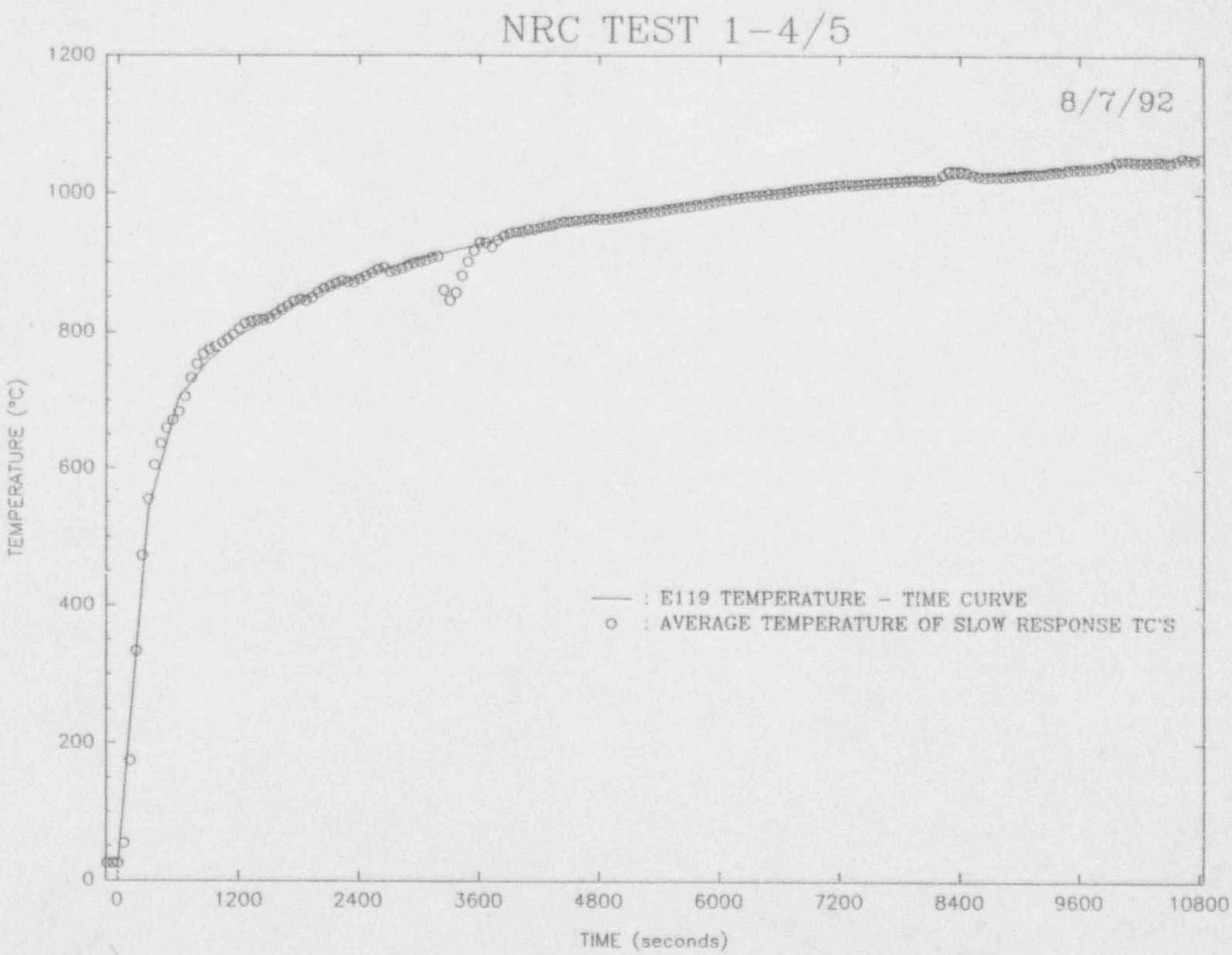

Fig. VI.11. Furnace temperatures, test 1-4/5.

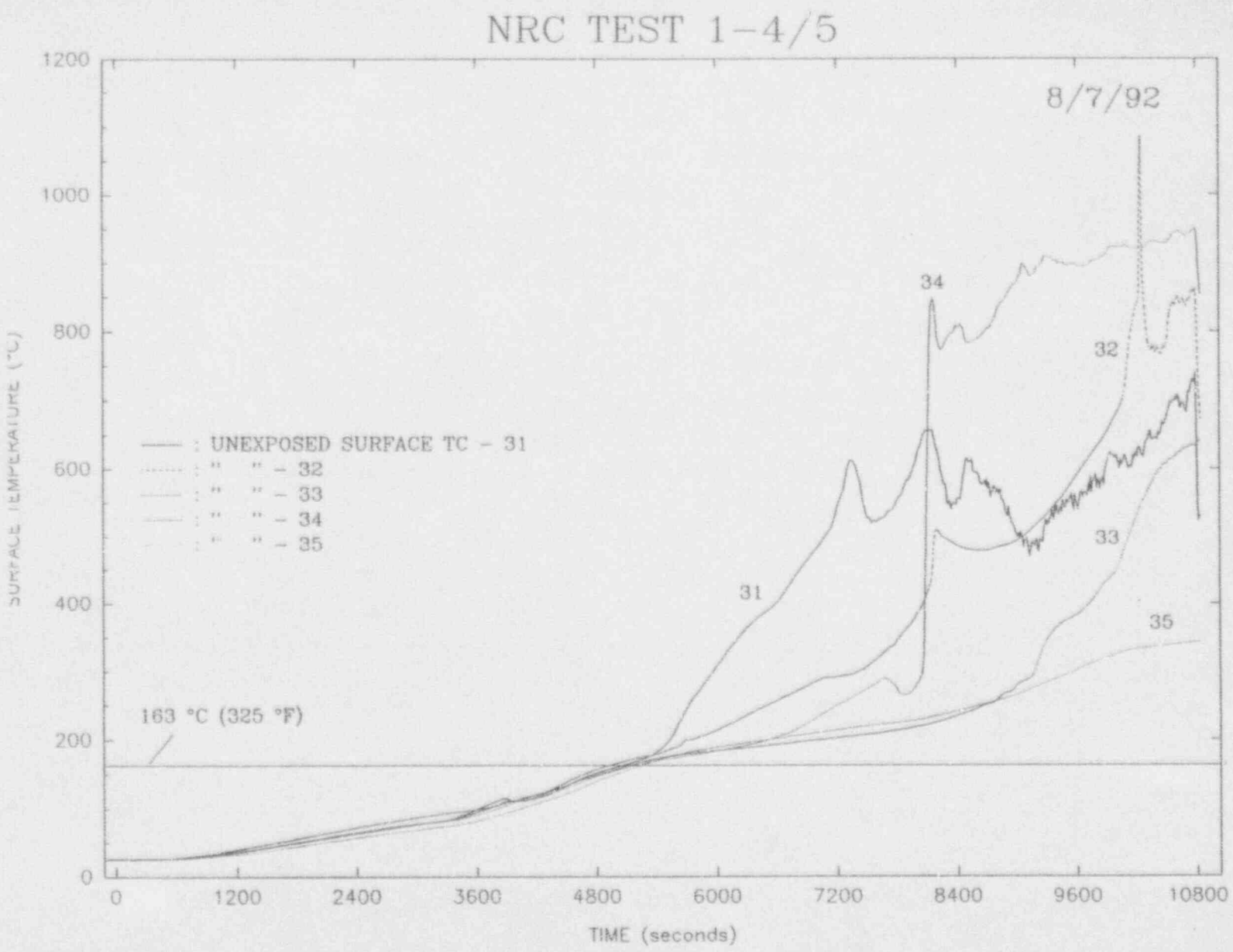

Fig. VI.12. Unexposed-surface temperatures, test 1-4/5.

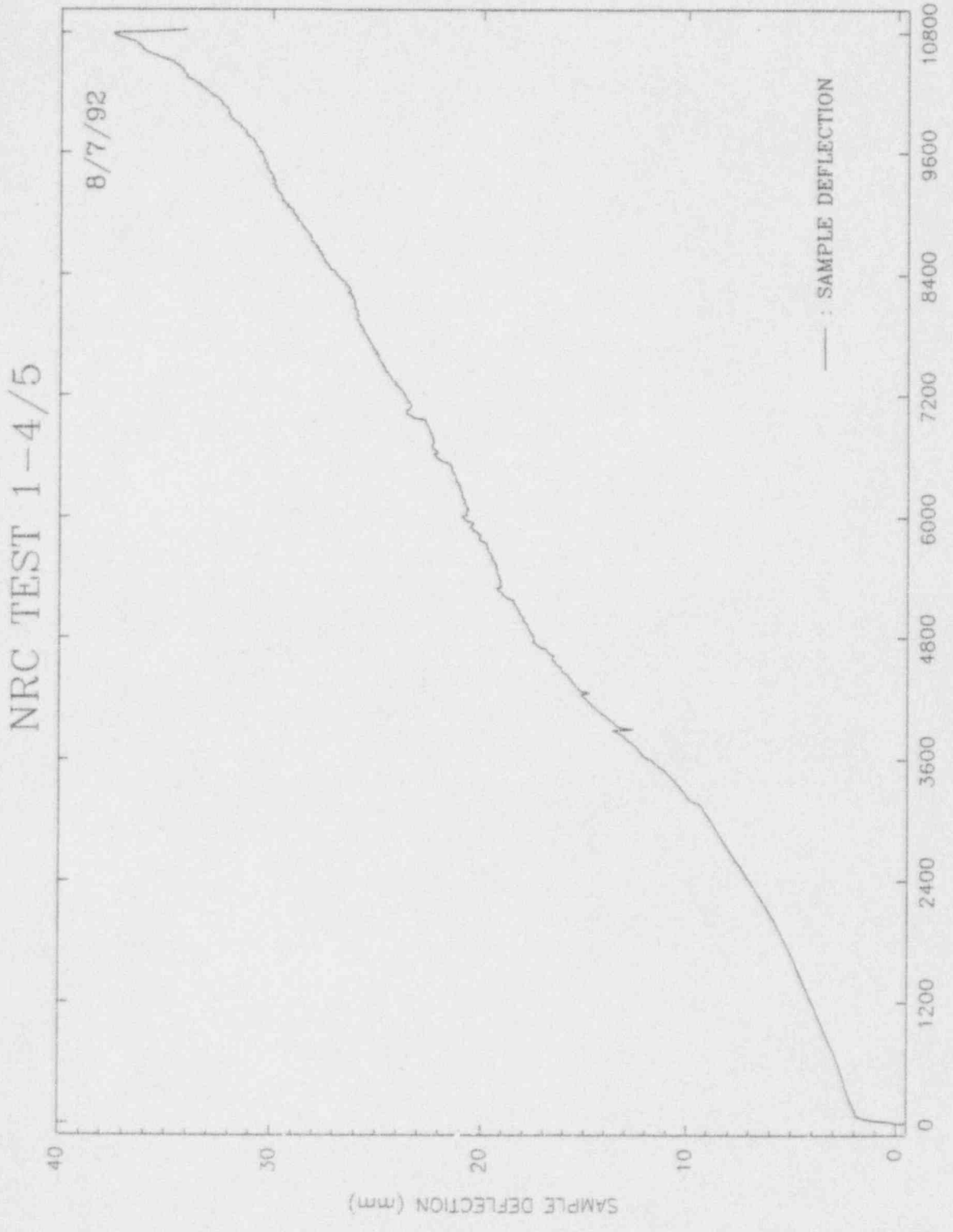

Fig. VI.13. Deflection at center of specimen, test 1-4/5.

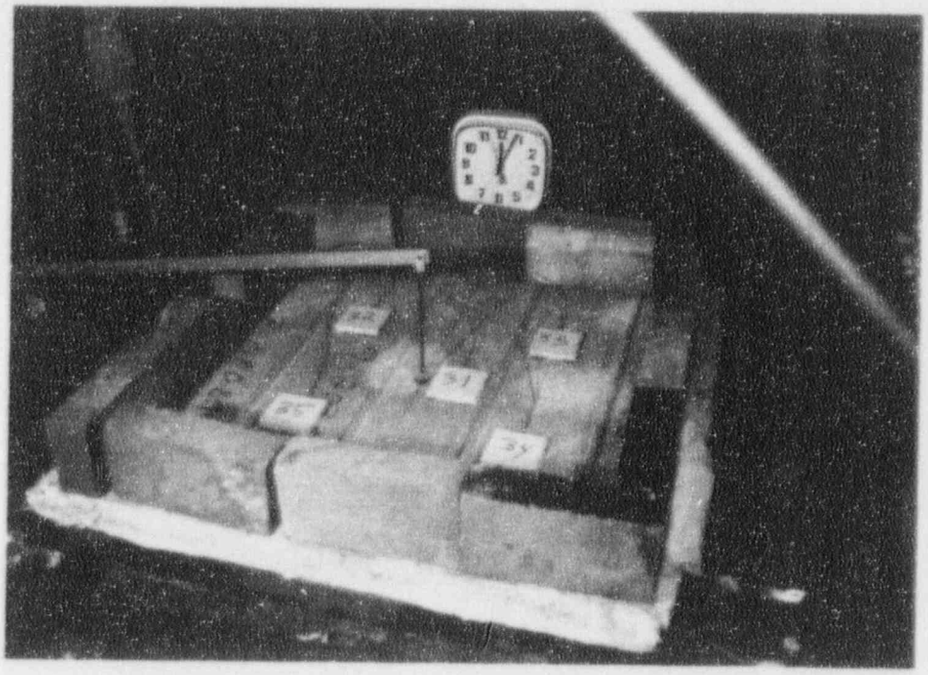

Fig. VI.14. Photograph of unexposed surface during test.

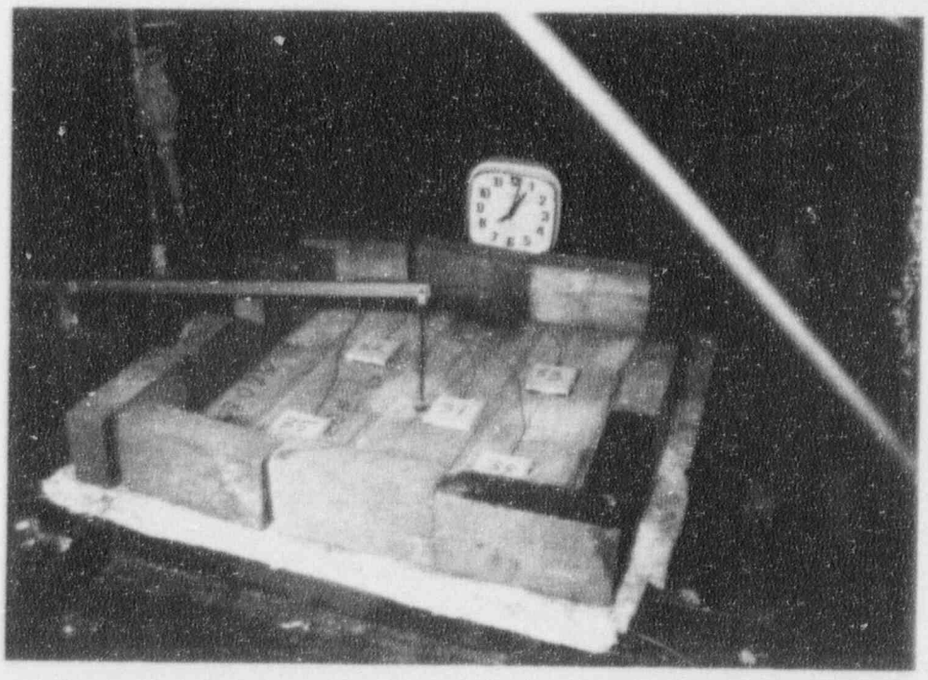

Fig. VI.15. Photograph of unexposed surface during test.

Fig. VI.16. Photograph of unexposed surface during test.

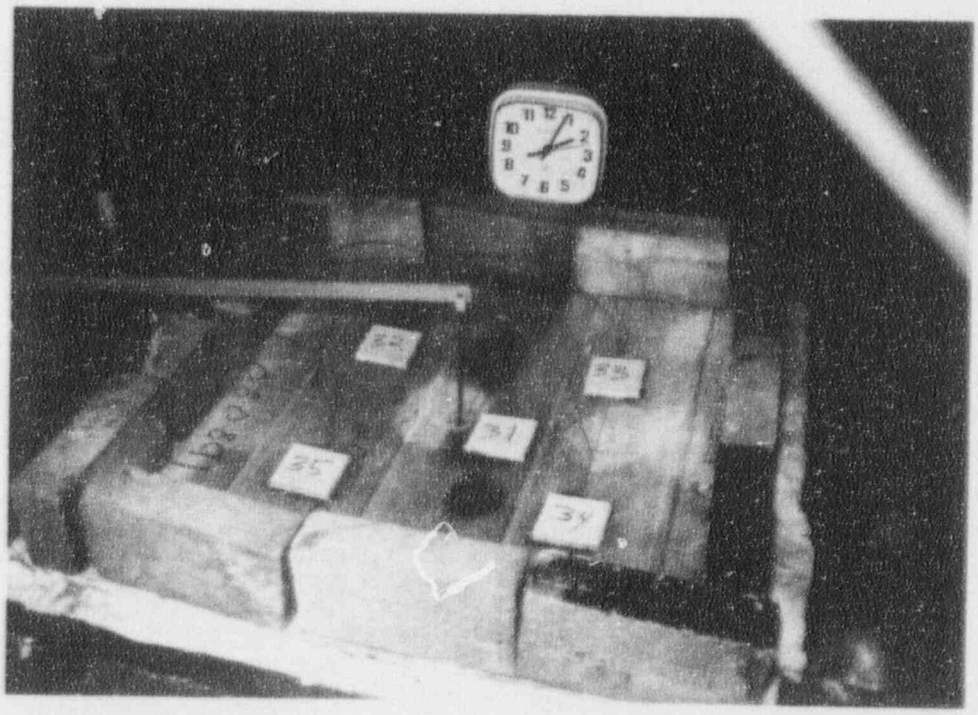

Fig. VI.17. Photograph of unexposed surface during test.

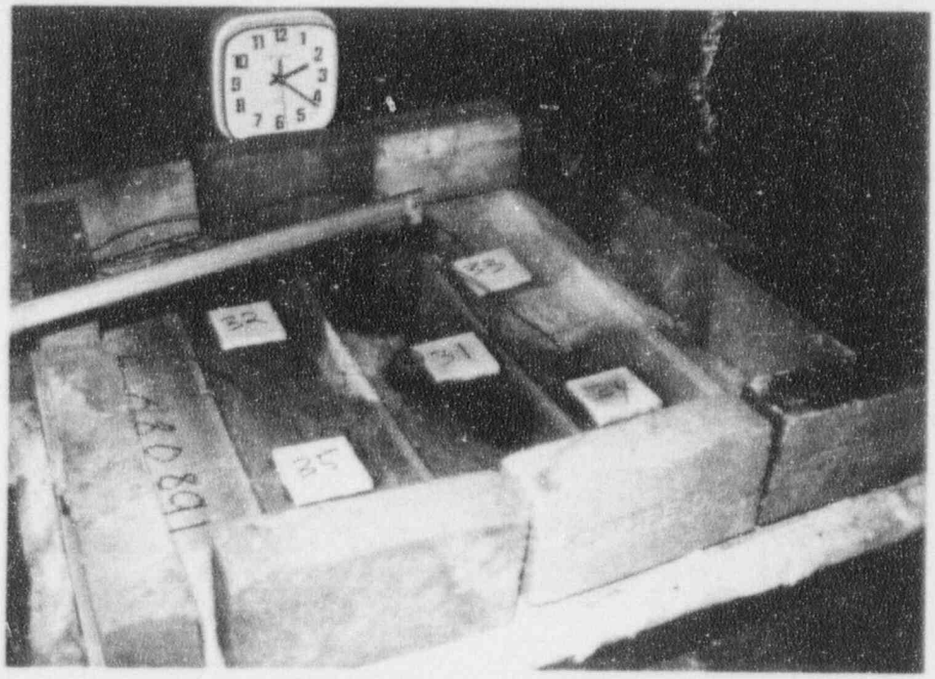

Fig. VI.18. Photograph of unexposed surface during test.

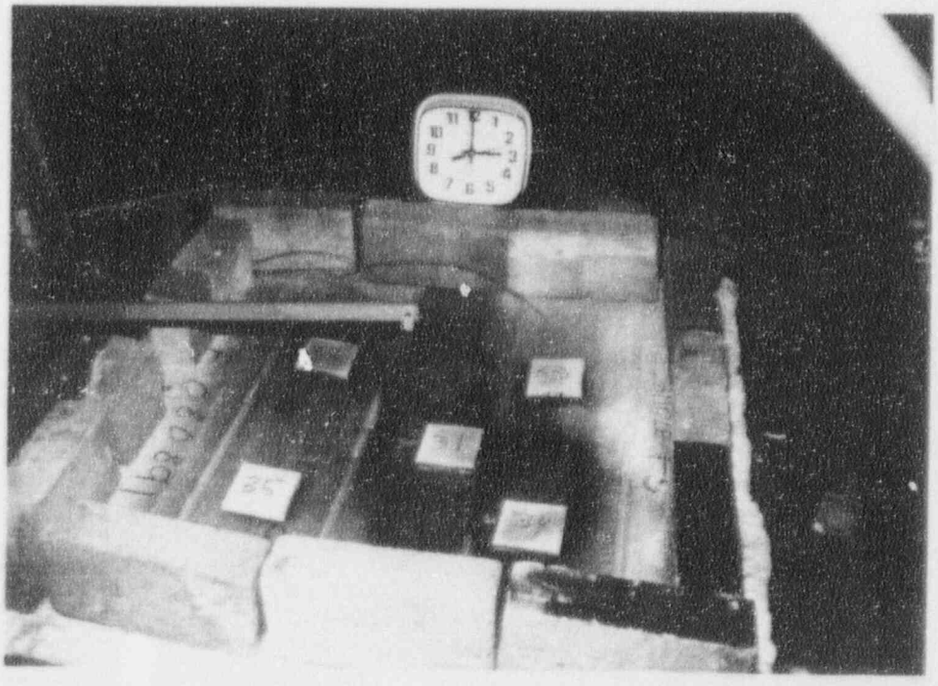

Fig. VI.19. Photograph of unexposed surface during test.

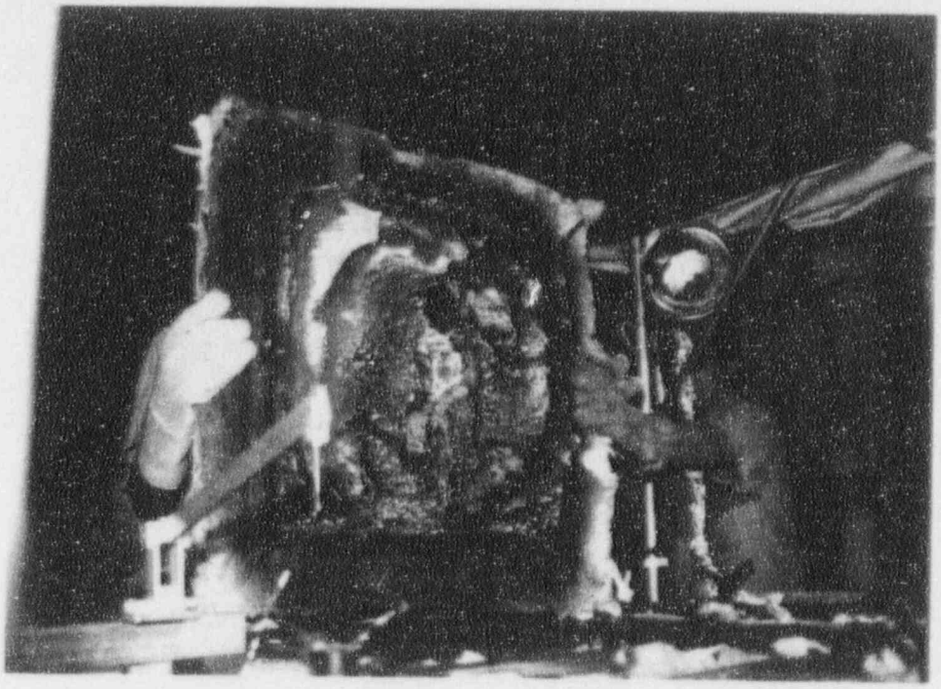

Fig. VI.20. Post-test exposed surface, test 1-4/5.

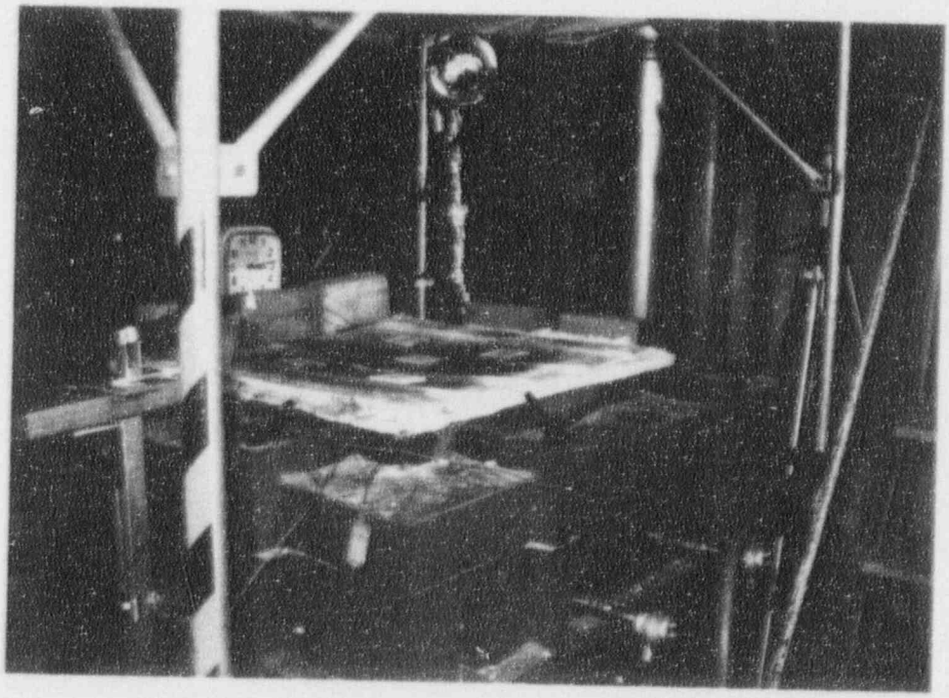

Fig. VI.21. Post-test unexposed surface, test 1-4/5.

VII. Test 1-6/7

A. Description of Test Assembly

The test assembly consisted of two sheets of NRC-supplied 1-hour subliming fire-barrier panel. This panel is manufactured with a "flat" face, a ribbed face, and wire mesh covering only the ribbed face. The two sheets (specimens) were tested with their flat faces back-to-back. Consequently, both the exposed and unexposed surfaces of the assembly were ribbed faces with wire-mesh coverings. The mesh covered the entire areas of the unexposed and exposed faces of the assembly.

The fire barrier specimens, designated sample 1-6 and sample 1-7, were cut to the dimensions shown in Fig. VII.1 and VII.2, respectively. Sample 1-6, which became the lower sheet in the assembly, was cut from a panel labeled by the manufacturer as F92-02037 and F080891. Sample 1-7, the upper sheet, was cut from a panel labeled F92-02037 and F080891. Both samples exhibited two distinct layers like those reported previously (see samples 1-4 and 1-5 above).

Included in Fig. VII.1 are off-rib thicknesses of the specimen along the perimeter and beneath the five surface-temperature-measurement points. Measurements were made at an additional 5 off-rib locations marked as quality control measurement points by the manufacturer. These latter locations are not identified in Fig. VII.1. The thickness data can be summarized as follows:

	Sample 1-6: Off-Rib Thickness (mm [in])			
	avg.	std. dev.	max.	min.
perimeter & below pads	17 [0.67]	1.2 [0.047]	19 [0.75]	14 [0.55]
Mfrs. QC pts.	16 [0.63]	1.1 [0.043]	17 [0.67]	15 [0.59]

Thicknesses at ribs varied from 24 to 28 mm (0.94 to 1.1 in). The pre-test mass of sample 1-6 was 11.8 kg (26.0 lb).

Figure VII.2 shows thicknesses measured at various off-rib locations on sample 1-7. Measurements were made at an additional 5 off-rib locations marked as quality control measurement points by the manufacturer. These latter points are not identified in the

figure. The thickness data can be summarized as follows:

Sample 1-7: Off-Rib Thickness (mm [in])	avg.	std. dev.	max.	min.
perimeter & below pads	17 [0.65]	1.6 [0.063]	22 [0.87]	14 [0.55]
Mfrs. QC pts.	16 [0.63]	1.1 [0.043]	17 [0.67]	14 [0.55]

Thicknesses at ribs varied from 22 to 25 mm (0.87 to 0.98 in). The pre-test mass of sample 1-5 was 11.6 kg (25.6 lb).

Pre-test photographs of the faces of samples 1-6 and 1-7 are shown in Figs. VII.3 to VII.6.

The test assembly consisted of sample 1-7 atop sample 1-6 with their "flat" faces back-to back. No trowel-grade subliming material or adhesive was inserted at their interface. Since the adjoining faces were not truly flat, uneven interstitial air gaps were formed between them (Fig. VII.7). These gaps provided passageways for the leads of thermocouples (formed from 30 gauge wire) attached to the flat faces of the two samples at locations A and B (Fig. VII.2) and C and D (Fig. VII.1). Point E in Fig. VII.1 marks the location of a thermocouple which measured the air temperature in the gap. The larger of the gaps along the perimeter of the assembly were filled with ceramic fiber insulation and then the edge perimeter wrapped with nominal 25.4 mm (1 in) thick ceramic fiber insulation.

Since neither of the wire-mesh coverings were cut back, both were constrained by the vertical load of the bricks which were placed along the perimeter of the assembly.

B. Fire Test Procedures and Results

The test was conducted on August 14, 1992 and was witnessed by official observer I. Moghissi (NRC).

The specimen was subjected to a 3-hour fire exposure controlled by the ASTM E 119-88 standard temperature-time curve. Plots of the furnace temperatures recorded by the individual furnace thermocouples and their average values are presented in Fig. VII.8 and tabulated in Table VII.1. The average furnace temperatures and the standard temperature-time curve are shown in Fig. VII.9.

Unexposed-surface thermocouples measured surface temperatures beneath insulation pads at 5 locations designated 31 to 35 in Fig. VII.2. The thermocouples at these locations are designated TC31 to TC35, respectively, and their outputs are plotted in

Fig. VII.10 and tabulated in Table VII.1. Included in the table are the averages of the unexposed-surface temperatures as a function of time.

Temperatures recorded by interstitial thermocouples A through E (see Figs. VII.1 and VII.2) are presented in Table VII.2.

The deflection at the center of the specimen was measured throughout the test and is plotted in Fig. VII.11 and tabulated in Table VII.1. Positive deflection indicates sag into the furnace. The maximum recorded deflection of 11.3 mm (0.44 in) occurred at 10,800 seconds (3:00:00) (hr:min:s), when shutdown was initiated.

Figures VII.12 to VII.15 show the appearance of the unexposed surface during the test. With the exception of a few crystals the appearance of the unexposed surface did not change during the test. A log of observations and temperatures measured with the movable thermocouple are presented in Table VII.3.

The exposed and unexposed surfaces after the test are shown in Figs. VII.16 and VII.17, respectively. The char layer on the exposed surface was bulging but still attached to the assembly and intact at the start of the test-assembly removal process. The char layer spit open to the condition shown in Fig. VII when the lower panel (sample 1-6) folded during the lift-and-prop process. Prior to splitting, the char layer was approximately 64 mm (2.5 in) thick at the center of the sample.

The lower face of the upper panel (sample 1-7) was covered with a 6 to 13 mm (0.25 to 0.5 in) char layer. Approximately 10 mm (0.4 in) of solid barrier material remained at the center of the panel. The thermocouple pads on the unexposed surface of this panel were still securely attached and had to be pried off. The areas of the specimen beneath these pads were only slightly discolored (Fig. VII.17).

The post-test mass of the assembly was 14.8 kg (32.6 lb). Only a few flakes of char were found at the bottom of the furnace.

C. Analysis of Test Results

The ASTM E 119-88 thermal transmission acceptance criteria are that the average temperature rise of the unexposed-surface thermocouples shall not exceed 139°C (250°F) above its initial temperature (in this test, 25°C [77°F]) and the temperature rise of any of these thermocouples shall not exceed 181°C (325°F) above the initial temperature. Another criterion is that at no time during the test should hot gases or flame pass through the assembly so as to ignite cotton waste held against the unexposed surface. In addition to these criteria, NRC requirements include the time at

which any of the unexposed-surface thermocouples reaches 162.8°C (325°F).

On the basis of the experimental temperature data presented in Table VII.1, the above temperature criteria were met at the following locations and times:

Criterion	Location	Time (sec)	Time [hr:min:sec]
E 119 avg. unexposed surf. temp. (164°C) [327°F]		9420	[2:37:00]
E 119 peak unexposed surf. temp. (206°C) [403°F]	-----	(not reached)	-----
NRC unexposed surf. temp., 1st occurrence (162.8°C) [325°F]	TC 33	8868	[2:27:48]

Concerning E 119 criteria, the average temperature was the controlling factor and the E 119 fire-endurance period was 9420 seconds (2:37:00). Since the period was greater than 1/2 hour, a correction was required to account for deviations of the actual average furnace temperature from the standard temperature-time curve (see ASTM E 119-88, Par. 7.4). This correction was +3 s and **the corrected fire-endurance period was 9423 s (2 hours and 37.0 minutes).**

Neither glowing nor flame passage were observed during the test. The E 119 cotton-waste test was not conducted at any time during the test. Post-test inspection revealed no burnthrough areas. The char layer on the exposed surface remained intact throughout the test.

TABLE VII.1. Temperatures, test 1-6/7.

NRC TEST 1-6/7

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
-110	24	24	24	24	25	25	25	25	25	25	0.0
-100	24	24	24	23	25	25	25	25	25	25	0.0
-90	24	24	24	23	25	25	25	25	25	25	0.0
-80	24	24	24	23	25	25	25	25	25	25	-0.0
-70	24	24	24	24	25	25	25	25	25	25	-0.0
-60	24	24	24	23	25	25	25	25	25	25	-0.0
-50	24	24	24	23	25	25	25	25	25	25	-0.0
-40	24	24	24	23	25	25	25	25	25	25	-0.0
-30	24	24	24	23	25	25	25	25	25	25	-0.0
-20	24	24	24	23	25	25	25	25	25	25	-0.0
-10	24	24	24	23	25	25	25	25	25	25	0.0
-1	24	24	24	24	25	25	25	25	25	25	0.0
0	24	24	24	23	25	25	25	25	25	25	0.0
10	24	24	24	23	25	25	25	25	25	25	0.1
20	24	24	24	24	25	25	25	25	25	25	0.6
30	27	27	27	26	25	25	25	25	25	25	1.2
40	33	31	32	31	25	25	25	25	25	25	1.5
50	43	37	40	40	25	25	25	25	25	25	1.7
60	58	46	50	51	25	25	25	25	25	25	1.8
70	76	56	63	65	25	25	24	25	25	25	1.9
80	98	69	79	81	25	25	25	25	25	25	2.0
90	123	84	96	100	25	24	25	25	25	25	2.0
100	150	103	116	122	25	25	25	25	25	25	2.0
110	178	124	137	146	25	25	25	25	25	25	2.0
120	208	147	160	172	25	25	25	25	25	25	2.0
130	239	171	184	197	25	25	25	25	25	25	2.1
140	269	196	208	224	25	25	25	25	25	25	2.1
150	300	222	234	252	25	25	25	25	25	25	2.1
160	329	249	260	279	25	25	25	25	25	25	2.1
170	358	275	286	306	25	25	25	25	25	25	2.2
180	385	302	312	333	25	25	25	25	25	25	2.2
190	411	328	338	359	25	25	25	25	25	25	2.2
200	436	354	363	384	25	25	25	24	25	25	2.2
210	458	379	388	408	25	25	25	25	25	25	2.3
220	480	403	411	430	25	25	24	25	25	25	2.3
230	499	425	432	451	25	25	25	25	25	25	2.3
240	517	445	452	471	25	25	25	25	25	25	2.4
250	533	464	470	488	25	25	25	25	25	25	2.4
260	547	481	487	505	25	25	25	25	25	25	2.4
270	560	497	503	519	25	25	25	25	25	25	2.4
280	572	512	517	534	25	25	25	25	25	25	2.5
290	583	525	530	546	25	25	25	25	25	25	2.5
300	592	537	542	557	25	25	25	25	25	25	2.5

TABLE VII.1. Temperatures, test 1-6/7 (cont.).

NRC TEST 1-6/7

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
360	631	585	591	601	25	25	25	25	25	25	2.7
420	653	613	620	628	25	25	25	25	25	25	2.8
480	664	632	637	644	25	25	25	25	25	25	2.9
540	679	650	655	661	25	25	25	25	25	25	3.0
600	707	675	682	687	26	25	26	25	25	25	3.2
660	734	703	709	715	26	26	26	26	26	26	3.3
720	753	726	730	736	27	26	26	26	26	26	3.5
780	767	742	746	751	27	26	27	27	27	27	3.6
840	779	755	760	764	28	27	28	27	27	27	3.7
900	786	765	769	773	29	28	28	28	28	28	3.7
960	791	773	777	780	30	28	29	29	28	29	3.8
1020	797	779	784	786	31	29	30	30	29	30	4.0
1080	799	785	790	791	32	30	31	30	30	31	4.0
1140	804	790	795	796	33	31	32	31	30	32	4.1
1200	806	797	801	801	34	32	33	32	31	33	4.2
1260	807	802	805	804	36	33	35	34	32	34	4.2
1320	806	804	808	806	37	34	36	35	33	35	4.3
1380	808	809	812	809	39	35	37	36	34	36	4.3
1440	811	815	815	813	40	36	39	37	36	38	4.4
1500	818	820	820	819	42	37	40	38	37	39	4.4
1560	822	827	826	825	43	39	41	39	38	40	4.5
1620	826	833	832	830	44	40	43	41	40	42	4.5
1680	832	838	837	835	46	41	45	42	41	43	4.6
1740	835	841	841	839	47	42	46	44	43	44	4.6
1800	839	845	843	842	48	43	48	45	44	46	4.7
1860	845	851	850	848	50	44	49	46	45	47	4.8
1920	854	858	858	856	51	45	51	48	47	48	4.8
1980	853	859	858	856	52	47	52	49	48	50	4.9
2040	861	863	865	862	54	48	54	51	49	51	4.9
2100	864	868	868	866	55	49	55	52	51	52	5.0
2160	864	870	870	867	56	50	57	54	52	54	5.0
2220	866	872	872	869	57	51	58	55	53	55	5.1
2280	869	875	874	872	59	52	60	56	54	56	5.1
2340	871	878	876	875	60	53	61	58	55	58	5.1
2400	874	880	878	877	61	55	63	59	57	59	5.1
2460	878	883	882	880	63	56	64	60	58	60	5.1
2520	881	887	885	884	64	57	65	62	59	61	5.0
2580	884	890	888	887	65	58	67	63	60	63	5.0
2640	887	892	890	890	66	59	68	64	62	64	4.9
2700	891	895	895	893	68	60	69	65	63	65	4.9
2760	894	899	898	896	69	62	70	66	64	66	4.9
2820	895	902	900	899	70	63	72	68	65	67	4.9

TABLE VII.1. Temperatures, test 1-6/7 (cont.).

NRC TEST 1-6/7

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
2880	896	903	901	900	71	64	73	69	66	69	4.8
2940	899	905	903	902	72	65	74	70	67	70	4.9
3000	901	906	905	904	73	66	75	71	68	71	4.9
3060	904	910	908	906	74	67	76	72	69	72	4.9
3120	906	912	909	909	76	68	77	73	70	73	4.8
3180	909	914	912	911	77	69	78	74	71	74	4.7
3240	911	916	914	913	78	70	79	75	72	75	4.7
3300	913	918	916	915	79	71	80	76	73	76	4.6
3360	916	919	919	918	79	72	81	77	74	77	4.5
3420	920	922	924	921	80	73	82	77	75	78	4.4
3480	920	924	924	922	81	74	83	78	76	79	4.2
3540	920	924	924	922	82	75	84	79	77	80	4.0
3600	924	926	928	925	83	76	85	80	77	80	3.7
3660	925	928	928	926	84	77	86	81	78	81	3.3
3720	929	931	932	930	84	78	87	82	79	82	2.9
3780	931	934	934	933	85	79	88	83	80	83	2.5
3840	935	936	938	936	86	80	89	84	81	84	2.3
3900	937	938	940	937	86	81	90	84	81	85	1.9
3960	937	939	940	938	87	82	91	85	82	85	1.4
4020	939	940	942	940	88	82	92	86	83	86	0.9
4080	942	943	946	943	89	83	92	87	84	87	0.7
4140	945	946	948	946	89	84	93	88	84	88	0.4
4200	946	948	950	947	90	85	94	88	85	88	-0.7
4260	947	948	951	948	91	85	95	89	86	89	-0.9
4320	948	949	952	949	92	86	96	90	86	90	-1.2
4380	949	951	953	950	92	87	97	91	87	91	-1.7
4440	950	952	953	951	93	87	98	92	88	91	-1.9
4500	951	953	955	953	94	88	99	92	88	92	-2.1
4560	955	957	959	956	95	89	100	93	89	93	-2.3
4620	957	959	961	959	96	89	100	94	90	94	-2.3
4680	959	961	964	961	96	90	101	95	90	94	-3.0
4740	961	963	964	962	97	91	102	95	91	95	-3.1
4800	963	964	966	964	98	92	103	96	91	96	-3.1
4860	964	965	968	966	99	92	104	97	92	97	-3.4
4920	966	967	969	967	100	93	103	98	93	98	-3.8
4980	967	969	971	968	100	94	105	99	94	98	-4.3
5040	969	970	973	970	101	95	106	99	94	99	-4.5
5100	970	971	974	971	102	96	107	100	95	100	-4.6
5160	972	973	975	973	103	96	108	101	96	101	-4.9
5220	973	974	976	973	103	97	109	102	96	102	-5.1
5280	975	976	978	975	104	98	110	103	97	102	-5.3
5340	976	977	979	976	105	99	111	103	98	103	-5.4

TABLE VII.1. Temperatures, test 1-6/7 (cont.).

NRC TEST 1-6/7

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
5400	976	977	980	977	106	100	112	104	99	104	-5.5
5460	978	979	981	979	107	100	113	105	100	105	-5.3
5520	980	981	983	981	107	101	114	106	100	106	-5.3
5580	981	982	984	982	108	102	115	106	101	107	-5.0
5640	982	983	985	983	109	103	116	107	102	107	-4.7
5700	983	984	987	984	110	104	117	108	103	108	-4.4
5760	985	986	987	985	111	105	118	109	104	109	-4.1
5820	986	988	989	987	112	106	119	110	104	110	-3.8
5880	988	989	991	988	112	107	120	110	105	111	-3.5
5940	988	989	991	989	113	108	122	111	106	112	-3.2
6000	990	990	993	990	114	109	123	112	107	113	-2.9
6060	991	992	994	992	115	110	124	113	108	114	-2.6
6120	992	993	995	993	116	111	126	114	109	115	-2.4
6180	993	994	997	994	117	112	127	115	110	116	-2.0
6240	994	995	997	994	118	113	128	116	111	117	-1.7
6300	996	996	998	996	119	114	130	117	111	118	-1.3
6360	996	997	999	997	121	115	131	118	112	120	-0.9
6420	997	998	1000	998	122	116	132	120	114	121	-0.5
6480	998	999	1001	999	123	117	133	121	115	122	-0.0
6540	999	1000	1001	999	124	119	134	122	116	123	0.4
6600	999	1000	1002	1000	125	120	136	123	117	124	0.8
6660	1001	1001	1003	1001	126	121	137	125	118	125	1.1
6720	1001	1002	1004	1002	127	122	138	126	119	126	1.5
6780	1001	1003	1004	1002	128	123	139	127	120	128	1.8
6840	1003	1004	1005	1003	129	125	140	129	122	129	2.1
6900	1003	1004	1006	1004	130	126	141	130	123	130	2.4
6960	1004	1005	1006	1005	132	127	142	132	124	131	2.7
7020	1005	1006	1007	1005	133	128	142	133	125	132	3.0
7080	1006	1007	1008	1006	134	130	143	134	127	133	3.2
7140	1006	1007	1008	1007	135	131	144	136	128	135	3.4
7200	1008	1009	1010	1008	136	132	145	137	129	136	3.7
7260	1010	1010	1012	1010	137	133	146	138	131	137	3.9
7320	1011	1011	1013	1011	138	134	147	139	132	138	4.1
7380	1012	1012	1013	1012	138	135	148	141	133	139	4.4
7440	1013	1013	1014	1013	139	136	148	142	134	140	4.6
7500	1013	1014	1015	1014	140	137	149	143	136	141	4.8
7560	1014	1014	1015	1014	141	138	150	144	137	142	4.9
7620	1015	1016	1017	1015	142	139	151	145	138	143	5.2
7680	1016	1017	1017	1016	143	140	151	146	139	144	5.4
7740	1016	1016	1018	1017	144	141	152	147	140	145	5.5
7800	1017	1017	1018	1017	145	142	153	148	141	146	5.6
7860	1018	1019	1019	1019	146	143	154	149	142	147	5.6

TABLE VII.1. Temperatures, test 1-6/7 (cont.).

NRC TEST 1-6/7

TIME	TEMPERATURE (°C)										SAMPLE
	FURNACE				UNEXPOSED SURFACE						DEFLECT
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
7920	1019	1019	1020	1019	147	144	154	150	143	148	5.8
7980	1020	1020	1021	1020	148	145	155	151	144	148	5.9
8040	1021	1022	1021	1021	148	146	156	152	144	149	5.9
8100	1021	1022	1022	1021	149	147	156	153	145	150	5.5
8160	1021	1022	1022	1021	150	148	157	154	146	151	5.5
8220	1022	1022	1022	1022	151	149	157	155	147	152	5.5
8280	1022	1023	1022	1022	151	150	158	155	147	152	5.3
8340	1023	1022	1024	1022	152	150	159	156	148	153	4.8
8400	1024	1024	1025	1024	153	151	159	157	149	154	4.7
8460	1025	1024	1026	1025	153	152	160	157	150	154	4.1
8520	1026	1025	1027	1026	154	153	160	158	151	155	3.5
8580	1027	1026	1028	1027	154	153	161	159	152	156	2.9
8640	1028	1027	1028	1027	155	154	161	159	152	156	2.5
8700	1028	1026	1029	1028	156	155	162	160	153	157	2.3
8760	1029	1028	1029	1028	156	156	162	160	154	158	2.3
8820	1030	1028	1030	1029	157	156	162	161	155	158	2.4
8880	1030	1028	1031	1029	158	157	163	161	155	159	2.6
8940	1030	1028	1032	1029	158	158	163	162	156	159	2.9
9000	1031	1028	1032	1030	159	158	164	162	157	160	3.3
9060	1032	1029	1033	1031	159	159	165	163	157	161	3.9
9120	1033	1030	1034	1032	160	159	165	163	158	161	4.7
9180	1033	1031	1034	1032	161	160	165	164	158	162	5.2
9240	1034	1032	1036	1033	161	160	166	164	159	162	5.7
9300	1035	1034	1036	1035	162	161	166	165	160	163	6.0
9360	1037	1035	1038	1036	162	161	167	165	160	163	6.8
9420	1038	1037	1039	1038	163	162	167	165	161	164	6.9
9480	1038	1038	1039	1038	163	162	168	166	161	164	7.2
9540	1039	1039	1040	1039	164	163	169	166	162	165	7.4
9600	1040	1039	1040	1039	165	163	169	167	163	165	7.7
9660	1040	1039	1041	1040	165	164	170	167	163	166	7.9
9720	1041	1040	1042	1040	166	164	170	168	164	166	8.1
9780	1041	1041	1042	1041	167	165	171	168	164	167	8.4
9840	1042	1042	1043	1042	167	165	171	169	165	168	8.5
9900	1042	1042	1043	1042	168	166	172	169	166	168	8.8
9960	1042	1041	1044	1042	169	166	172	170	166	169	9.0
10020	1043	1042	1044	1042	169	167	173	170	167	169	9.2
10080	1044	1043	1045	1044	170	167	174	171	167	170	9.4
10140	1045	1045	1045	1044	170	168	174	172	168	170	9.5
10200	1046	1046	1047	1046	171	168	175	172	168	171	10.1
10260	1047	1047	1047	1046	172	169	175	173	168	171	10.3
10320	1048	1048	1048	1048	173	170	176	173	169	172	10.3
10380	1048	1048	1049	1048	173	170	176	174	169	173	10.6

TABLE VII.1. Temperatures, test 1-6/7 (cont.).

NRC TEST 1-6/7

TIME	TEMPERATURE (°C)										SAMPLE DEFLECT
	FURNACE				UNEXPOSED SURFACE						
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.	mm
10440	1048	1048	1049	1048	174	171	176	174	170	173	10.7
10500	1049	1050	1049	1049	175	171	177	175	170	174	10.7
10560	1049	1050	1050	1049	175	172	177	176	171	174	10.8
10620	1050	1051	1050	1049	176	172	178	176	172	175	11.0
10680	1050	1051	1050	1050	177	173	178	177	172	175	11.1
10740	1051	1051	1052	1051	177	173	179	177	173	176	11.2
10800	1051	1051	1051	1051	178	174	179	178	173	176	11.3

TABLE VII.2. Temperatures in interstitial space between panels, test 1-6/7.

Location	(see Fig. VII.2) A	B	(see Fig. VII.1) C	D	E
Time [s]	Temperature [°C]				
60	23	23	23	-	23
300	25	26	36	-	46
600	24	37	68	-	83
900	46	55	92	-	70
1200	67	71	109	-	89
1500	81	83	132	109	109
1800	98	91	155	125	109
2100	109	100	164	141	110
2400	115	114	170	152	113
2700	122	113	177	152	120
3000	132	126	185	159	126
3300	147	137	192	165	132
3600	158	148	197	174	140
3900	165	152	203	183	153
4200	172	154	209	196	171
4500	180	163	215	209	180
4800	189	172	219	214	184
5100	195	191	222	231	192
5400	198	202	227	249	218
5700	204	210	236	259	219
6000	210	224	253	279	222
6300	218	245	273	297	231
6600	227	249	280	322	246
6900	248	259	274	355	279
7200	264	267	328	338	306
7500	287	282	355	350	318
7800	303	283	378	348	307
8100	307	312	386	362	323
8400	320	350	383	391	356
8700	344	374	379	429	366
9000	361	360	376	446	362
9300	368	349	373	403	364
9600	375	375	377	443	372
9900	381	397	385	501	382
10200	386	419	395	551	386
10500	393	466	405	590	396
10800	398	518	413	621	405

TABLE VII.3. Observations, test 1-6/7.

The following observations were made during the test:

(Note: MTC indicates surface temperature measured with movable thermocouple)

Time	
0:12:00	No obvious changes to unexposed surface.
0:44:45	Still no change.
1:00:00	No change visible.
1:03:00	Outgassing can be seen. Crystals forming between thermocouple pads 34 and 35.
1:14:00	No outgassing now. Previous outgassing stopped soon after it started.
1:16:30	Crystals in white area E. of 35 at N./S. centerline (CL).
1:20:	76°C (169°F) (MTC) measured between pads 34 and 35.
1:30:	Still no discoloration. No outgassing.
1:45:00	No discoloration or outgassing.
1:54:00	Some outgassing near E. edge.
1:55:00	Outgassing stopped.
2:00:00	No discoloration or outgassing.
2:02:30	Slight outgassing in S.W. corner but no discoloration.
2:06:00	Outgassing increasing.
2:09:	103°C (217°F) (MTC) between 34 and 35.
2:15:00	Outgassing picking up but no change in appearance of unexposed surface.
2:30:00	No visible change to surface.
2:33:	118°C (244°F) (MTC) between 33 and 34.
2:34:45	No visible change to surface. No browning.
2:36:	122°C (252°F) (MTC) between 33 and 34.
2:39:40	With the exception of a few crystals, the surface appears unchanged from start of test.
2:45:	Still no browning.
2:51:	132°C (270°F) (MTC) between 34 and 35.
2:59:30	Still no browning.
3:00:00	Shutdown.
3:12:	W. edge of assembly lifted and propped. At start of lift the charred exposed surface was bulged but attached to the test assembly. The char layer cracked as a result of lifting the assembly.

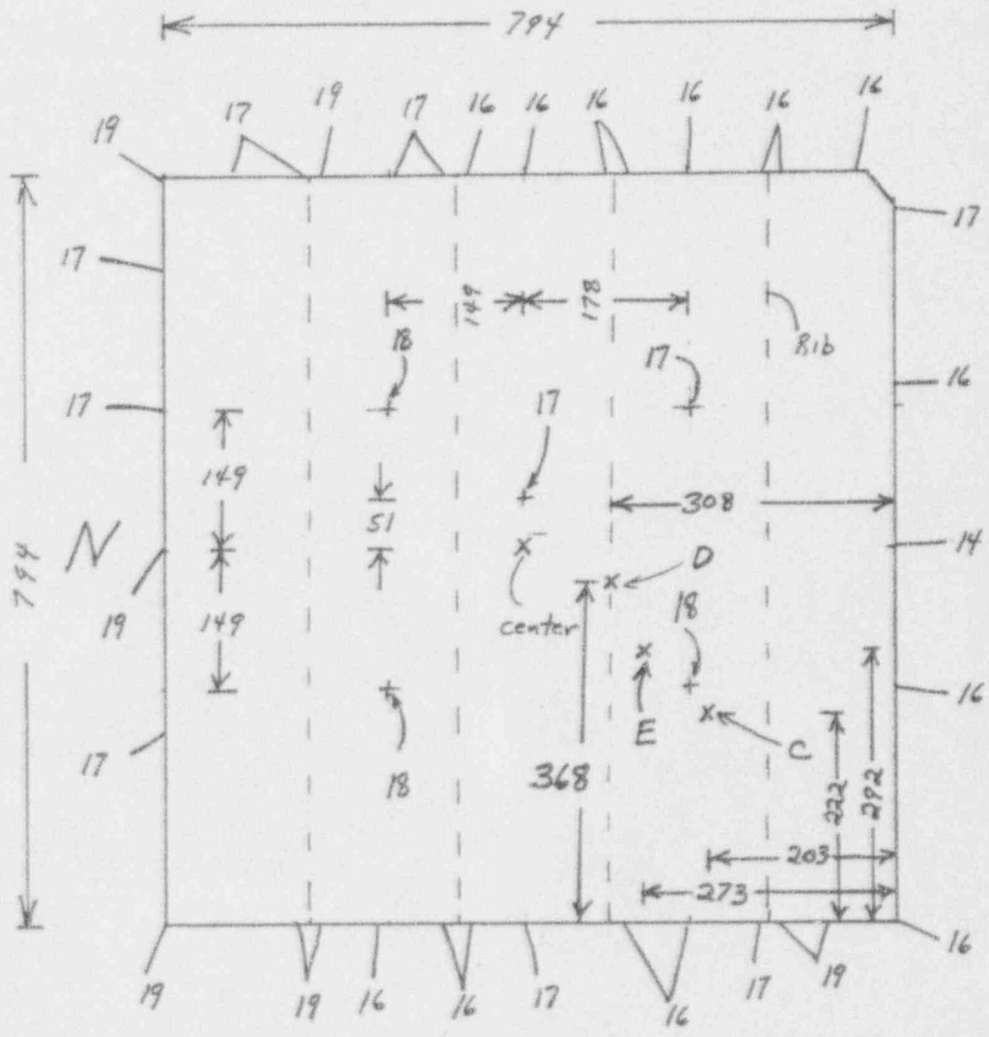

Fig. VII.1. Dimensions, sample 1-6. All dimensions in millimeters. Other numbers not between arrows indicate thickness.

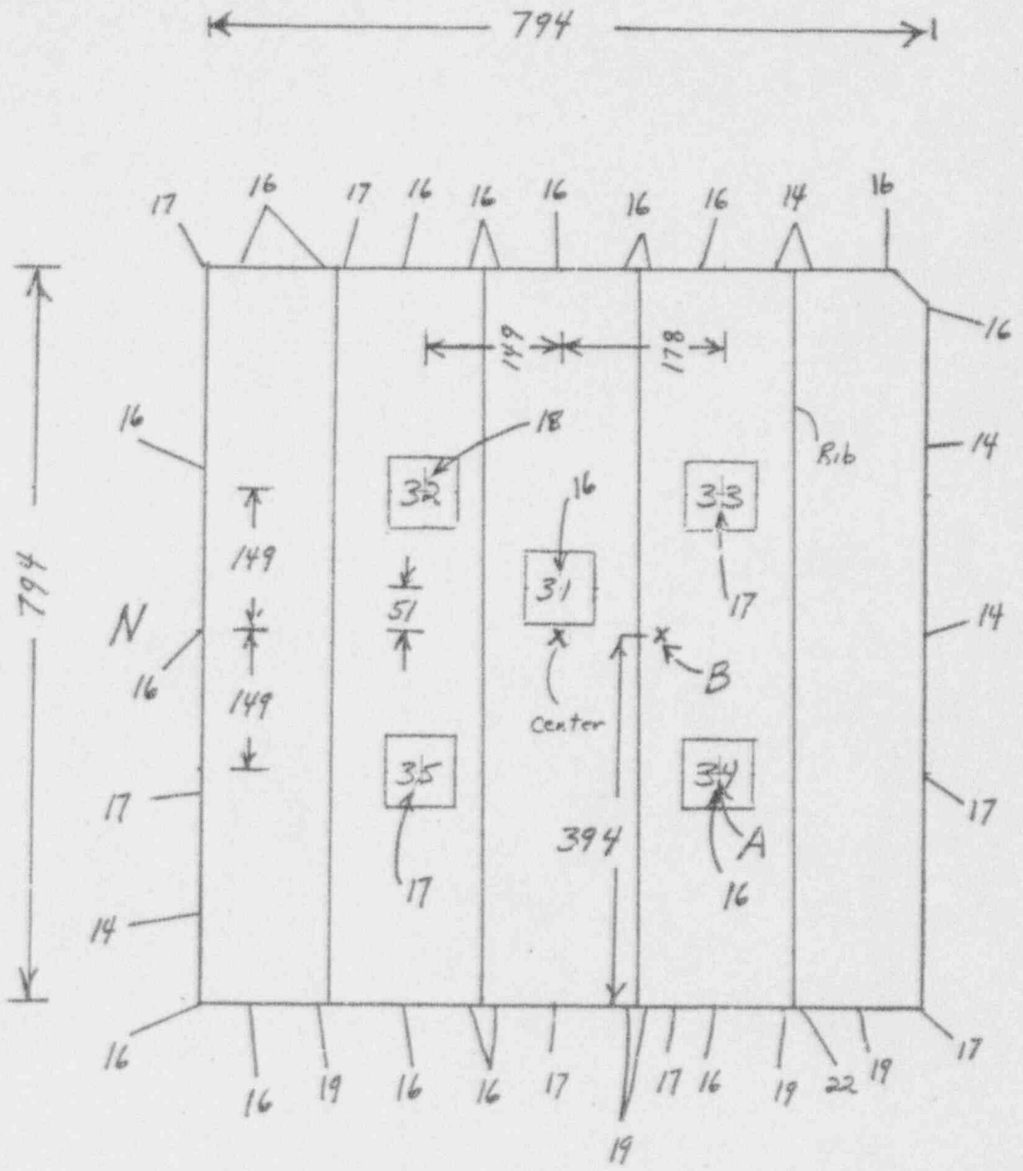

Fig. VII.2. Dimensions, sample 1-7. All dimensions in millimeters. Numbered squares denote unexposed-surface thermocouple pads. Other numbers not between arrows indicate thickness.

Fig. VII.3. Pre-test exposed surface, sample 1-6.

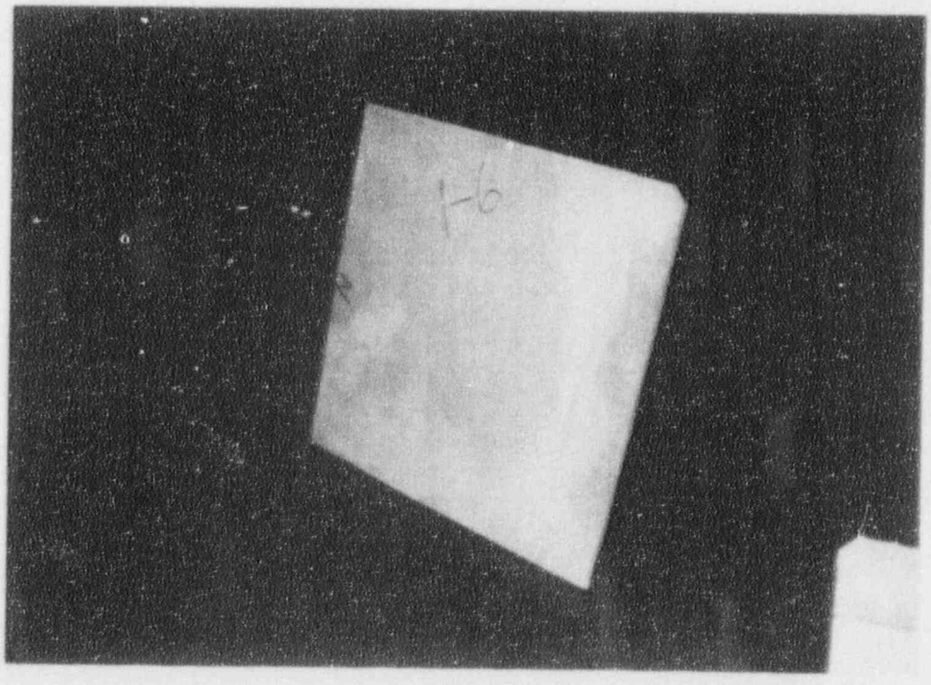

Fig. VII.4. Pre-test upper face, sample 1-6

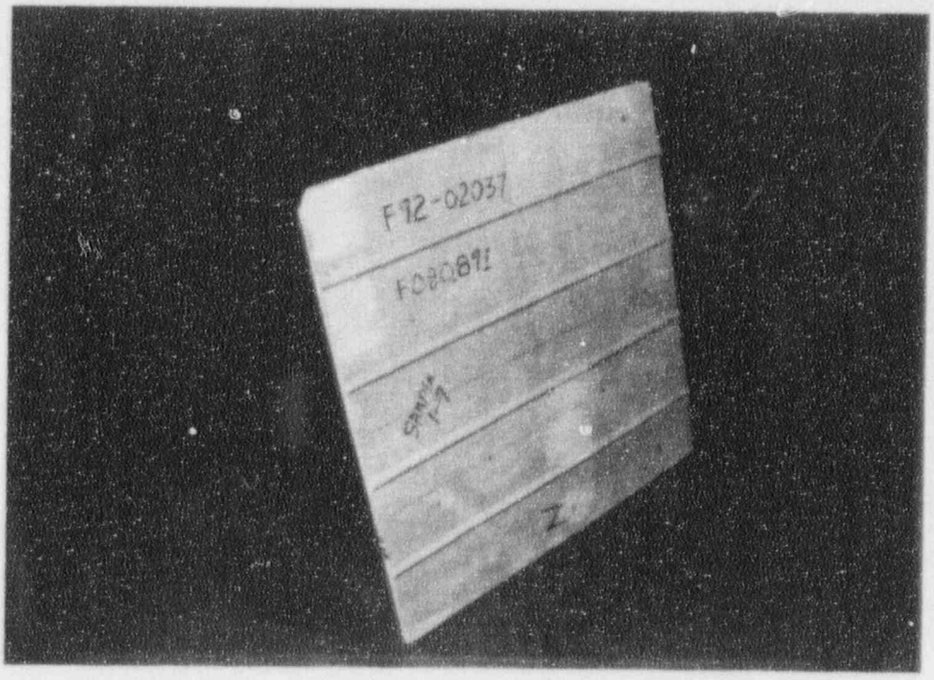

Fig. VII.5. Pre-test unexposed surface, sample 1-7.

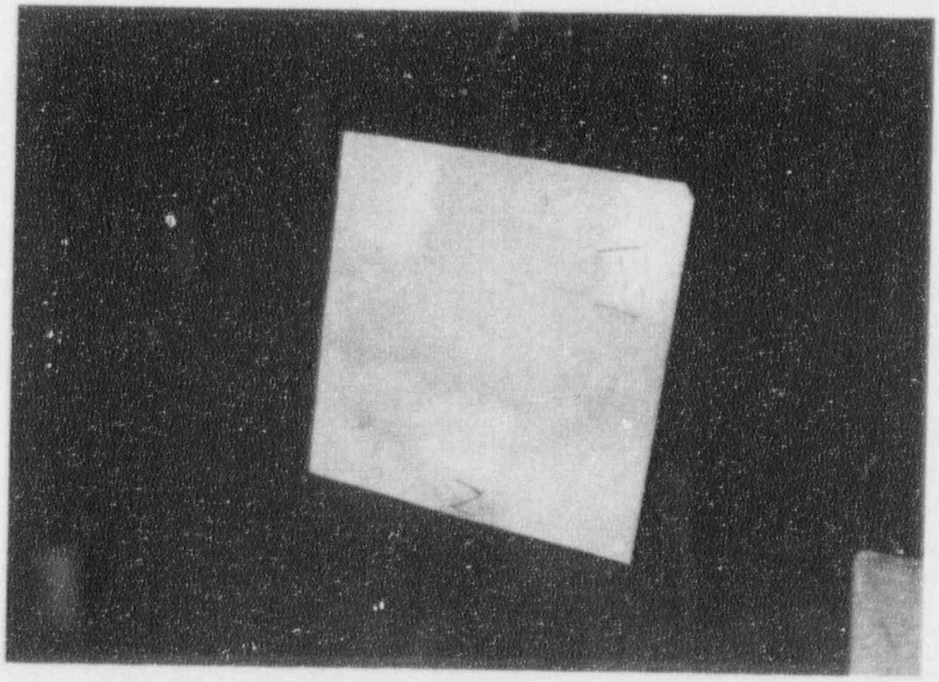

Fig. VII.6. Pre-test lower face, sample 1-7.

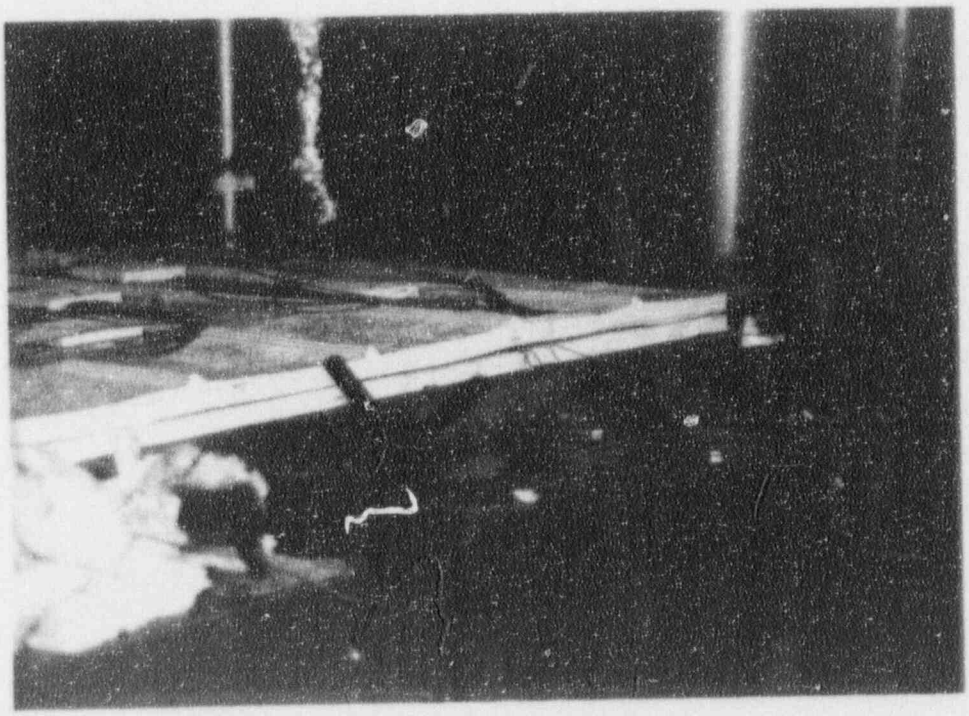

Fig. VII.7. Edge view showing air gap between samples.

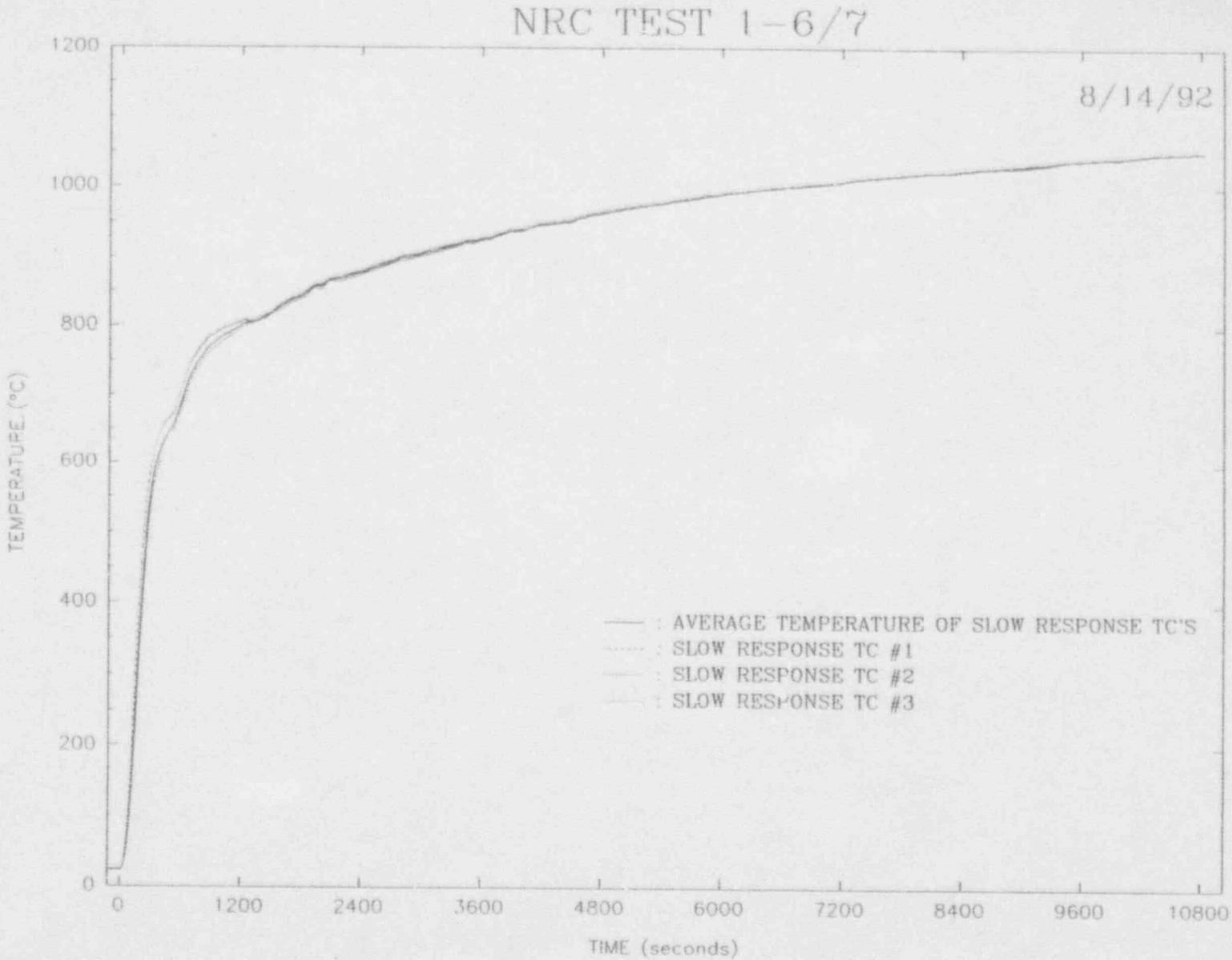

Fig. VII.8. Furnace temperatures, test 1-6/7.

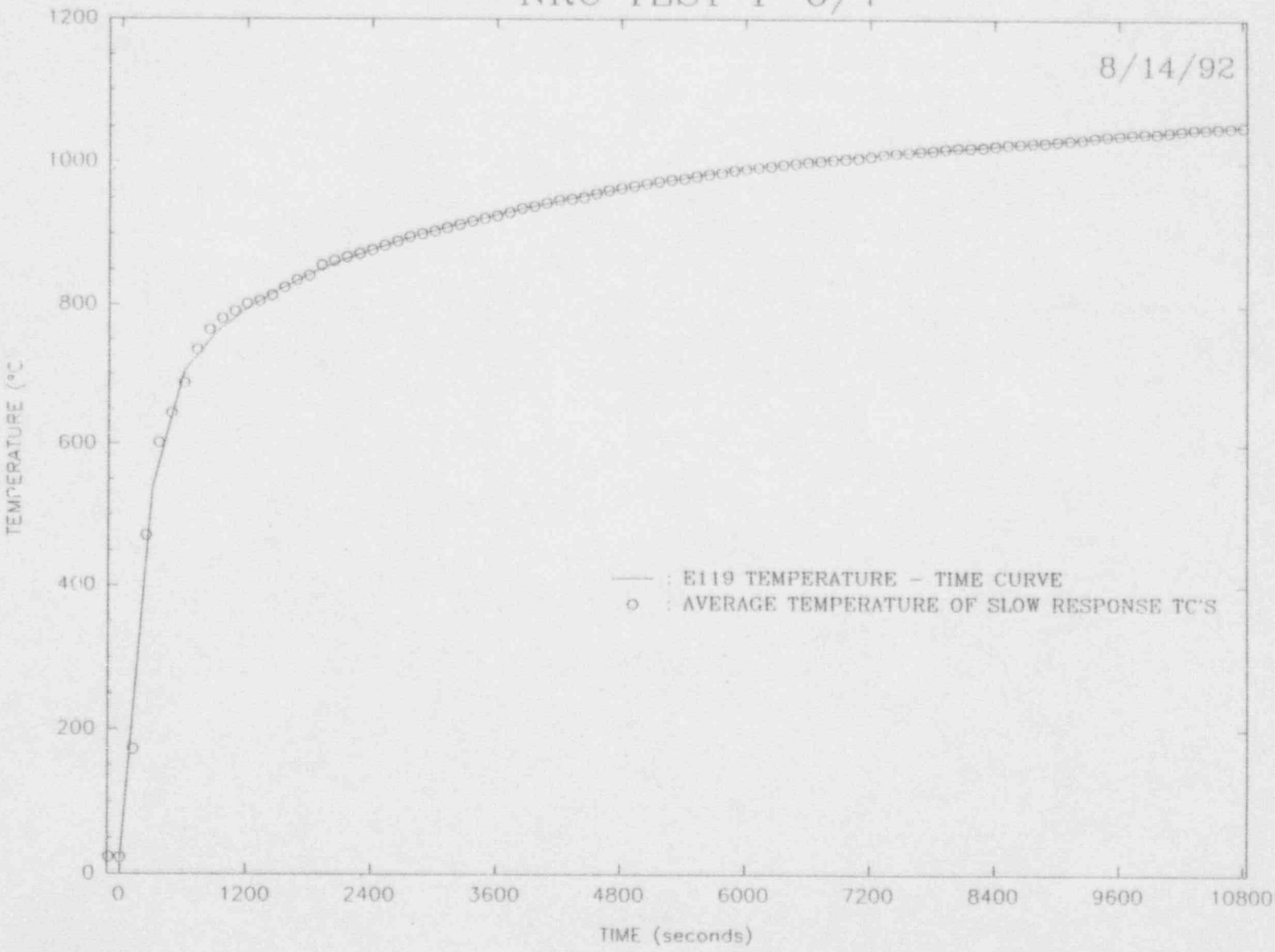

Fig. VII.9. Furnace temperatures, test 1-6/7.

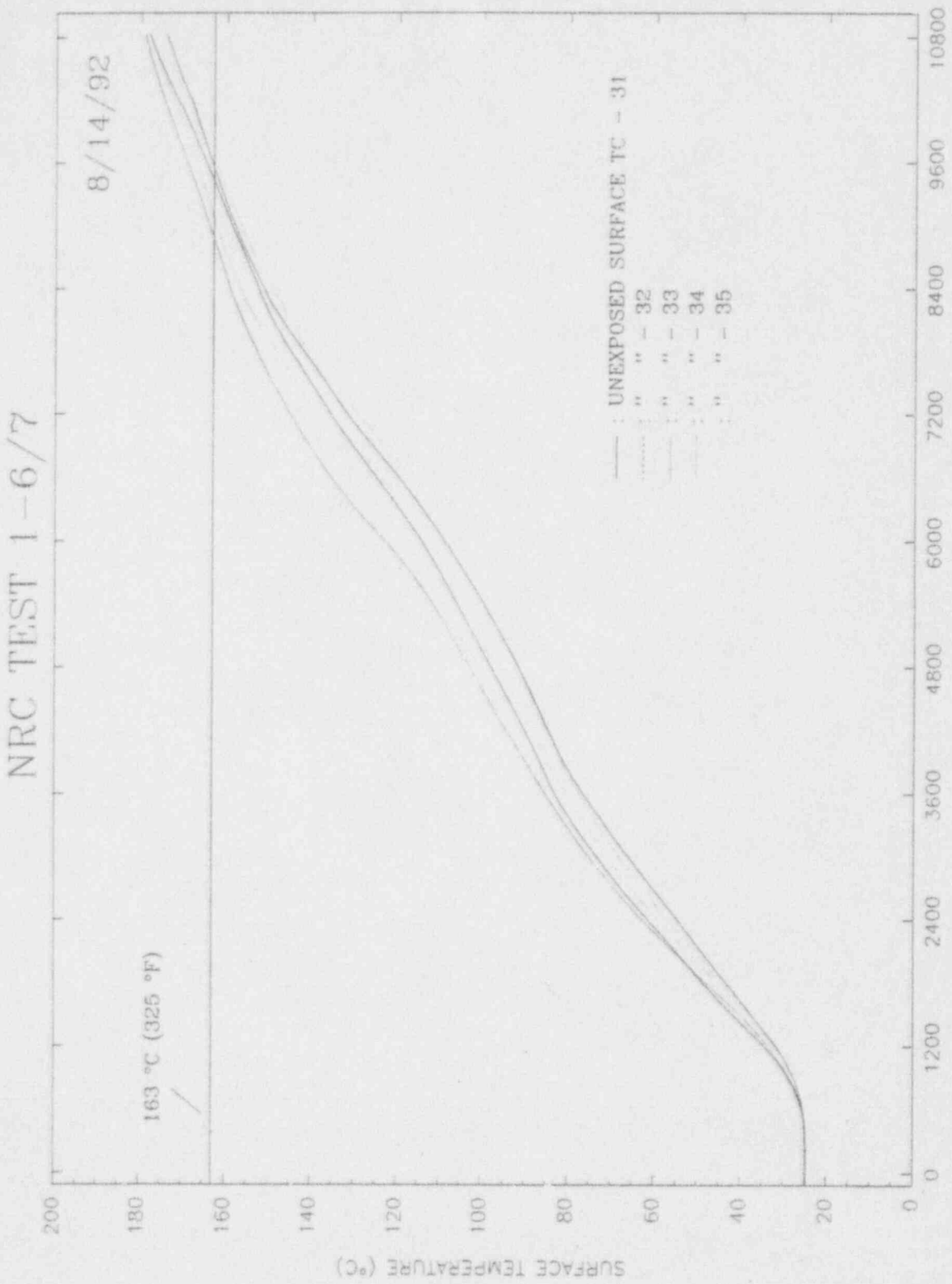

Fig. VII.10. Unexposed surface temperatures, test 1-6/7.

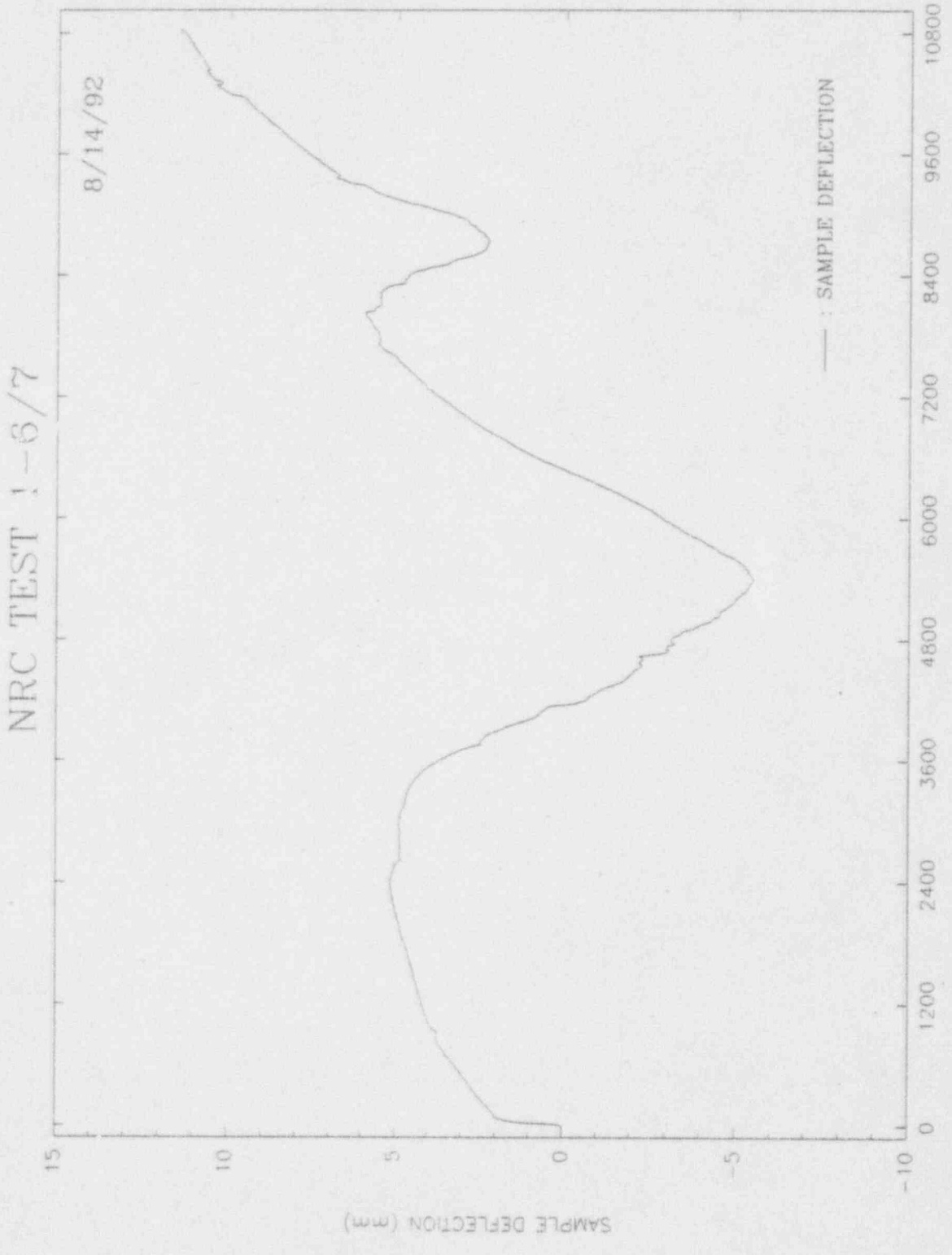

Fig. VII.11. Deflection at center of assembly, test 1-6/7.

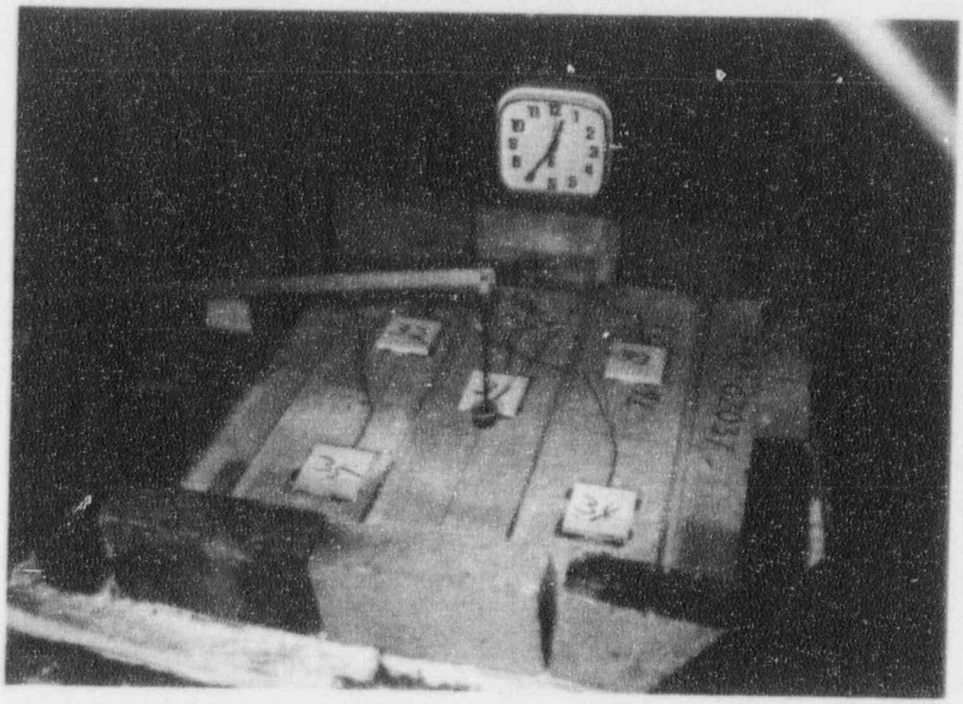

Fig. VII.12. Photograph of unexposed surface during test 1-6/7.

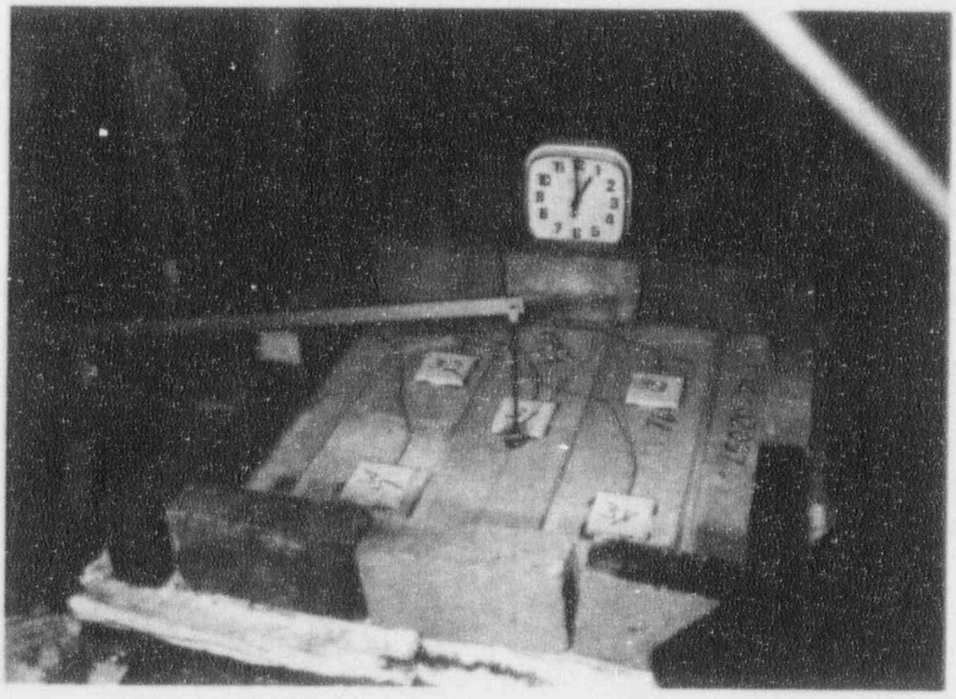

Fig. VII.13. Photograph of unexposed surface during test 1-6/7.

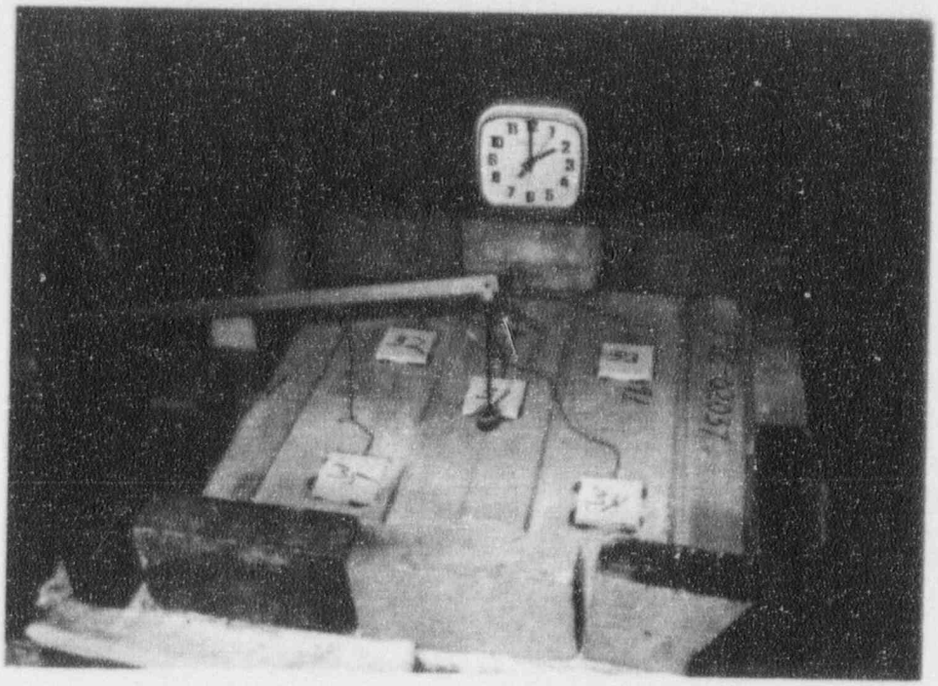

Fig. VII.14. Photograph of unexposed surface during test 1-6/7.

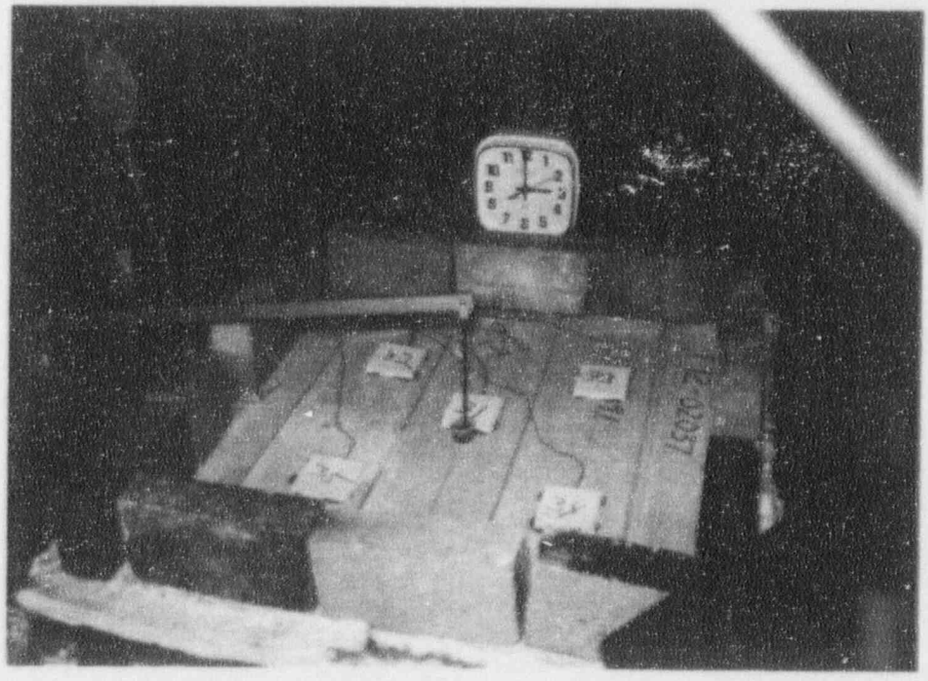

Fig. VII.15. Photograph of unexposed surface during test 1-6/7.

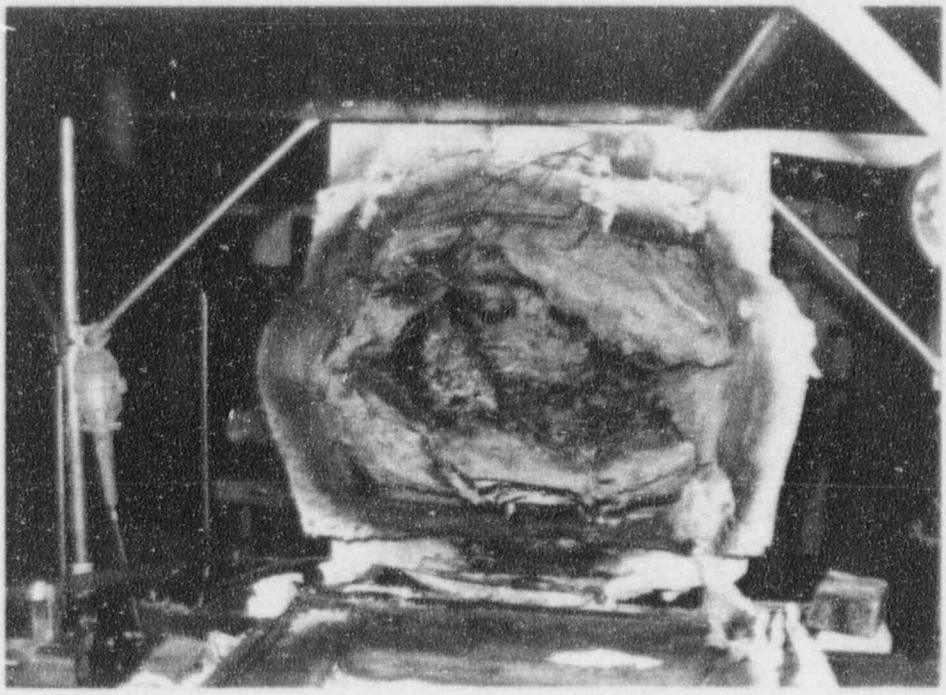

Fig. VII.16. Post-test exposed surface, test 1-6/7.

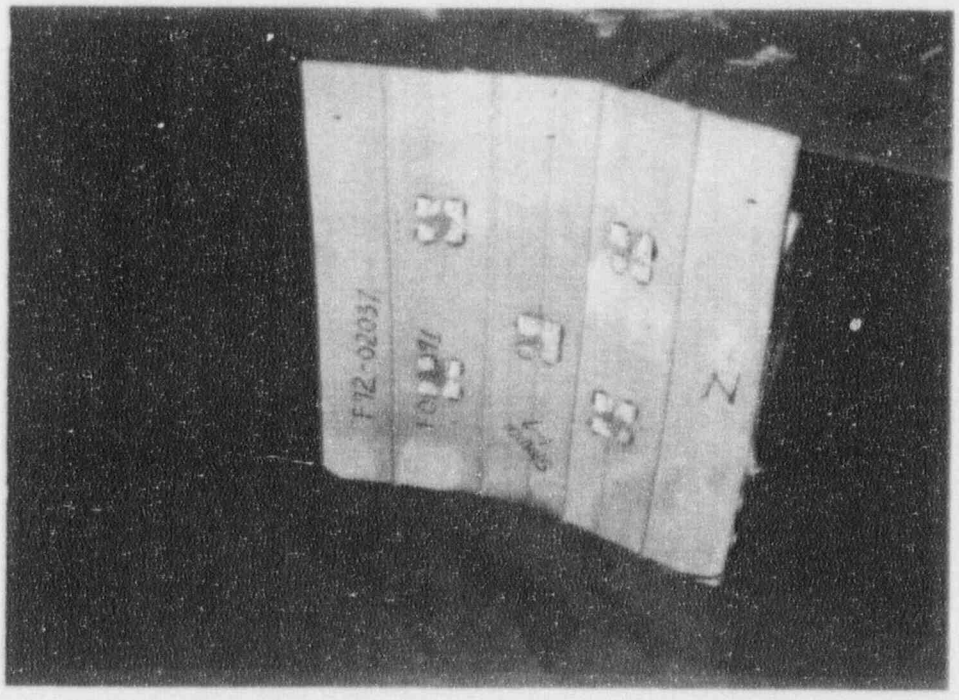

Fig. VII.17. Post-test unexposed surface, test 1-6/7.

VIII. Test G-1

A. Description of Test Assembly

The test assembly consisted of one layer of 16 mm (5/8 in) gypsum board (type SC) attached with drywall screws to both sides of 92 mm (3-5/8 in) steel studs, no insulation in the stud cavity, and no seams on either the exposed or unexposed surfaces. The dimensions of the assembly are shown in Fig. VIII.1. Steel studs framed the perimeter of the assembly and the outer sides of these studs were covered with one layer of gypsum board. The edges of the frame were taped and covered with joint compound. All drywall screws were covered with joint compound.

Letters A, B, and C in Fig. VIII.1 indicate the locations of thermocouples (chromel-alumel, formed from 30 gauge wire) for measuring temperatures at stud-panel interfaces and air temperature in the stud cavity.

The pre-test mass of the assembly was 20.2 kg (44.5 lb) and the moisture content of the gypsum board and dried joint compound at the time of test ranged from 6.3 to 7.5 percent. Pre-test photographs of the assembly are shown in Figs. VIII.2 to VIII.4.

The assembly is shown on the furnace in Fig. VIII.5. The large thickness of the assembly required that its sides be insulated. Nominal 25.4 mm (1 in) thick ceramic fiber insulation was wrapped around the sides and the exterior covered with aluminum foil as shown if Fig. VIII.6. The lower edge of the foil was taped to the furnace with duct tape. The upper edges of the insulation and foil were held in place by the bricks which load the perimeter of the assembly. Both gypsum-board face panels of the test assembly were constrained by the vertical load of the these bricks.

B. Fire Test Procedures and Results

The test was conducted on September 35, 1992 and was witnessed by official observers R. Architzel (NRC) and I. Moghissi (NRC).

The specimen was subjected to a 1-hour fire exposure controlled by the ASTM E 119-88 standard temperature-time curve. Plots of the furnace temperatures recorded by the furnace thermocouples and their average values are presented in Fig. VIII.7 and tabulated in Table VIII.1. The average furnace temperatures and the standard temperature-time curve are shown in Fig. VIII.8.

Unexposed-surface thermocouples measured surface temperatures beneath insulation pads at 5 locations designated 31 to 35 in Fig. VIII.1. The thermocouples at these locations are designated TC31 to TC35, respectively, and their outputs are plotted in Fig. VIII.9 and tabulated in Table VIII.1. Included in the table

are the averages of the unexposed-surface temperatures as a function of time.

Temperatures recorded by interstitial thermocouples A through C (see Fig. VIII.1) are presented in Table VIII.2.

The deflection at the center of the specimen was not measured during this test.

Figures VIII.10 to VIII.13 show the appearance of the unexposed surface during the test. A portion of the lower gypsum-board panel apparently fell into the furnace at 0:30:00 (hr:min:s). Nevertheless, the appearance of the unexposed surface did not change until 0:41:45 when the joint compound over the screw heads on the centerline began to outgas and brown. At 0:54:30 paper on the unexposed face began to brown south of pad 31 and by 0:58:45 the paper along most of the edges of the thermocouple pads was charred. Following shutdown, the unexposed surface continued to crack as the assembly cooled. A log of observations is presented in Table VIII.3.

Figure VIII.14 shows the unexposed surface at about 4:00:00, just prior to the removal of the assembly from the furnace. The paper facing was thoroughly charred underneath all the thermocouple pads as well as at two locations along the eastern edge where the pried-off pads had lain. Paper on most of the remaining area of the unexposed surface was intact.

During the removal of the assembly from the furnace (Fig. VIII.15), the remnants of the lower panel separated from the assembly and remained resting on the sample-support lip (Fig. VIII.16). Most of the exposed area of this panel had fallen into the furnace prior to the specimen-removal process. The mass of the portion of the assembly removed from the furnace (the steel frame, sides and remnants of the top panel) was 9.8 kg (21.6 lb).

C. Analysis of Test Results

The ASTM E 119-88 thermal transmission acceptance criteria are that the average temperature rise of the unexposed-surface thermocouples shall not exceed 139°C (250°F) above its initial temperature (in this test, 24°C [75°F]) and the temperature rise of any of these thermocouples shall not exceed 181°C (325°F) above the initial temperature. Another criterion is that at no time during the test should hot gases or flame pass through the assembly so as to ignite cotton waste held against the unexposed surface. In addition to these criteria, NRC requirements include monitoring the time at which any of the unexposed-surface thermocouples reaches 162.8°C (325°F).

On the basis of the experimental temperature data presented in Table VIII.1, the above temperature criteria were met at the following locations and times:

Criterion	Location	Time (sec)	Time [hr:min:sec]
E 119 avg. unexposed surf. temp. (163°C) [325°F]		3195	[0:53:15]
E 119 peak unexposed surf. temp. (205°C) [401°F]	TC 31	3220	[0:53:40]
NRC unexposed surf. temp., 1st occurrence (162.8°C) [325°F]	TC 31	3165	[0:52:45]

Concerning E 119 criteria, the average temperature was the controlling factor and the E 119 fire-endurance period was 3195 seconds (0:53:15). Since the period was greater than 1/2 hour, a correction was required to account for deviations of the actual average furnace temperature from the standard temperature-time curve (see ASTM E 119-88, Par. 7.4). This correction was +2 s and **the corrected fire-endurance period was 3197 s (53.3 minutes).**

Neither glowing nor flame passage were observed during the test. Post-test inspection at 1:10:00 revealed that the paper on the unexposed face of gypsum board beneath and near the edges of the thermocouple pads was severely charred[13] and flaked away easily. There were cracks below some pads. A dull glow was observed on the exposed gypsum beneath pad 35 during the post-test inspection. The E 119 cotton-waste test was not conducted at any time during or after the test.

It should be noted that Underwriters Laboratories lists such an assembly [1] as having a 1-hr rating <u>when tested as a wall (vertical) assembly</u> with studs 24 in O.C. The G-1 assembly in the current test series was tested in the <u>horizontal orientation</u> and failed the average-unexposed-surface-temperature-rise criterion at 53.3 minutes. This shorter fire endurance for the horizontal assembly relative to a vertical assembly likely is due to the greater gravitational-force moments on the horizontal gypsum panels which lead to somewhat earlier mechanical failure.

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[13]Maximum temperatures are expected to occur beneath pads (see section I.C).

TABLE VIII.1. Temperatures, test G-1.

NRC TEST G-1

TIME	TEMPERATURE (°C)									
	FURNACE				UNEXPOSED SURFACE					
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.
-110	23	23	23	23	24	24	24	24	24	24
-100	23	23	23	23	24	24	24	24	24	24
-90	23	23	23	23	24	24	24	24	24	24
-80	23	23	23	23	24	24	24	24	24	24
-70	23	23	23	23	24	24	24	24	24	24
-60	23	23	23	23	24	24	24	24	24	24
-50	23	23	23	23	24	24	24	24	24	24
-40	23	23	23	23	24	24	24	24	24	24
-30	23	23	23	23	24	24	24	24	24	24
-20	23	23	23	23	24	24	24	24	24	24
-10	23	23	23	23	24	24	24	24	24	24
-1	23	23	23	23	24	24	24	24	24	24
0	23	23	23	23	24	24	24	24	24	24
10	23	23	23	23	24	24	24	24	24	24
20	24	24	24	23	24	24	24	24	24	24
30	26	27	27	26	24	24	24	24	24	24
40	32	31	32	31	24	24	24	24	24	24
50	41	38	41	40	24	24	24	24	24	24
60	55	48	52	51	24	24	24	24	24	24
70	71	59	66	65	24	24	24	24	24	24
80	91	72	82	81	24	24	24	24	24	24
90	113	87	100	100	24	24	24	24	24	24
100	137	103	120	120	24	24	24	24	24	24
110	163	123	140	141	24	24	24	24	24	24
120	189	141	161	164	24	24	24	24	24	24
130	217	166	183	188	24	24	24	24	24	24
140	245	189	206	213	24	24	24	24	24	24
150	275	213	230	238	24	24	24	24	24	24
160	305	238	255	265	24	24	24	24	24	24
170	334	264	281	293	24	24	24	24	24	24
180	363	291	308	320	24	24	24	24	24	24
190	391	317	333	346	24	24	24	24	24	24
200	417	343	359	372	24	24	24	24	24	24
210	442	368	384	397	24	24	24	24	24	24
220	465	393	407	422	24	24	24	24	24	24
230	487	417	430	444	24	24	24	24	24	24
240	507	439	450	465	24	25	25	24	24	24
250	525	459	468	484	24	25	25	24	25	25
260	542	477	485	501	24	25	25	25	25	25
270	556	494	500	517	25	25	25	25	25	25
280	569	509	514	530	25	25	25	25	25	25
290	580	523	526	543	25	25	25	25	25	25
300	591	535	538	554	25	26	26	25	25	25

TABLE VIII.1. Temperatures, test G-1. (cont.).

NRC TEST G-1

TIME	TEMPERATURE (°C)									
	FURNACE				UNEXPOSED SURFACE					
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.
360	637	592	591	607	26	28	27	27	27	27
420	664	625	624	637	28	30	30	30	30	30
480	679	644	644	655	31	33	32	33	32	32
540	693	661	660	671	33	36	35	36	35	35
600	710	679	679	689	35	39	38	39	38	38
660	732	703	702	712	38	41	41	42	40	40
720	753	727	725	735	40	44	43	45	43	43
780	767	742	740	749	42	46	45	47	45	45
840	777	753	751	760	44	49	48	50	48	48
900	784	760	759	767	46	51	50	53	50	50
960	791	768	767	775	48	53	52	55	52	52
1020	799	776	775	783	50	55	54	57	54	54
1080	805	784	783	790	52	57	56	59	56	56
1140	810	789	789	795	54	59	58	61	58	58
1200	815	795	796	801	55	60	59	63	60	59
1260	819	800	801	806	57	62	61	64	61	61
1320	819	801	802	807	58	64	62	66	63	62
1380	822	804	805	810	60	65	63	67	65	64
1440	828	810	811	816	62	67	65	69	66	66
1500	834	816	817	822	65	69	67	71	69	68
1560	838	820	821	826	67	72	69	73	71	70
1620	840	823	825	828	70	74	72	76	73	73
1680	844	827	829	833	73	76	74	78	75	75
1740	850	834	836	839	76	78	76	80	77	77
1800	856	839	841	845	78	78	77	80	78	78
1860	858	843	845	848	79	79	77	81	79	79
1920	862	846	847	851	81	80	78	82	80	80
1980	865	849	851	854	82	82	80	83	81	82
2040	868	853	854	858	83	83	82	84	83	83
2100	872	857	858	862	85	85	84	85	84	85
2160	875	861	862	866	86	86	85	86	85	86
2220	873	856	857	861	89	89	89	91	89	89
2280	876	856	856	862	92	91	92	93	90	92
2340	871	858	859	862	94	93	94	94	92	94
2400	884	874	880	878	97	96	96	96	94	96
2460	882	874	874	876	98	98	99	97	96	98
2520	887	879	878	881	100	100	101	100	98	100
2580	894	887	887	889	103	103	104	102	101	103
2640	897	889	888	891	106	106	107	105	103	105
2700	899	891	888	892	109	109	110	109	106	109
2760	902	894	891	895	112	113	113	112	109	112
2820	905	897	896	899	116	116	115	116	113	115

TABLE VIII.1. Temperatures, test G-1. (cont.).

NRC TEST G-1

TIME	TEMPERATURE (°C)									
	FURNACE				UNEXPOSED SURFACE					
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.
2880	908	900	899	902	119	119	118	120	116	119
2940	911	903	901	905	122	122	121	123	119	121
3000	913	903	902	905	125	125	124	126	121	124
3060	915	904	904	907	131	129	128	129	124	128
3120	917	907	907	910	142	137	137	136	128	136
3150	919	909	908	912	155	144	146	139	132	143
3160	920	909	909	912	160	149	151	141	133	147
3170	921	910	909	913	166	154	156	143	134	150
3180	921	910	910	913	173	157	160	147	136	155
3190	922	911	910	914	182	162	165	152	137	160
3200	922	911	911	914	189	169	174	156	140	166
3210	923	912	911	915	197	178	183	161	143	172
3220	923	912	912	915	205	186	191	164	147	178
3230	924	913	913	916	212	193	199	170	151	185
3240	924	913	913	916	219	201	207	177	156	192
3250	925	913	913	917	226	208	215	185	160	199
3260	925	914	914	917	234	216	222	193	167	206
3270	925	914	914	917	241	223	230	200	174	214
3280	926	914	914	917	248	230	237	207	182	221
3290	926	914	914	917	256	238	244	214	190	228
3300	926	914	914	917	264	245	252	220	197	236
3310	926	914	914	918	273	253	260	227	204	243
3320	926	914	914	918	282	261	269	234	211	251
3330	926	914	914	918	291	269	277	240	218	259
3340	927	914	914	918	301	278	286	247	225	267
3350	927	914	915	918	311	287	296	253	231	276
3360	927	915	915	919	322	296	306	260	238	285
3370	927	915	915	919	332	306	316	267	245	294
3380	927	915	916	919	344	316	327	275	253	303
3390	927	915	916	919	357	326	337	282	260	312
3400	928	915	916	919	371	336	349	290	268	323
3410	928	916	916	919	384	347	362	298	276	333
3420	928	916	917	919	397	359	376	306	285	345
3430	928	916	917	920	409	372	390	315	294	356
3440	929	916	917	920	419	385	403	323	303	367
3450	929	917	917	921	429	396	414	332	313	377
3460	930	917	918	921	439	407	424	342	322	387
3470	930	917	918	922	447	416	434	351	332	396
3480	931	918	919	922	455	425	442	362	342	405
3490	932	919	920	923	463	433	451	372	353	414
3500	933	920	920	924	470	440	458	383	365	423
3510	933	921	921	924	477	448	465	394	378	432

TABLE VIII.1. Temperatures, test G-1. (cont.).

NRC TEST G-1

TIME	TEMPERATURE (°C)									
	FURNACE				UNEXPOSED SURFACE					
Sec	S.R.1	S.R.2	S.R.3	AVG.	LOC.31	LOC.32	LOC.33	LOC.34	LOC.35	AVG.
3520	934	921	922	925	484	455	472	404	391	441
3530	934	922	922	926	494	462	479	413	402	450
3540	935	923	923	926	497	468	485	421	413	457
3550	936	924	923	927	501	474	491	429	422	463
3560	936	924	924	928	504	481	496	436	430	470
3570	937	925	925	928	508	486	502	443	438	476
3580	937	925	925	929	512	492	508	450	445	481
3590	938	926	926	929	516	498	513	456	452	487
3600	938	926	926	930	520	503	518	462	459	492
3610	938	927	927	930	523	509	523	468	465	498
3620	935	924	924	927	527	514	528	474	472	503

TABLE VIII.2. Temperatures in stud cavity, test G-1.

Location	(see Fig. VIII.1) A	B	C
Time [s]	Temperature [°C]		
0	22	22	22
300	36	45	75
600	58	63	88
900	68	82	97
1200	76	97	121
1500	90	138	176
1800	165	221	297
2100	195	269	327
2400	356	607	696
2700	737	760	796
3000	799	798	808
3300	822	818	825
3600	831	838	859

TABLE VIII.3. Observations, test G-1.

The following observations were made during the test:

Time	
0:15:30	No obvious changes to unexposed surface.
0:20:00	No outgassing. No discoloration.
0:30:00	Still no change in appearance of unexposed surface. No outgassing. "Thump" in furnace (gyp. bd. fell?).
0:40:00	Still no discoloration or outgassing.
0:41:45	Outgassing starting at screw heads on centerline.
0:46:00	Only change on unexposed surface is the darkening of the joint compound over the screw heads. Moisture is venting from the cavity at the point on the N. side where the TC wires emerge from the cavity.
0:54:30	Outgassing around thermocouple pad 31. Paper is browning S. of 31.
0:55:00	Paper is darkening S. of 31.
0:56:00	Strong outgassing. Brown areas are extending.
0:57:30	Charred paper on the S. side of 31 is lifting.
0:57:45	Darkening on W. side of 32.
0:58:45	Paper is scorched at most pad edges.
1:00:00	Shutdown.
1:03:15	Water sprayed on unexposed surface in attempt to delay collapse.
1:10:	Pads come off easily. Cracks beneath all pads. Dull glow beneath 35.
1:27:00	Cracking continues.
4:05:00	Cracked gyp. bd. on exposed surface located at 33 fell into furnace since last entry. Test assembly removed from furnace. As the assembly was lifted the remnants of the lower panel separated and stayed resting on the furnace lip.

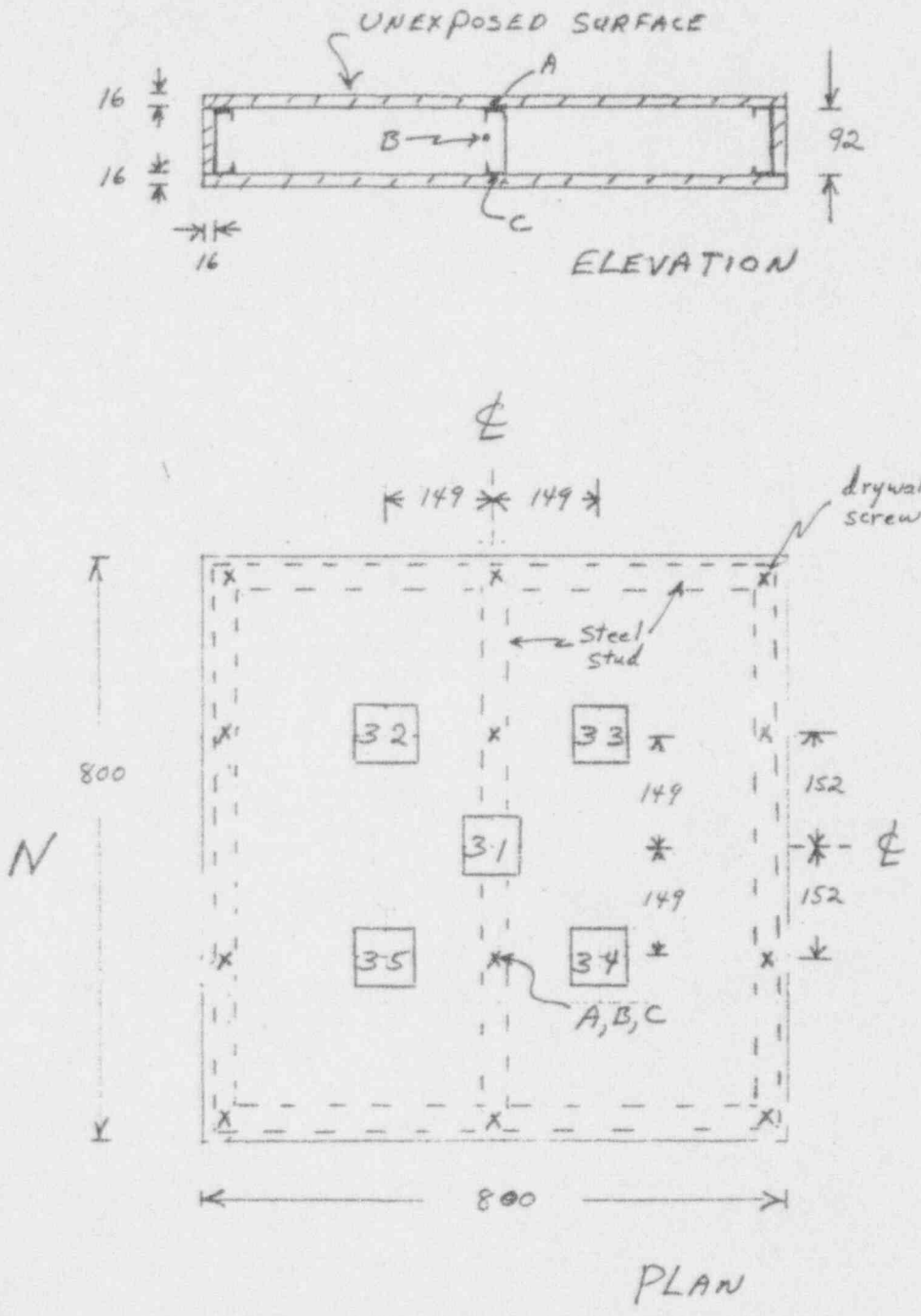

Fig. VIII.1. Dimensions of assembly, test G-1.

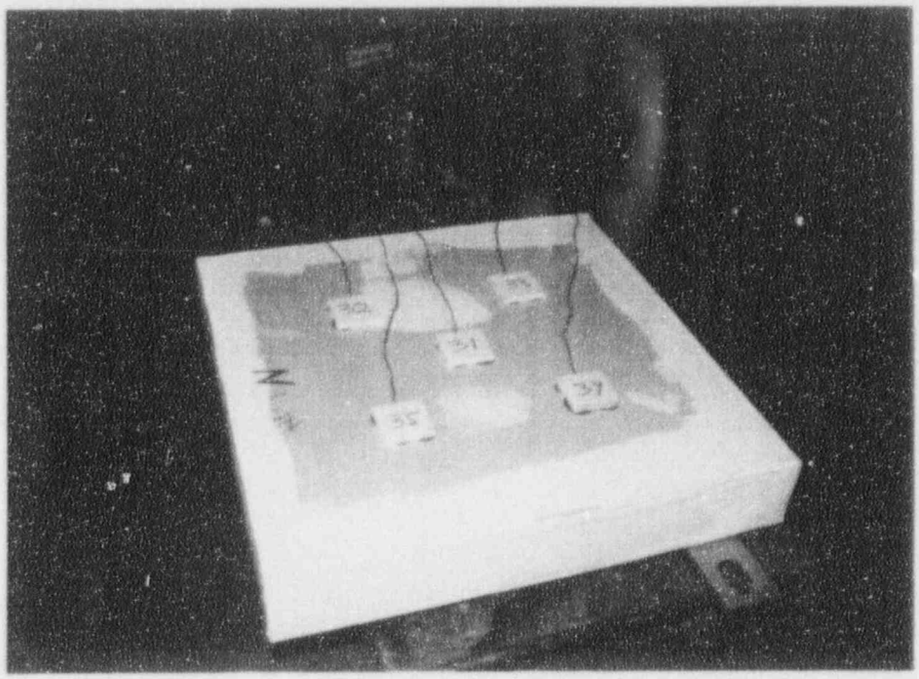

Fig. VIII.2. Pre-test unexposed surface, test G-1.

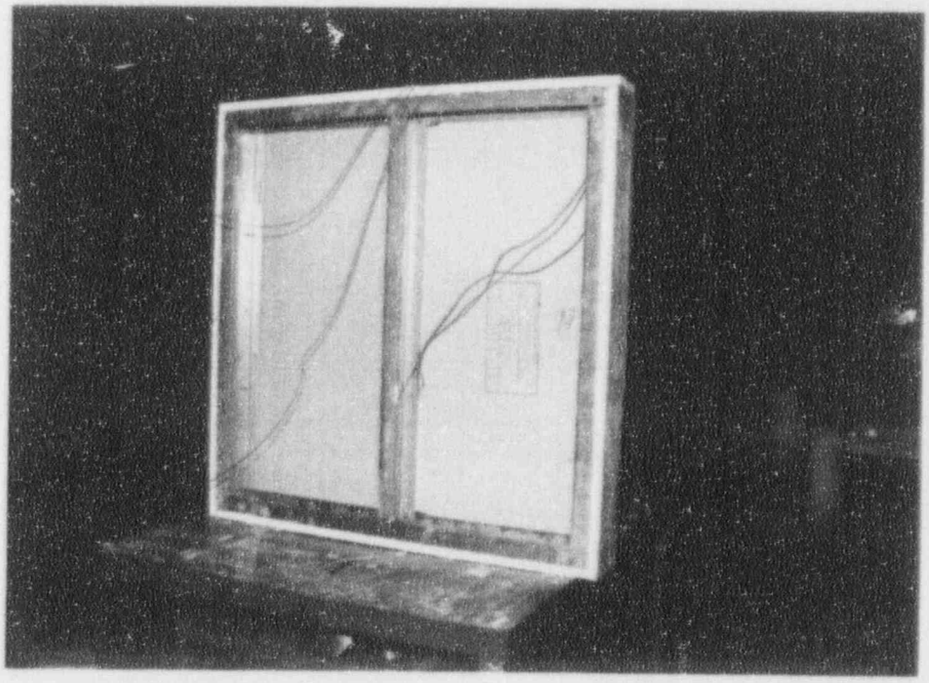

Fig. VIII.3. Pre-test view of assembly prior to attachment of lower (exposed) panel.

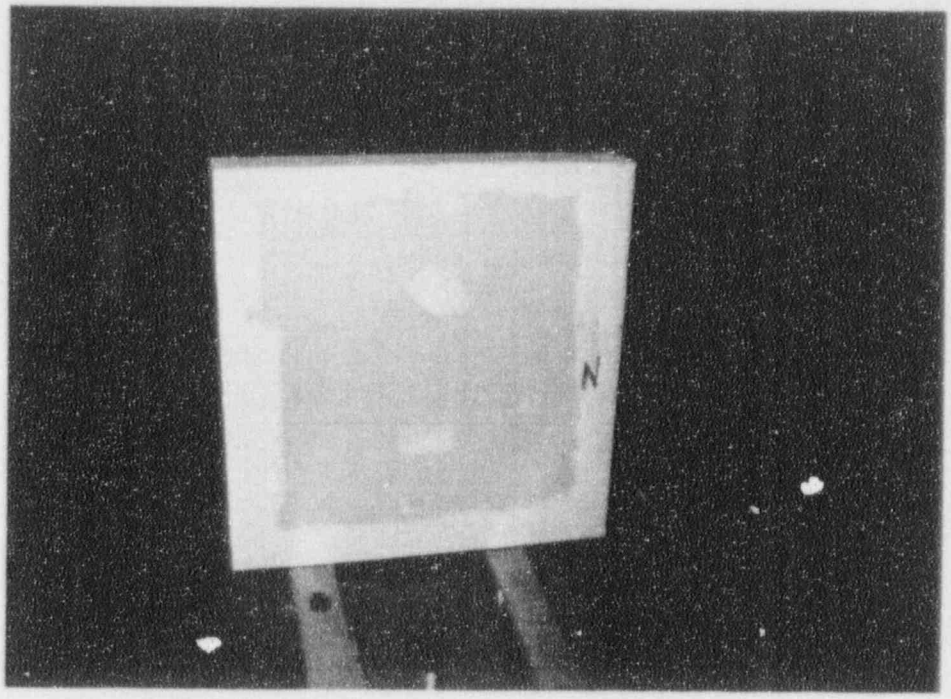

Fig. VIII.4. Pre-test exposed face of assembly, test G-1.

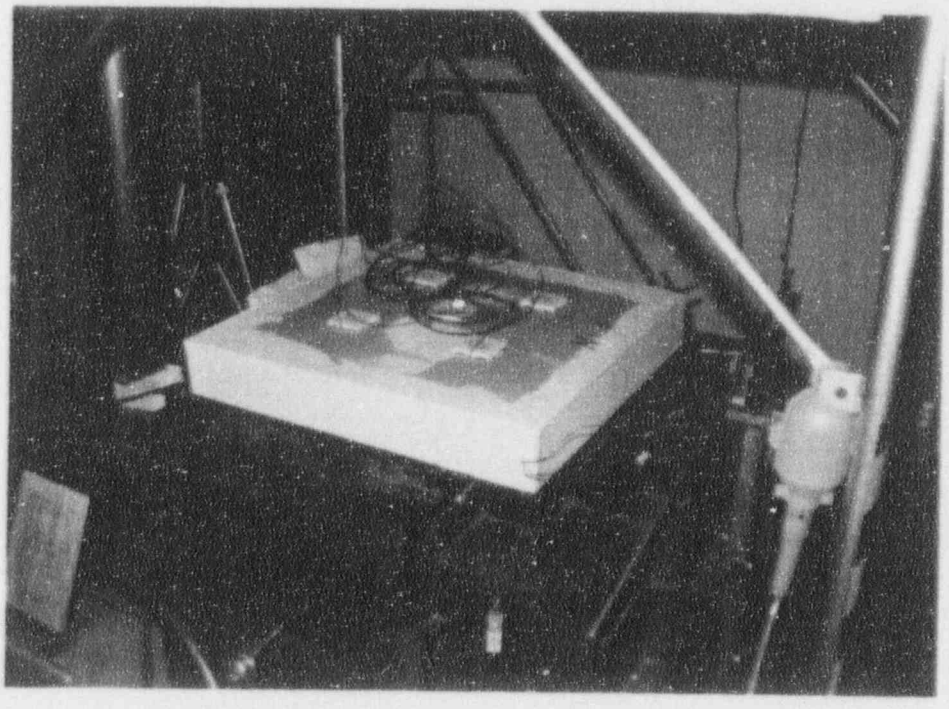

Fig. VIII.5. Test assembly on furnace prior to installation of edge insulation, test G-1.

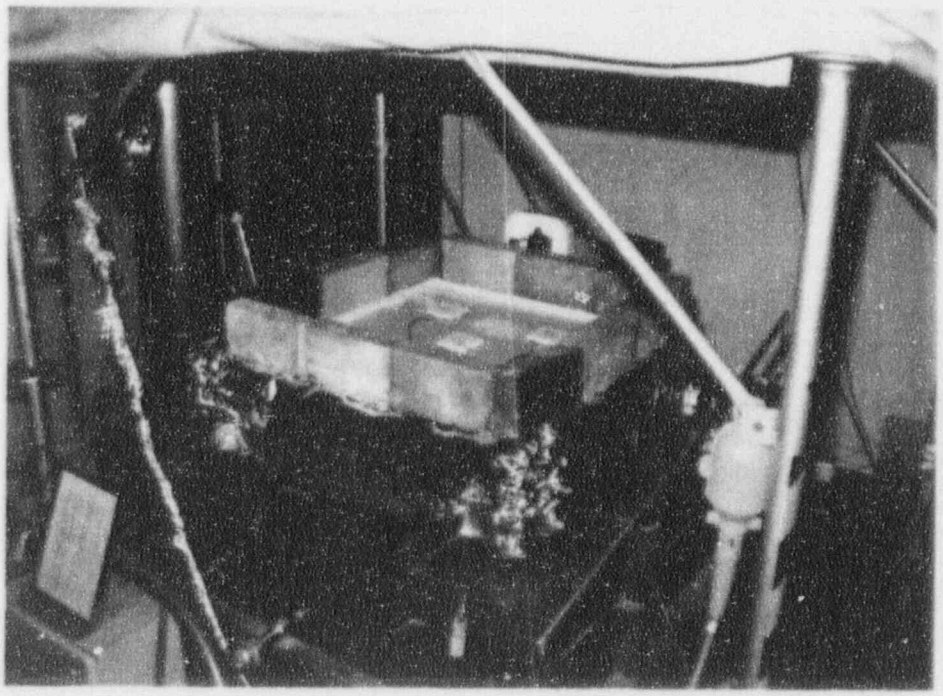

Fig. VIII.6. Test assembly with edge insulation and aluminum foil covering in place, test G-1.

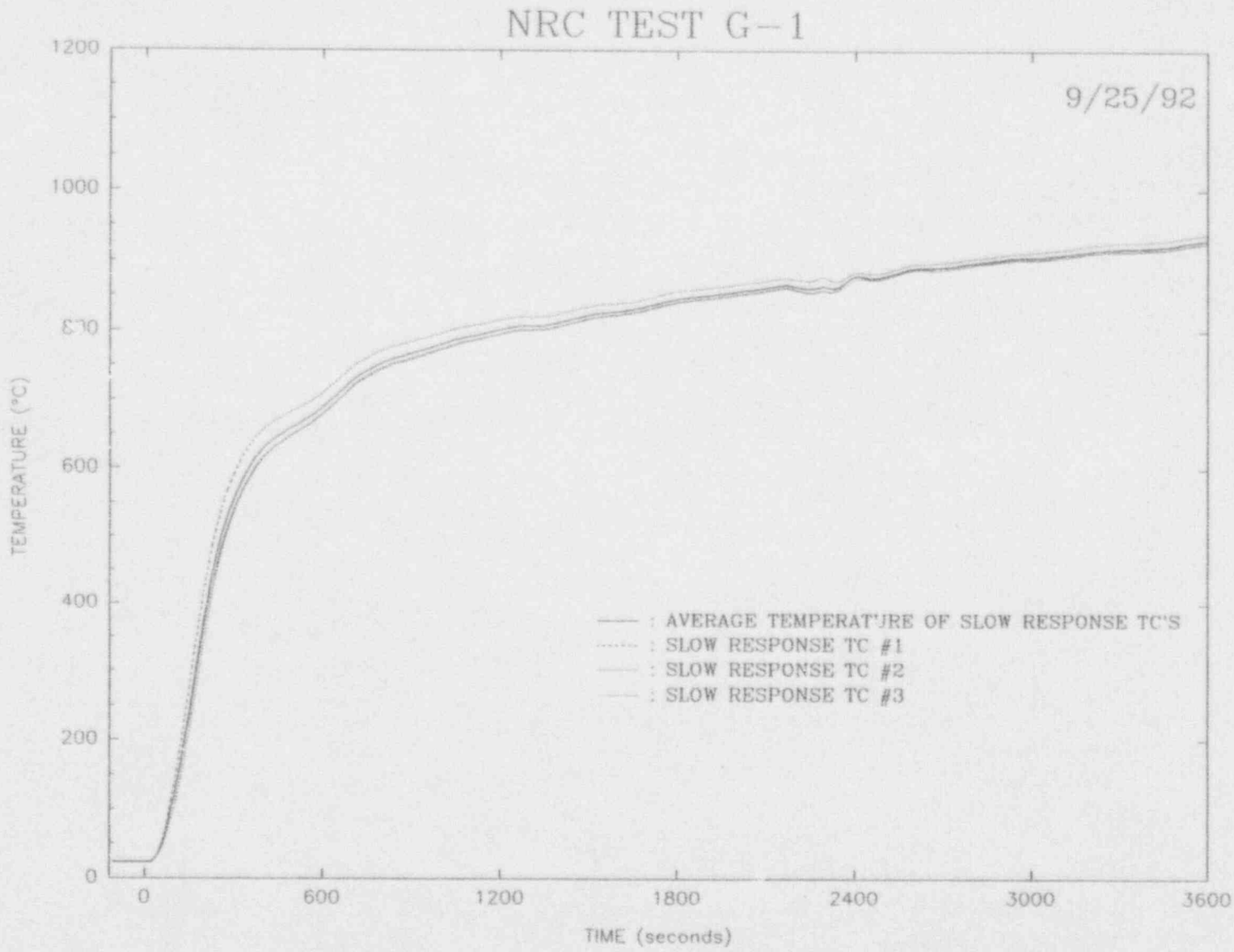

Fig. VIII.7. Furnace temperatures, test G-1.

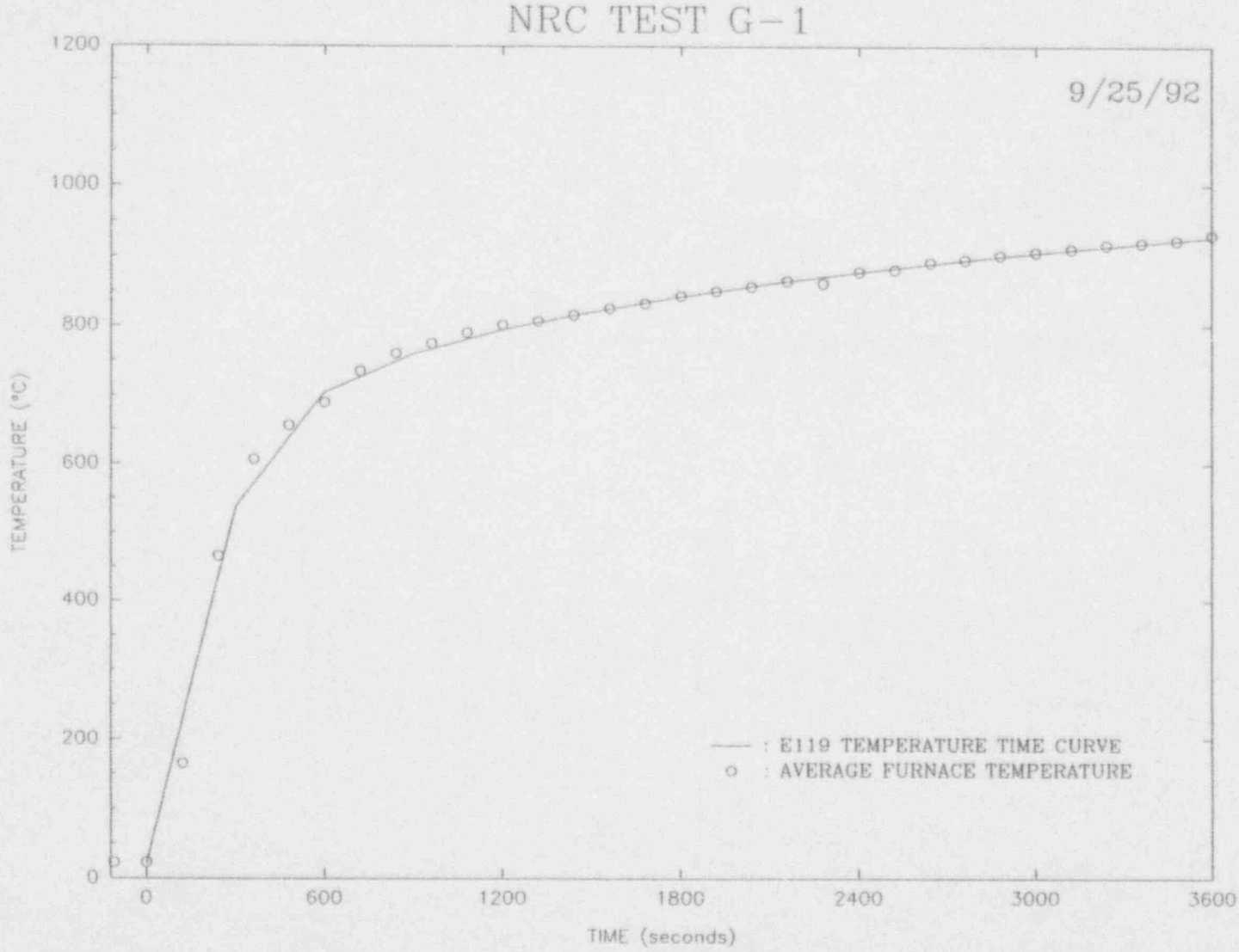

Fig. VIII.8. Furnace temperatures, test G-1.

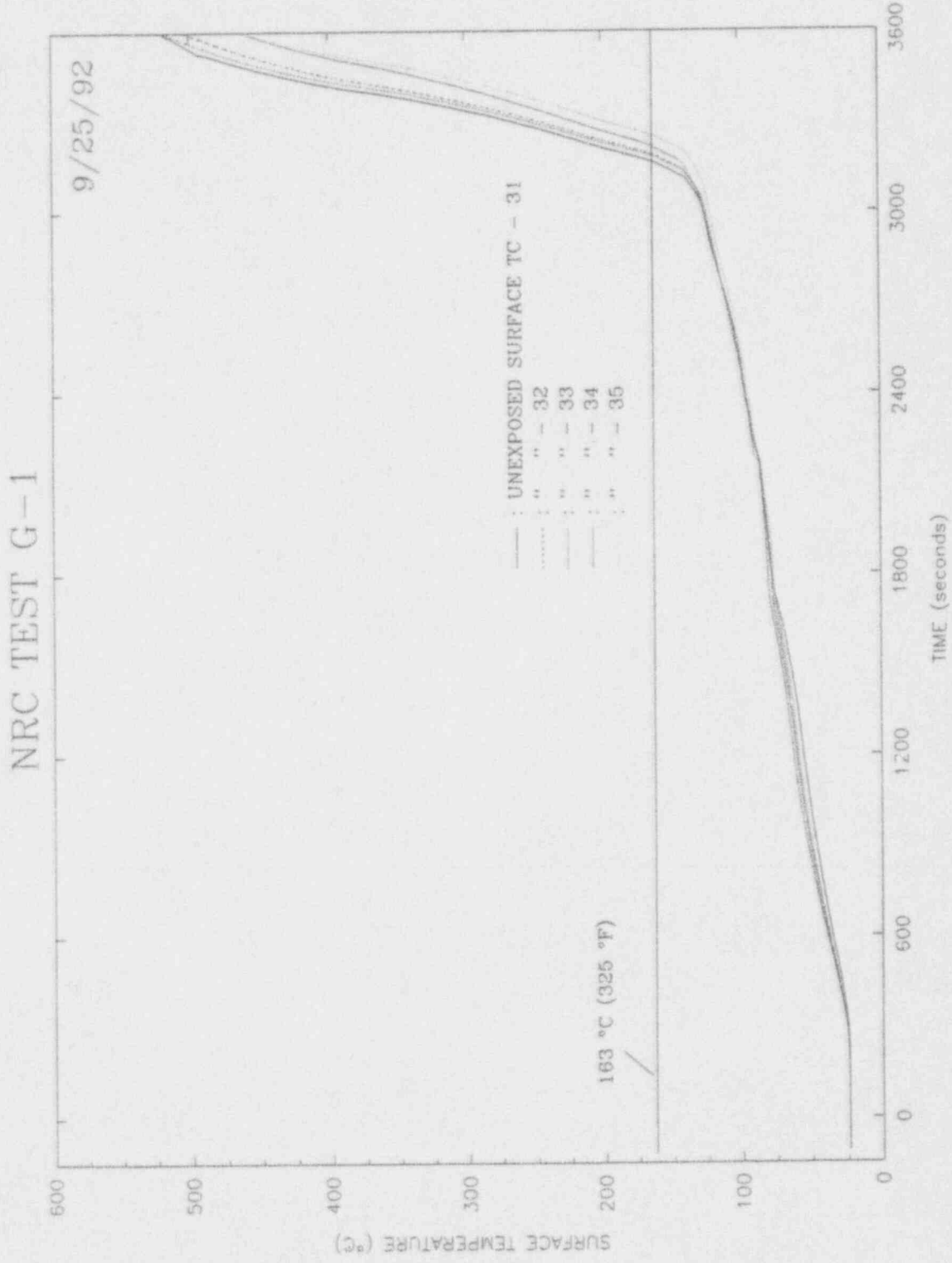

Fig. VIII.9. Unexposed surface temperatures, test G-1.

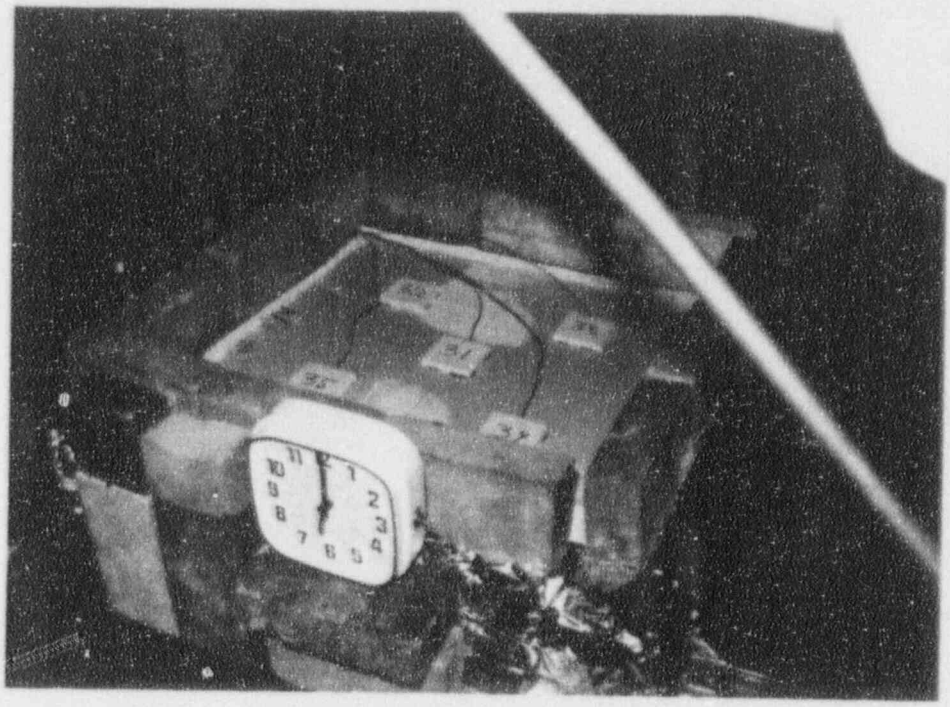

Fig. VIII.10. Photograph of unexposed surface during test G-1.

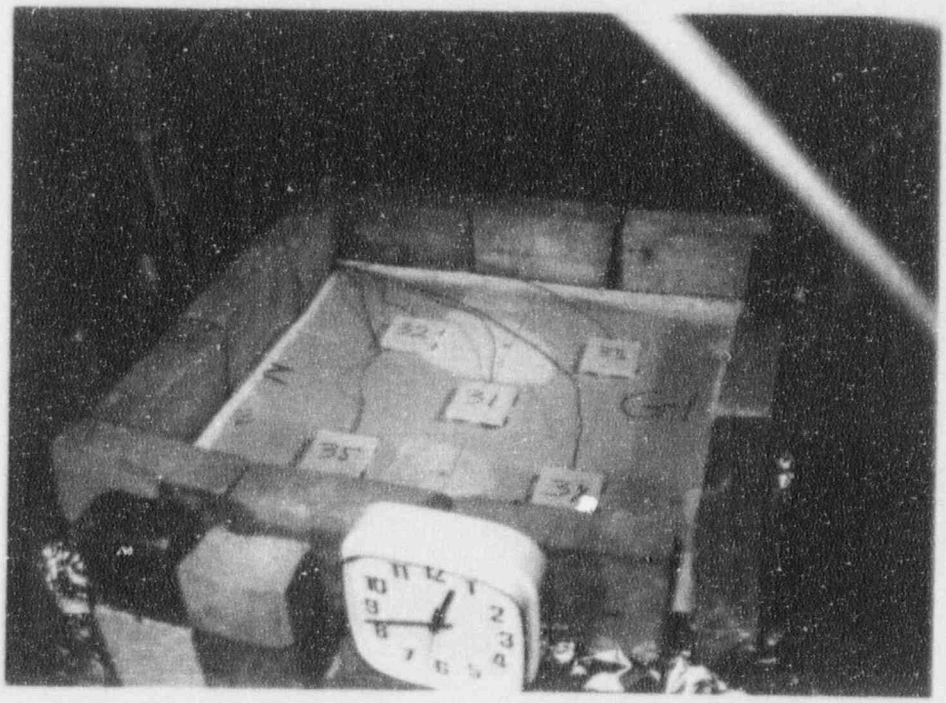

Fig. VIII.11. Photograph of unexposed surface during test G-1.

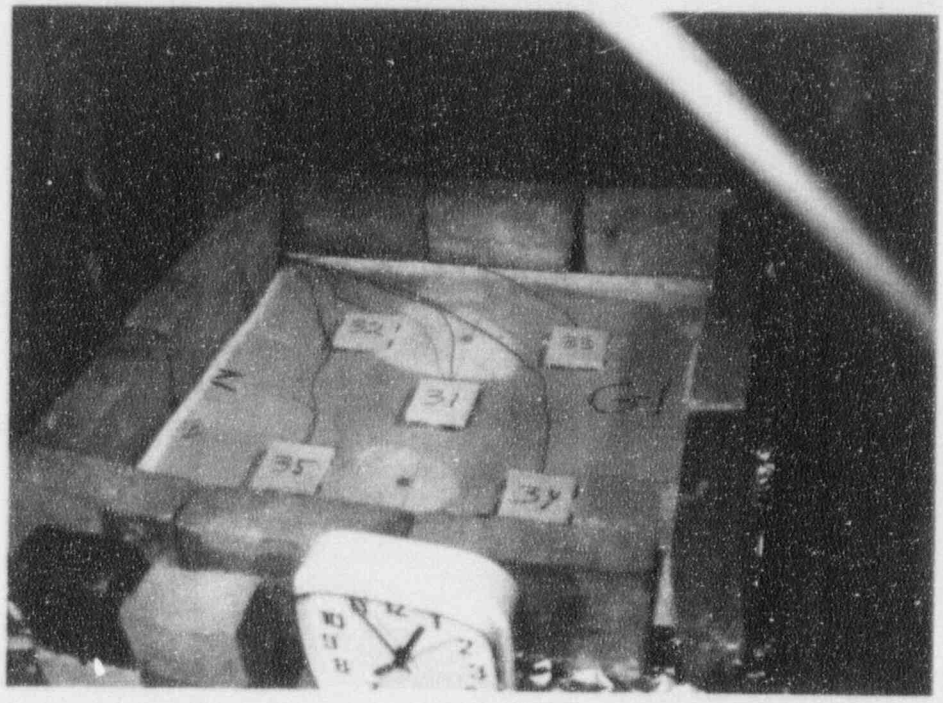

Fig. VIII.12. Photograph of unexposed surface during test G-1.

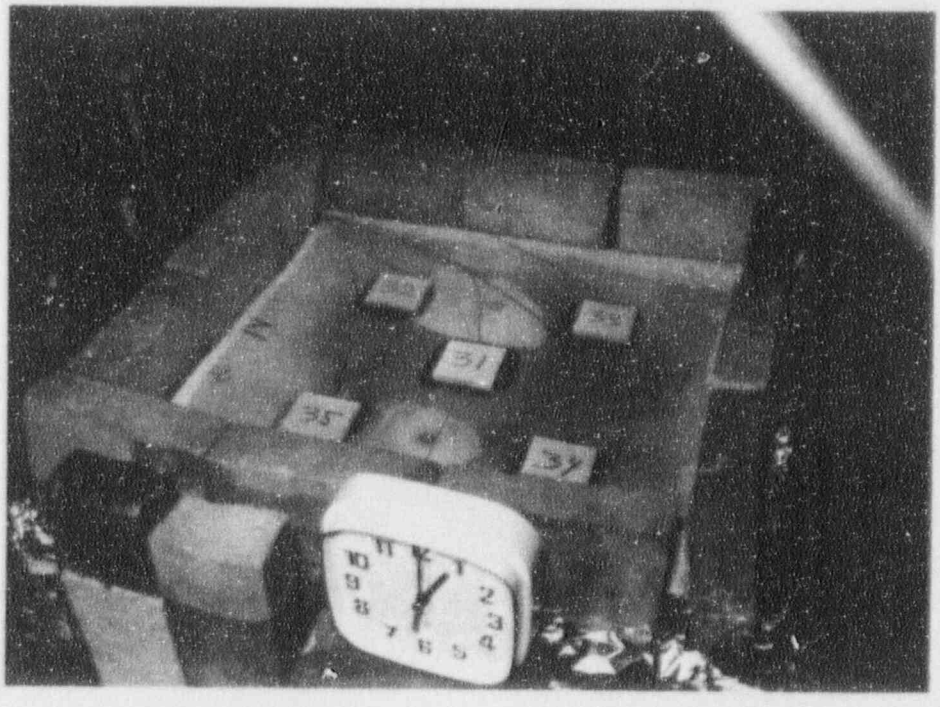

Fig. VIII.13. Photograph of unexposed surface during test G-1.

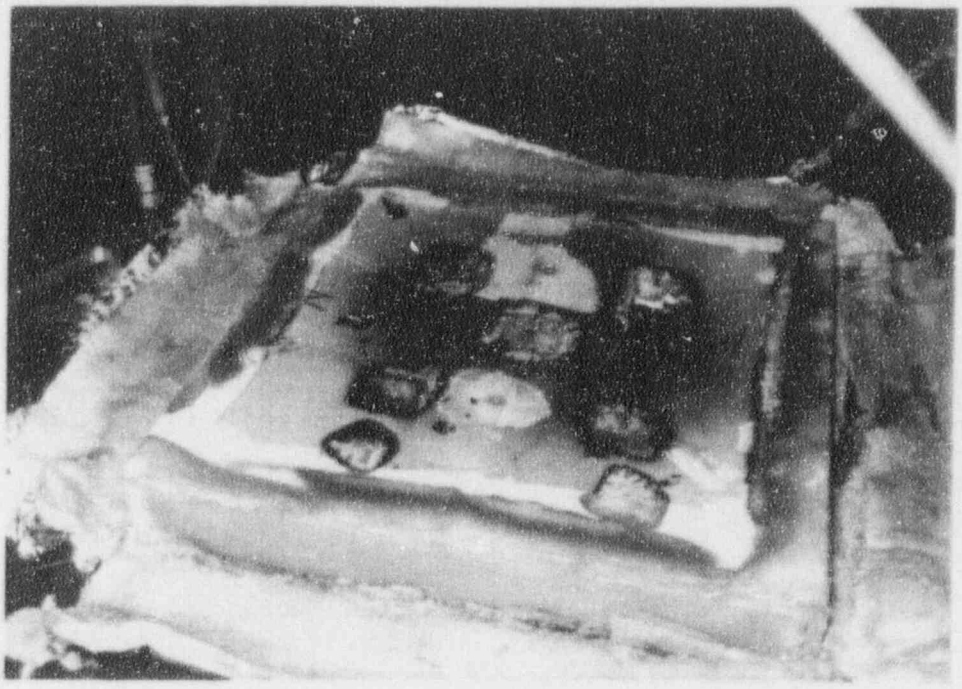

Fig. VIII.14. Post-test unexposed surface, test G-1.

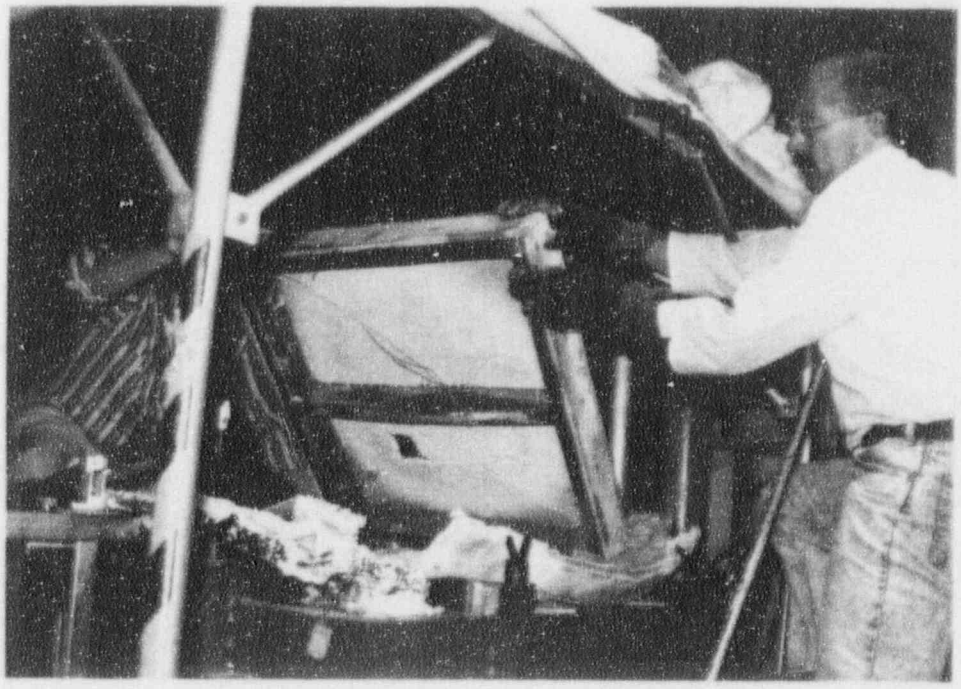

Fig. VIII.15. Removing assembly from furnace, test G-1.

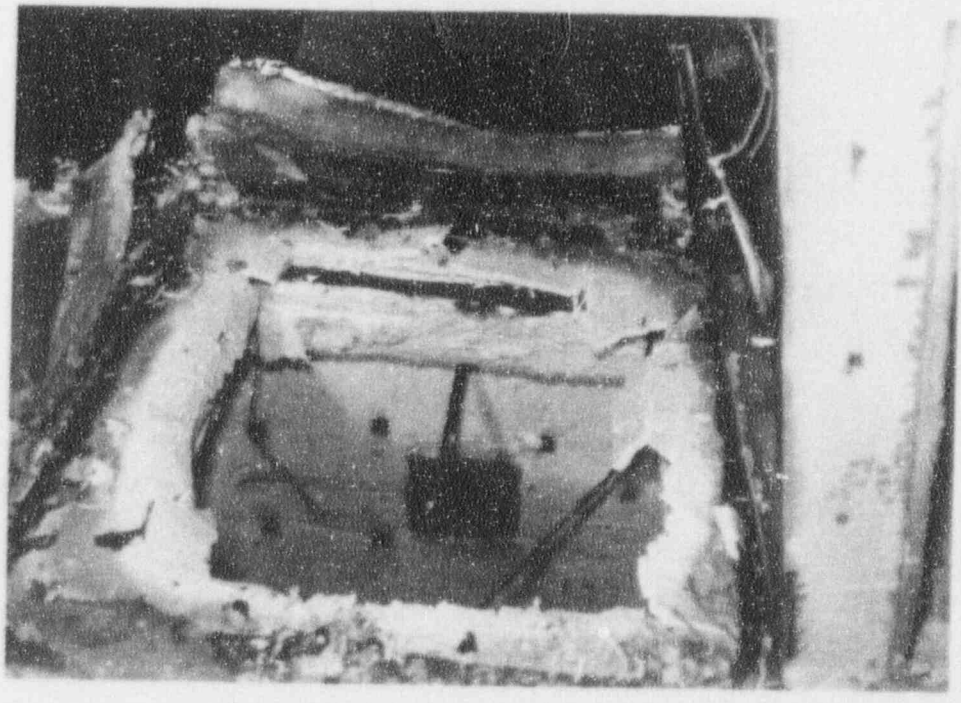

Fig. VIII.16. Remnants of lower panel on furnace lip.

IX. Test 1T-1

A. Description of Test Assembly

The test assembly consisted of a single sheet of NRC-supplied 1-hour subliming fire-barrier panel mounted horizontally in the top opening of the test furnace with the barrier's wire-mesh ribbed surface facing upward. A 0.30 m (nominal 12 in) wide steel cable tray, with cables was set atop the fire barrier panel. **The sides, top, and ends of the tray were insulated to produce a first-cut (but still less severe) approximation of the heating of the cable-tray assembly on all sides.**

The fire-barrier panel is manufactured with a "flat" face, a ribbed face, and wire mesh covering only the ribbed face. The fire-barrier specimen, designated sample 1T-1, was cut to the dimensions shown in Fig. IX.1 from a panel labeled by the manufacturer as F9-20300i and F080891. None of the wire mesh was removed.

Figure IX.1 shows a total of 33 off-rib thicknesses of the specimen along the perimeter, at the center, and beneath the surface thermocouples (insulation pads were not used). Measurements were not made at locations marked as quality control measurement points by the manufacturer. The thickness data can be summarized as follows:

	Off-Rib Thickness (mm [in])			
	avg.	std. dev.	max.	min.
perimeter, ctr., & beneath TCs	17 [0.68]	1.6 [0.063]	21 [0.83]	15 [0.59]

Thicknesses at ribs ranged from 22 to 29 mm (0.87 to 1.1 in). The pre-test mass of the fire-barrier specimen was 7.50 kg (16.5 lb). Pre-test photographs of the exposed and unexposed surfaces of the specimen are shown in Figs. IX.2 and IX.3.

Since this specimen was smaller than the opening in the furnace, an insulated steel "mask" (Figs. IX.4 and IX.5) was installed in the sample frame (Fig. IX.6). The mask consisted of a 793.8 x 793.8 x 4.76 mm (31.25 x 31.25 x 0.1875 in) cold rolled steel plate with two 356 x 314 mm (14.0 x 12.4 in) cutouts separated by a 13 mm (0.50 in) wide steel strip along the east-west centerline. Except for the central steel strip, the surfaces and exposed edges of the plate were insulated with nominal 25.4 mm (1 in) ceramic fiber batting. The central steel strip was provided to approximate a steel band support which is used in actual field installations.

The fire-barrier specimen and cable tray were installed atop the mask as shown in Figs. IX.7 to IX.12. The barrier panel was tested with its ribbed surface as the unexposed surface (facing upward) and with the wire mesh covering unaltered; i.e., the entire upper

face was covered by the wire mesh. Consequently, the upper (the only) wire mesh was constrained by the vertical load of the bricks located along the eastern and western edges of the specimen. The 0.30 m (nominal 12 in) wide steel cable tray contained one full layer of cables (12 instrumentation and 16 power-and-control cables). A single, bare, 14-gauge, copper wire was attached along the north-south centerline to the underside of the rungs with 28-gauge nickel-chromium bare wire. The sides, top, and ends of the tray were insulated with a nominal 25.4 mm (1 in) thick ceramic fiber blanket backed with 1/2 in (12.7 mm) gypsum board. Joints between the gypsum-board panels were sealed with duct tape.

Two types of cables were used in the test assembly: a two-conductor 14-gauge power-and-control cable with cross-sectional dimensions 6.6 x 9.9 mm (0.26 x 0.39 in) and a three-conductor, 16-gauge, 11 mm (0.43 in) diameter instrumentation cable. NRC provided these cables as well as the steel cable tray.

a. Thermocouple locations and means of attachment

A key to the locations of the 39 thermocouples in the test assembly is presented in Table IX.1 and Figs. IX.1, IX.13, and IX.14. Thermocouples were attached to the unexposed surface of the fire-barrier specimen **without the use of insulating pads**. An awl was used to make short slits immediately beneath the wire mesh at the 5 TC locations identified in Fig. IX.1. Thermocouple junctions (formed from 0.25 mm [0.010 in] chromel and alumel wires) were placed in these holes and then covered with a thin layer of trowel-grade fire-barrier material which was allowed to dry for at least 24 hours prior to the test.

Tray temperatures were measured with thermocouples secured with sheet-metal screws at the locations identified in Fig. IX.13. The measuring junctions were squeezed between the tray and the heads of these screws.

It should be noted that there is no standard method for attaching thermocouples to wires or cables. This test provided an opportunity to try several techniques and compare results.

Attempts to spot-weld thermocouples to the 14-gauge bare copper wire mounted beneath the tray were unsuccessful. Four junctions were attached, however, at the locations indicated in Fig. IX.14 by taping the bead against the copper wire with one wrap of fiberglass tape and then securing the bead and tape with a twist of bare 28-gauge nickel-chromium wire around the tape.

All cable temperatures were measured at the lower (exposed) face of the cable at or very near its surface. Most thermocouples were attached to the cables by the tape/wire-twist method described above. Exceptions were the following three groups (see

Fig. IX.14): TCS 19, 20, 21; TCS 22, 23, 24; and TCS 25, 26, 27. Thermocouples within a group were closely spaced but differed in their size or means of attachment. Thermocouples 19, 22, and 25 were formed from 0.25 mm (0.010 in) wires and were attached with one wrap of fiberglass tape. Due to an oversight, wire twists were not used over these junctions. Thermocouples 20, 23, and 26 were formed from 0.08 mm (0.003 in) wires and placed in shallow slits in the jacket parallel to the cable axis. These 38 to 51 mm (1.5 to 2.0 in) slits provided an approximate isothermal plane for the bead and its adjacent lead wires. Following insertion, the slits tended to close over the junction and leads. Thermocouples 21, 24, and 27 were formed from 0.08 mm (0.003 in) wires and placed in short (approximately 2 mm [0.08 in]), shallow, circumferential slits in the jacket.

B. Fire Test Procedures and Results

The test was conducted on October 26, 1992 and was witnessed by the following official observers: P. Madden (NRC), S. West (NRC), and C. McCracken (NRC).

The assembly was subjected to a 1-hour fire exposure controlled by the ASTM E 119-88 standard temperature-time curve. All temperatures recorded during the test are tabulated in Table IX.2. Plots of the furnace temperatures recorded by the furnace thermocouples and their average values are presented in Fig. IX.15. The average furnace temperatures and the standard temperature-time curve are shown in Fig. IX.16.

The only part of the assembly that was visible during the test was the exterior of the gypsum-board box, which did not change in appearance (Fig. IX.17). Light smoke began emanating from the north face of the gypsum-board enclosure at 0:45:00 (hr:min:s) and continued until the test was ended at 1:00:00. No other changes were observed during the test. A log of observations is presented in Table IX.3.

Post-test views of the exposed and unexposed surfaces of the fire-barrier specimen are shown in Figs. IX.18 and IX.19, respectively. Char, which ranged in thickness from 38 to 51 mm (1.5 to 2 in), covered the entire exposed area of the exposed surface. The southern two-thirds of the exposed area had a hard-crusted uncracked char, whereas the northern one-third had a partially broken char. A shallow imprint (about 1 mm [0.04 in]) from the narrow steel strip at the centerline of the mask was visible in the char.

Although most of the exposed area of the unexposed surface was discolored light to dark brown, there was no indication of burnthrough. Some of the white tape bands securing thermocouple beads to cables had yellowed but most remained white. The nickel-

chromium wire twists remained tight. None of the cables showed any fire damage such as swelling, cracks, blisters, discoloration, etc. (Fig. IX.20).

The five surface thermocouples, TC3 through TC7, remained attached to the unexposed surface of the fire barrier. Their outputs are plotted in Fig. IX.21. Note that TC4 and TC6 are located on ribs whereas the remaining thermocouples are not. Cable-tray temperatures measured by TC8 through TC14 are presented in Fig. IX.22.

Temperatures measured on the 14-gauge solid wire are plotted in Fig. IX.23. Post-test inspection revealed that the bead of TC18 was not in direct contact with the copper wire.

Temperatures recorded by the three groups of closely spaced thermocouples attached to cables #9, #15, and #20 are presented in Figs. IX.24, IX.25, and IX.26, respectively. Recall that there were no wire twists holding down larger gauge thermocouples TC15, TC19, and TC22. Consequently, these beads may have lifted slightly from the cable surface during the test.

The post-test mass of the fire-barrier specimen was 6.68 kg (14.7 lb). No significant residue was found at the bottom of the furnace.

C. Analysis of Test Results

The ASTM E 119-88 thermal transmission acceptance criteria are that the average temperature rise of the unexposed-surface thermocouples shall not exceed 139°C (250°F) above its initial temperature (in this test, 19°C [66°F]) and the temperature rise of any of these thermocouples shall not exceed 181°C (325°F) above the initial temperature. Another criterion is that at no time during the test should hot gases or flame pass through the assembly so as to ignite cotton waste held against the unexposed surface. In addition to these criteria, NRC requirements include monitoring the times at which the following reach 162.8°C (325°F): any unexposed-surface thermocouple, any point on the 14-gauge bare copper wire, and any thermocouple attached to the surface of a cable.

On the basis of the experimental temperature data presented in Table IX.2, the above temperature criteria were met at the following locations and times:

Criterion	Location	Time (sec)	Time [hr:min:sec]
E 119 avg. unexposed surf. temp. (158°C) [316°F]		2100	[0:35:00]
E 119 peak unexposed surf. temp. (200°C) [392°F]	TC 3	2850	[0:47:30]
NRC unexposed surf. temp., 1st occurrence (162.8°C) [325°F]	TC 3	1617	[0:26:57]
NRC bare copper wire temp., 1st occurrence (162.8°C) [325°F]	TC16	3174	[0:52:54]
NRC cable surface temp., 1st occurrence (162.8°C) [325°F]	---- (not reached) ----		

Concerning E 119 criteria, the average temperature was the controlling factor and the E 119 fire-endurance period was 2100 seconds (0:35:00). Since the period was greater than 1/2 hour, a correction was required to account for deviations of the actual average furnace temperature from the standard temperature-time curve (see ASTM E 119-88, Par. 7.4). This correction was -2 s and **the corrected fire-endurance period was 2098 s (35.0 minutes).**

Neither glowing nor flame passage were observed during the test. Post-test inspection revealed no burnthrough areas and no fire damage to the cables. The E 119 cotton-waste test was not conducted at any time during the test.

The highest cable temperatures occurred at 1:00:00 in the center section of the assembly at TC22 (158°C) [316°F], TC25 (154°C) [309°F], and TC33 (151°C) [304°F].

Temperatures measured by closely spaced thermocouples which were attached to the same wire or cable but which differed in their size and/or method of attachment, showed differences up to 19°C (34°F).

TABLE IX.1. Thermocouple key.

NOTE: 1. Unless otherwise noted, all thermocouples were made from 0.25 mm (0.010 in) diameter chromel and alumel wires.
2. All cable thermocouples were attached to the bottom (exposed) sides of the cables.
3. Abbreviations: p. & c. = power and control cable
inst. = instrumentation cable

TC	Location
3	Unexposed surf. fire-barrier specimen, off rib (Fig. IX.1)
4	Unexposed surf. fire-barrier specimen, on rib (Fig. IX.1)
5	Unexposed surf. fire-barrier specimen, off rib (Fig. IX.1)
6	Unexposed surf. fire-barrier specimen, on rib (Fig. IX.1)
7	Unexposed surf. fire-barrier specimen, off rib (Fig. IX.1)
8	Cable tray, top of rung, center (Fig. IX.13)
9	Cable tray, top of bottom siderail flange (Fig. IX.13)
10	Cable tray, top of top siderail flange (Fig. IX.13)
11	Cable tray, center of siderail web (Fig. IX.13)
12	Cable tray, top of bottom siderail flange (Fig. IX.13)
13	Cable tray, top of rung, center (Fig. IX.13)
14	Cable tray, top of bottom siderail flange (Fig. IX.13)
15	Bare 14-gauge copper wire, north end (Fig. IX.14)
16	Bare 14-gauge copper wire, center (Fig. IX.14). TC formed from 0.51 mm (0.020 in) diameter chromel and alumel wires.
17	Bare 14-gauge copper wire, center (Fig. IX.14).
18	Bare 14-gauge copper wire, south end (Fig. IX.14).
19	Cable #9 (p. & c.), S. sect., 25 mm (1.0 in) N. of TC20 (Fig. IX.14). TC formed from 0.25 mm (0.010 in) wires, taped against cable surface.
20	Cable #9 (p. & c.), S. sect., 216 mm (8.50 in) S. of E.-W. centerline (Fig. IX.14). TC formed from 0.08 mm (0.003 in) wires, located near surface in shallow slit parallel to cable axis.
21	Cable #9 (p. & c.), S. sect., 38 mm (1.5 in) S. of TC20 (Fig. IX.14). TC formed from 0.08 mm (0.003 in) wires, located near surface in short shallow slit along cable circumference.
22	Cable #15 (p. & c.), center sect., 51 mm (2.0 in) N. of TC23 (Fig. IX.14). TC formed from 0.25 mm (0.010 in) wires, taped against cable surface.
23	Cable #15 (p. & c.), center sect., center (Fig. IX.14). TC formed from 0.08 mm (0.003 in) wires, located near surface in shallow slit parallel to cable axis.

TABLE IX.1. Thermocouple key (cont.).

TC	Location
24	Cable #15 (p. & c.), center sect., 51 mm (2.0 in) S. of TC23 (Fig. IX.14). TC formed from 0.08 mm (0.003 in) wires, located near surface in short shallow slit along cable circumference.
25	Cable #20 (inst.), center sect., 51 mm (2.0 in) N. of TC26 (Fig. IX.14). TC formed from 0.25 mm (0.010 in) wires, taped against cable surface.
26	Cable #20 (inst.), center sect., center (Fig. IX.14). TC formed from 0.08 mm (0.003 in) wires, located near surface in shallow slit parallel to cable axis.
27	Cable #20 (inst.), center sect. 51 mm (2.0 in) S. of TC26 (Fig. IX.14). TC formed from 0.08 mm (0.003 in) wires, located near surface in short shallow slit along cable circumference.
28	Cable #1 (p. & c.), center sect. above siderail flange (Fig. IX.14). TC taped and secured with wire twist.
29	Cable #3 (inst.), above siderail flange at S. rung (Fig. IX.14). TC taped and secured with wire twist.
30	Cable #7 (p. & c.), center sect., center (Fig. IX.14). TC taped and secured with wire twist.
31	Cable #7 (p. & c.), above north rung (Fig. IX.14). TC taped and secured with wire twist.
32	Cable #7 (p. & c.), N. sect., 203 mm (8.0 in) from E.-W.centerline (Fig. IX.14). TC taped and secured with wire twist.
33	Cable #14 (inst.), center sect., center (Fig. IX.14). TC taped and secured with wire twist.
34	Cable #14 (inst.), N. sect., 203 mm (8.0 in) from E.-W. centerline (Fig. IX.14). TC taped and secured with wire twist.
35	Cable #14 (inst.), S. sect., 203 mm (8.0 in) from E.-W. centerline (Fig. IX.14). TC taped and secured with wire twist.
36	Cable #28 (inst.), center sect., center, above siderail flange (Fig. IX.14). TC taped and secured with wire twist.
37	Cable #28 (inst.), N. rung, above siderail flange (Fig. IX.14). TC taped and secured with wire twist.
38	Cable #18 (p. & c.), center sect., center (Fig. IX.14). TC taped and secured with wire twist.
39	Cable #18 (p. & c.), S. sect., 203 mm (8.0 in) from E.-W. centerline (Fig. IX.14).

TABLE IX.2. Temperatures, test 1T-1.

NRC TEST 1T-1

TEMPERATURE (°C)																				
TIME	FURNACE				TC LOCATIONS															
Sec	SR1	SR2	SR3	AVG.	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
-110	19	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
-100	19	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
-90	19	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
-80	19	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
-70	19	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
-60	19	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
-50	19	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
-40	19	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
-30	19	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
-20	19	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
-10	19	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
-1	19	19	19	19	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
0	19	19	19	19	19	20	19	19	19	20	20	20	20	20	20	20	20	20	20	20
10	19	19	19	19	19	20	19	19	19	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	19	20	19	19	19	20	20	20	20	20	20	20	20	20	20	20
30	22	23	23	23	19	20	19	19	19	20	20	20	20	20	20	20	20	20	20	20
40	26	28	29	28	19	20	19	19	19	20	20	20	20	20	20	20	20	20	20	20
50	36	35	39	37	19	20	19	19	19	20	20	20	20	20	20	20	20	20	20	20
60	49	44	51	48	19	19	19	19	19	20	20	20	20	20	20	20	20	20	20	20
70	65	54	65	61	19	20	19	19	19	20	20	20	20	20	20	20	20	20	20	20
80	84	67	82	78	20	20	19	19	19	20	20	20	20	20	20	20	20	20	20	20
90	106	83	100	96	20	20	20	19	20	20	20	20	20	20	20	20	20	20	20	20
100	130	100	121	117	20	20	20	19	20	20	20	20	20	20	20	20	20	20	20	20
110	155	120	143	139	20	20	20	19	20	20	20	20	20	20	20	20	20	20	20	20
120	182	141	165	163	21	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
130	210	164	188	187	21	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
140	239	187	212	213	22	20	21	20	20	20	20	20	20	20	20	20	20	20	20	20
150	269	212	236	239	23	20	21	20	20	20	20	20	20	20	20	20	20	20	20	20
160	299	237	260	265	24	20	22	20	21	20	20	20	20	20	20	20	20	20	20	20
170	329	262	285	292	25	20	23	20	21	20	20	20	20	20	20	20	20	20	20	20
180	359	288	310	319	26	20	23	20	22	20	20	20	20	20	20	20	21	21	20	20
190	387	314	334	345	27	20	24	20	22	20	20	20	20	20	20	20	21	21	21	20
200	414	340	358	371	28	21	25	20	23	20	20	20	20	20	20	20	21	21	21	20
210	440	365	382	396	29	21	26	21	24	20	20	20	20	20	20	20	21	21	21	20
220	465	389	405	419	31	21	27	21	24	20	20	20	20	20	20	20	22	22	21	20
230	487	412	426	442	32	22	29	21	25	20	20	20	20	20	20	20	22	22	22	21
240	508	434	447	463	34	22	30	22	26	20	20	20	20	20	20	20	22	23	22	21
250	527	455	466	483	35	23	31	22	27	20	20	20	20	20	20	20	23	23	22	21
260	544	474	484	501	37	23	33	23	28	20	20	20	20	20	20	20	23	24	23	21
270	559	491	501	517	38	24	34	23	29	20	20	20	20	20	20	20	24	24	23	21
280	572	507	515	531	40	25	35	24	30	21	20	20	20	21	20	20	24	25	23	22
290	583	521	529	544	41	25	37	24	31	21	20	20	20	21	20	20	25	25	24	22
300	593	534	541	556	43	26	38	25	32	21	20	20	20	21	20	20	25	26	24	22

TABLE IX.2. Temperatures, test 1T-1 (cont.).

NRC TEST 1T-1

TIME	TEMPERATURE (°C)																			
	FURNACE				TC LOCATIONS															
Sec	SR1	SR2	SR3	AVG.	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
360	632	586	590	603	52	31	47	29	39	22	21	20	21	21	21	21	29	30	27	24
420	643	608	610	620	61	37	56	35	47	23	22	20	21	21	21	21	32	34	31	26
480	647	618	619	628	69	42	64	41	54	24	22	20	21	22	22	22	36	38	34	29
540	664	634	635	644	76	48	71	47	60	26	24	21	21	23	24	22	39	42	38	32
600	690	659	662	670	83	54	78	52	67	28	25	21	22	24	25	23	43	46	42	34
660	724	694	697	705	89	59	84	58	72	30	27	21	22	24	27	24	46	51	46	37
720	754	726	729	736	94	64	89	63	77	33	28	22	23	26	29	26	49	55	49	40
780	775	749	751	758	100	68	94	68	82	35	30	23	24	27	31	27	52	59	53	43
840	786	762	764	771	104	73	99	73	87	38	32	24	25	29	33	28	55	62	56	45
900	792	771	773	778	109	77	103	77	92	40	34	25	26	31	36	30	57	65	59	48
960	796	777	778	784	114	80	108	81	95	43	36	26	27	33	38	32	60	68	63	50
1020	798	781	783	787	118	84	112	85	99	45	38	28	29	35	40	33	63	71	66	52
1080	798	783	784	788	122	88	116	89	102	47	40	29	30	36	42	36	65	73	69	54
1140	800	787	788	792	126	91	120	92	105	50	42	31	32	38	44	37	68	76	72	57
1200	804	791	792	796	131	95	124	95	108	52	44	32	33	40	46	38	70	80	74	59
1260	808	796	796	800	136	98	129	99	112	54	45	33	34	41	48	40	73	83	78	61
1320	813	801	802	805	142	100	133	102	115	57	47	35	36	43	50	41	77	87	81	63
1380	819	807	808	811	147	103	138	105	118	59	49	36	37	45	52	43	80	91	84	66
1440	825	814	814	817	152	106	143	108	122	62	51	37	39	46	54	44	83	94	88	68
1500	830	820	820	823	156	108	147	111	126	65	53	39	40	48	56	46	86	97	91	70
1560	836	824	825	828	159	112	151	113	130	68	56	40	42	50	58	48	88	100	94	72
1620	838	828	828	831	163	115	154	116	133	70	58	41	43	51	61	49	91	104	96	74
1680	841	832	832	835	166	118	158	119	137	73	60	42	44	53	63	51	94	106	99	77
1740	845	836	836	839	168	121	161	122	141	76	62	43	46	55	66	53	96	110	102	79
1800	852	842	842	845	170	125	163	125	144	79	64	44	47	57	68	54	99	112	105	81
1860	859	849	850	853	172	128	166	128	147	82	66	45	49	59	71	56	102	115	108	84
1920	866	855	856	859	174	131	168	132	150	85	68	47	51	61	73	58	104	118	110	86
1980	871	861	862	865	176	134	170	135	152	88	70	49	52	63	76	60	106	120	113	88
2040	874	865	865	868	177	137	172	138	154	90	73	51	54	64	78	61	108	122	115	90
2100	876	869	869	871	179	140	174	142	156	93	75	52	56	66	81	63	111	124	117	92
2160	879	872	872	874	181	142	176	145	157	96	77	54	57	68	83	65	113	126	120	93
2220	882	876	875	878	183	145	178	147	160	98	79	56	59	70	86	67	115	128	122	96
2280	885	879	878	881	184	147	179	150	162	101	81	58	61	72	88	69	118	131	124	97
2340	886	881	881	883	186	149	181	152	163	103	83	59	63	73	90	71	120	133	126	99
2400	889	884	883	885	188	151	183	153	165	106	85	61	64	75	93	72	122	135	128	101
2460	891	886	885	887	189	152	185	155	166	108	87	63	66	77	95	74	124	137	131	102
2520	893	888	887	889	191	154	187	157	167	110	89	64	68	79	97	76	126	139	133	104
2580	896	891	890	892	193	156	189	158	168	112	91	66	69	80	99	78	128	142	135	105
2640	898	893	892	895	194	157	191	159	170	114	93	68	71	82	101	80	130	145	137	107
2700	901	896	894	897	196	158	193	161	171	116	95	70	73	84	103	81	132	147	139	108

TABLE IX.2. Temperatures, test 1T-1 (cont.).

TIME	TEMPERATURE (°C)																		
	FURNACE				TC LOCATIONS														
Sec	SR1	SR2	SR3	AVG.	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2760	904	899	897	900	198	160	195	162	172	119	97	71	75	86	105	83	134	149	141	109
2820	905	901	899	902	199	161	197	163	173	121	99	73	76	87	106	85	137	152	143	110
2880	906	903	902	904	201	162	199	164	174	123	101	75	78	89	108	86	139	154	145	112
2940	908	904	903	905	203	163	201	165	176	125	103	76	80	91	110	88	141	156	147	113
3000	911	906	906	908	204	165	202	166	177	127	105	78	81	93	112	90	143	158	149	115
3060	912	908	907	909	206	166	204	168	179	129	107	79	83	94	113	92	145	160	151	117
3120	913	909	908	910	207	167	206	169	180	131	108	81	85	96	115	93	147	161	153	118
3180	914	911	910	912	209	168	208	170	182	133	110	83	86	98	117	95	148	163	154	120
3240	918	915	915	916	210	169	209	171	184	135	112	84	88	99	119	97	150	164	156	122
3300	920	918	916	918	212	170	211	172	185	137	114	86	90	101	120	98	152	166	158	123
3360	922	918	917	919	213	172	213	173	187	138	116	87	91	103	122	100	153	168	159	125
3420	923	919	918	920	215	173	215	175	188	140	117	89	93	105	124	102	155	170	161	127
3480	925	921	920	922	216	174	216	176	190	142	119	90	95	107	126	103	157	171	163	129
3540	927	924	923	925	217	175	218	177	191	144	121	92	96	108	127	105	158	172	164	130
3600	930	927	926	927	219	177	220	178	193	146	123	94	98	110	129	107	159	174	166	132

TABLE IX.2. Temperatures, test 1T-1 (cont.).

TIME	TEMPERATURE (°C) TC LOCATIONS																				
Sec	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
-110	20	19	19	20	20	20	20	20	20	20	20	19	19	20	19	20	19	20	20	20	20
-100	20	19	19	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
-90	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
-80	20	19	19	20	20	20	20	20	19	20	19	19	19	19	19	20	20	20	20	20	20
-70	20	19	19	20	20	20	20	20	20	20	20	19	20	20	19	20	20	20	20	20	20
-60	20	19	19	20	20	20	20	20	20	20	20	19	20	20	20	20	20	20	20	20	20
-50	20	19	19	20	20	20	20	20	20	20	20	19	20	20	20	20	20	20	20	20	20
-40	20	19	19	20	20	20	20	20	20	20	20	19	20	20	20	20	20	20	20	20	20
-30	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
-20	20	19	19	20	20	20	20	20	20	20	20	19	20	20	19	20	20	20	20	20	20
-10	20	19	19	20	20	20	20	20	20	20	20	19	20	20	20	20	20	20	20	20	20
-1	20	19	19	20	20	20	20	20	20	20	20	19	20	20	20	19	20	20	20	20	19
0	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
10	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
30	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
40	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
50	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
60	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
70	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
80	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
90	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
100	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
110	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
120	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
130	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
140	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
150	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
160	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
170	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
180	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
190	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
200	20	20	20	21	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
210	20	20	20	21	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
220	20	20	20	21	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
230	20	20	20	21	20	20	20	20	20	20	20	20	20	20	21	20	20	20	20	20	20
240	20	20	20	21	21	20	20	20	20	20	20	20	20	20	21	20	20	20	20	20	21
250	20	20	20	22	21	20	20	20	20	20	20	20	20	20	21	21	20	20	20	20	21
260	20	20	20	22	21	20	21	20	20	20	20	20	20	20	21	21	20	20	20	21	21
270	20	20	20	22	21	20	21	20	20	20	20	20	20	20	21	21	20	20	20	21	21
280	20	20	20	23	21	20	21	20	20	20	20	20	20	20	21	21	20	20	20	21	21
290	21	20	20	23	21	21	21	21	21	20	20	20	20	20	21	21	20	20	20	21	22
300	21	20	20	23	21	21	21	21	21	20	20	21	20	21	22	21	20	20	20	21	22

TABLE IX.2. Temperatures, test 1T-1 (cont.).

TIME	TEMPERATURE (°C) TC LOCATIONS																				
Sec	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
360	21	21	21	25	22	21	22	22	21	20	20	21	20	21	24	23	21	20	20	22	23
420	22	22	22	26	24	23	24	23	22	20	20	22	21	22	26	24	22	20	20	23	25
480	24	23	23	28	26	24	25	25	24	20	20	24	21	24	29	26	24	21	21	25	27
540	25	25	24	30	28	26	27	27	25	21	21	26	22	25	31	28	25	21	21	27	29
600	27	26	25	32	30	28	29	28	27	21	21	28	23	27	35	30	27	21	21	29	31
660	29	28	27	35	33	30	32	30	29	22	22	30	25	29	37	32	28	21	22	31	32
720	31	30	28	38	35	32	34	33	30	23	22	32	26	31	40	34	30	22	22	33	35
780	33	31	30	40	37	34	36	34	32	23	23	35	28	33	42	37	32	23	23	35	37
840	35	33	32	43	40	37	38	37	34	24	24	37	30	35	45	39	33	23	24	37	38
900	38	35	33	45	42	39	40	40	36	25	25	40	32	37	49	41	35	24	24	39	41
960	40	37	35	48	45	42	42	43	38	27	26	43	34	40	52	43	37	25	25	42	43
1020	43	39	37	51	48	44	45	45	41	28	27	46	36	42	56	45	39	26	26	44	45
1080	45	41	38	53	51	47	47	48	43	29	28	48	38	44	59	47	41	27	27	46	47
1140	48	43	40	57	54	49	49	50	46	30	30	51	41	46	62	49	42	28	28	49	49
1200	51	45	42	60	56	52	52	53	48	32	31	54	43	48	65	52	44	30	30	51	52
1260	53	47	44	63	59	54	55	55	50	33	32	56	45	50	68	54	46	31	31	53	53
1320	55	49	45	66	62	57	58	58	53	34	33	59	47	53	70	56	48	32	32	56	56
1380	57	51	47	69	65	59	60	61	56	35	35	63	49	55	73	59	50	33	33	58	58
1440	60	53	49	73	68	62	63	63	59	37	36	66	51	57	75	62	52	35	35	61	61
1500	62	55	51	76	71	65	66	65	61	38	37	69	54	60	78	64	54	36	36	64	63
1560	64	57	53	79	73	67	69	68	65	40	39	72	56	62	80	67	56	38	38	67	66
1620	66	58	54	82	76	70	71	70	67	41	40	74	58	65	83	69	57	39	39	70	68
1680	68	60	56	86	79	73	74	73	70	43	42	77	61	67	86	72	59	40	40	73	70
1740	70	62	58	88	81	76	77	75	72	44	43	80	63	70	88	74	61	42	42	75	73
1800	73	64	59	91	84	79	80	77	76	46	44	83	66	72	90	77	63	43	43	78	74
1860	75	66	61	94	87	81	82	80	78	47	46	86	68	75	93	79	65	44	45	81	77
1920	78	68	63	98	89	84	85	83	81	49	47	88	71	77	95	82	67	46	46	84	79
1980	80	70	65	100	92	87	88	85	85	50	48	91	73	80	98	84	69	47	47	87	81
2040	82	73	67	102	95	90	91	88	88	52	50	93	76	82	101	86	71	48	49	90	83
2100	85	75	69	105	97	92	94	91	91	54	51	96	79	85	103	89	73	50	50	93	86
2160	87	77	71	107	100	94	96	94	93	55	53	98	81	87	105	91	75	51	52	95	88
2220	89	79	73	109	102	97	99	96	95	57	54	100	83	89	107	93	77	53	53	98	90
2280	91	82	75	112	105	99	102	99	98	58	56	102	86	92	110	96	79	55	55	100	92
2340	94	84	77	114	107	102	105	102	100	60	57	105	88	94	112	98	81	56	57	103	93
2400	96	86	79	116	109	104	109	104	102	62	59	107	91	96	114	100	83	58	58	105	96
2460	97	88	81	118	112	106	112	107	105	64	61	109	93	99	117	102	85	60	60	108	97
2520	100	91	83	120	114	108	115	109	107	65	62	110	95	101	119	104	86	62	62	110	99
2580	102	93	85	123	116	111	117	111	109	67	64	112	97	103	121	106	88	64	64	112	101
2640	104	95	86	125	118	112	120	114	111	69	66	114	99	105	122	108	90	66	66	114	103
2700	107	97	88	127	120	114	123	116	113	71	68	116	101	107	124	111	92	68	68	116	105

TABLE IX.2. Temperatures, test 1T-1 (cont.).

TIME	TEMPERATURE (°C) TC LOCATIONS																				
Sec	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
2760	110	99	90	130	122	116	125	118	116	73	69	117	104	109	126	113	93	70	70	118	106
2820	111	100	92	132	124	118	127	120	118	75	71	119	105	111	128	115	95	72	72	119	108
2880	113	102	93	135	126	120	130	123	120	76	73	120	107	113	130	117	97	74	74	121	109
2940	115	104	95	137	128	122	132	125	122	78	74	122	109	115	132	120	99	75	76	122	111
3000	117	106	97	140	130	123	135	127	124	80	76	123	111	117	134	122	100	77	77	124	113
3060	118	108	98	140	132	125	137	129	126	82	78	125	113	119	136	124	102	79	79	126	115
3120	121	109	100	143	134	127	139	132	128	84	80	126	115	121	137	126	104	81	81	127	116
3180	122	111	102	145	136	129	141	133	130	86	81	128	116	122	139	128	105	83	82	129	118
3240	123	113	104	146	138	130	142	135	132	87	83	129	118	124	141	130	107	85	84	130	120
3300	125	115	106	149	140	132	144	137	133	89	85	131	119	125	143	132	109	86	85	132	122
3360	127	116	107	151	142	134	146	139	135	91	86	132	121	127	144	134	111	88	87	134	123
3420	128	118	109	153	144	136	148	141	137	93	88	134	123	128	146	136	112	90	89	136	125
3480	130	120	111	154	146	138	150	143	139	94	90	136	125	130	148	138	114	92	90	138	127
3540	131	122	113	156	147	140	152	145	141	96	91	137	127	132	150	140	115	94	92	140	128
3600	133	123	114	158	149	142	154	147	143	98	93	139	129	134	151	142	117	96	94	142	130

TABLE IX.3. Observations, test 1T-1.

The following observations were made during and after the test:

Time	
0:20:00	No apparent change to the exterior of the gypsum-board box.
0:44:00	Still no visible changes.
0:45:00	Some smoke emitting from N. face of box, possibly at point where TC leads penetrate the box.
0:48:45	Smoke is light but continuous from N. face.
0:58:20	Smoke from N. face continues to be light.
1:00:00	Shutdown.
1:11:	Cables removed from tray. No apparent fire damage to cables.
2:52:	Cable tray and fire-barrier specimen removed from furnace.

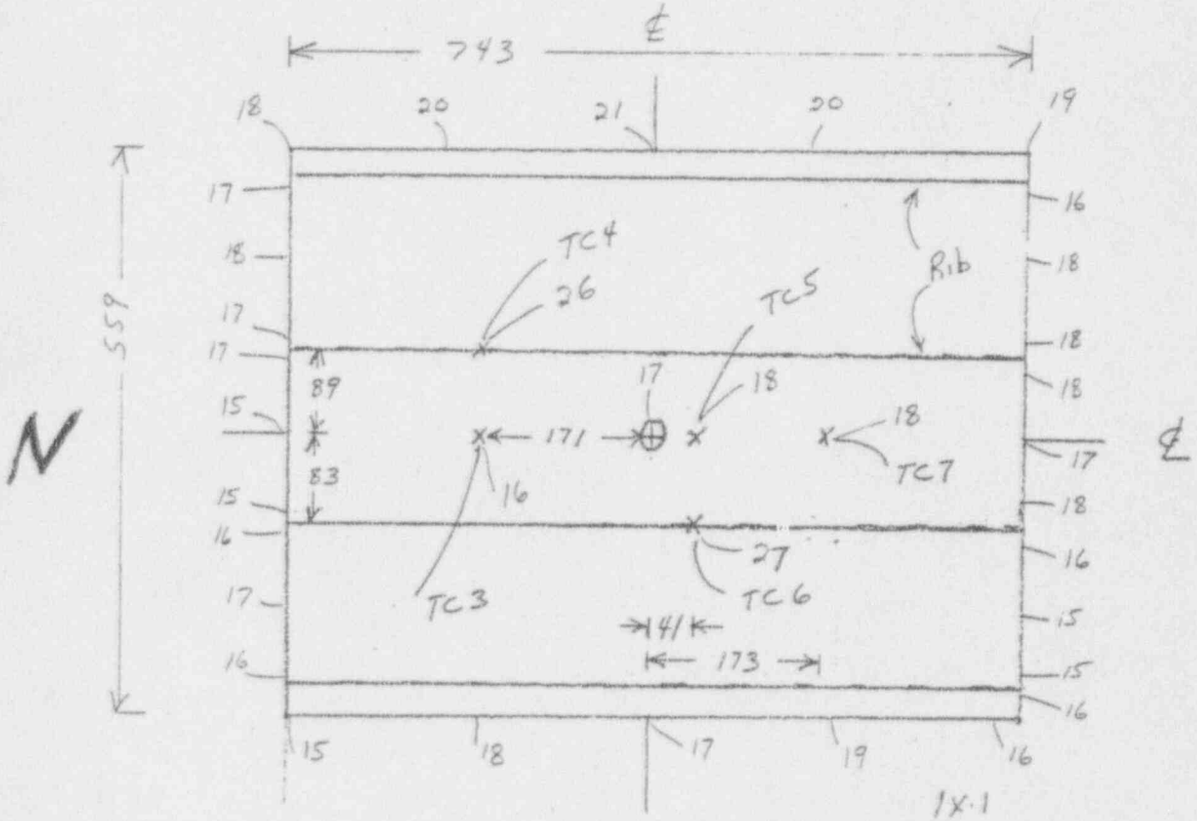

Fig. IX.1. Dimensions, fire barrier specimen, test 1T-1. Numbers not between arrows indicate thickness.

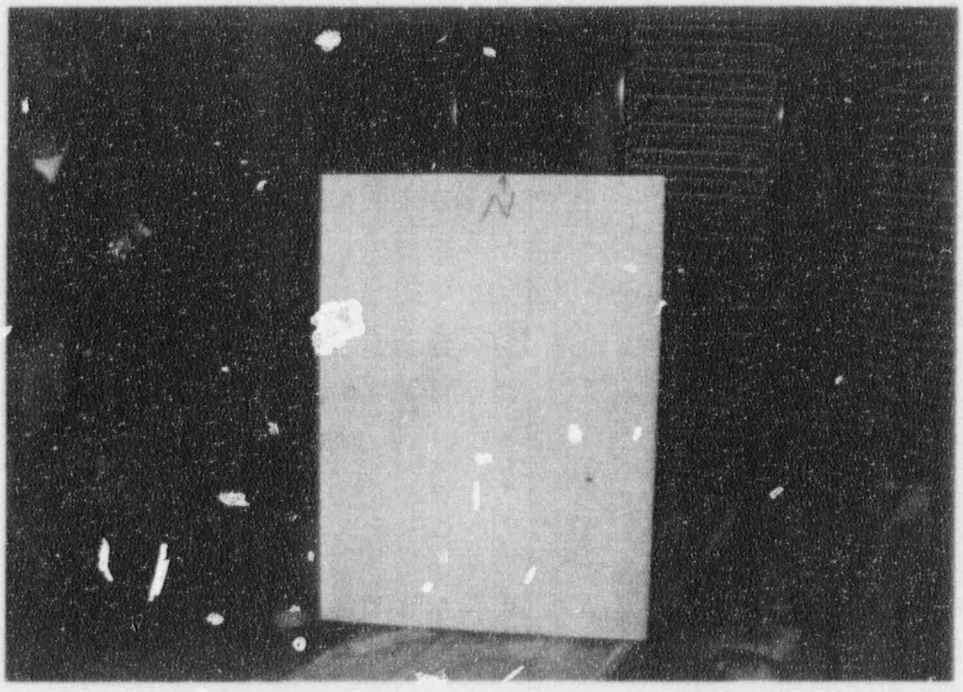

Fig. IX.2. Pre-test exposed surface of fire-barrier specimen, test 1T-1.

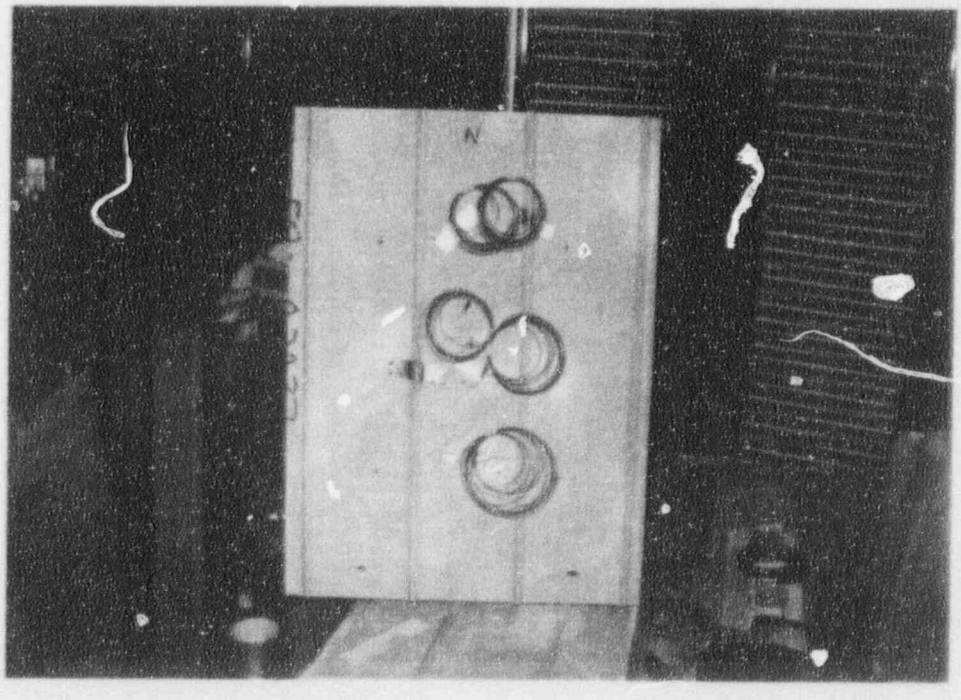

Fig. IX.3. Pre-test unexposed surface of fire-barrier specimen, test 1T-1.

Fig. IX.4. Steel mask, test 1T-1.

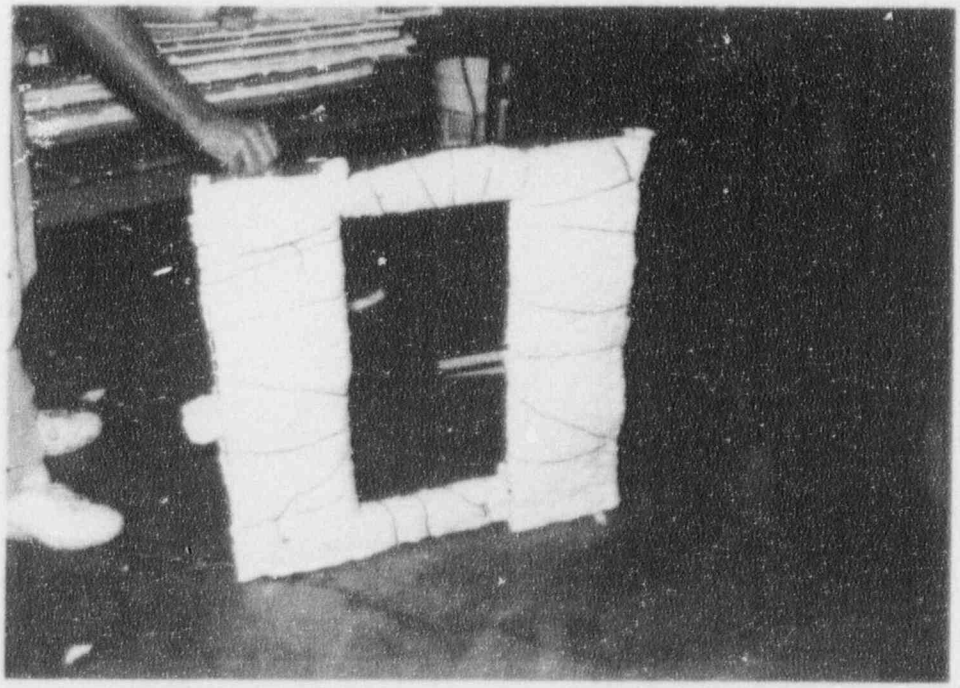

Fig. IX.5. Steel mask with insulation, test 1T-1.

Fig. IX.6. Insulated steel mask on furnace, test 1T-1.

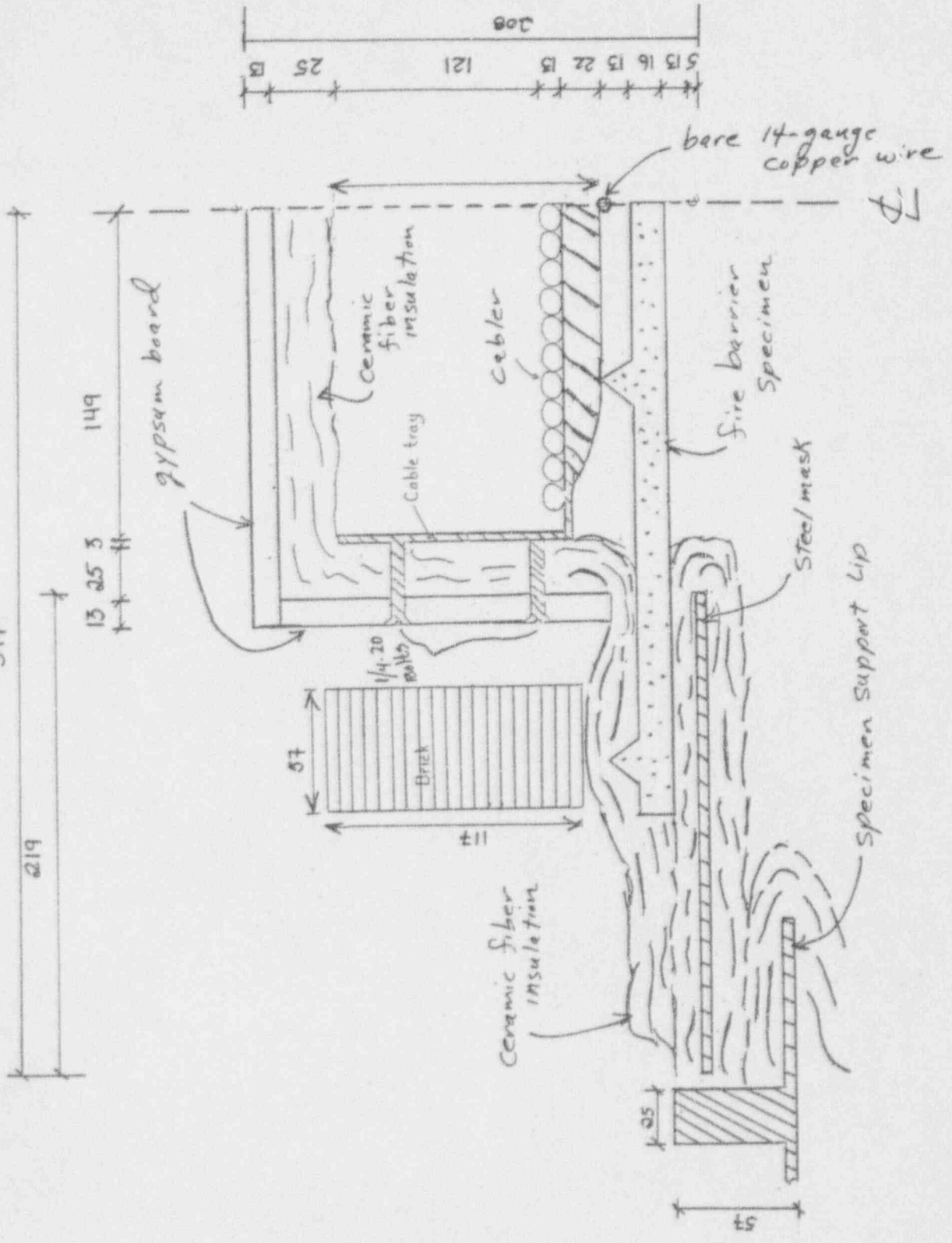

Fig. IX.7. Mounting detail, elevation in east-west plane. Dimensions in millimeters.

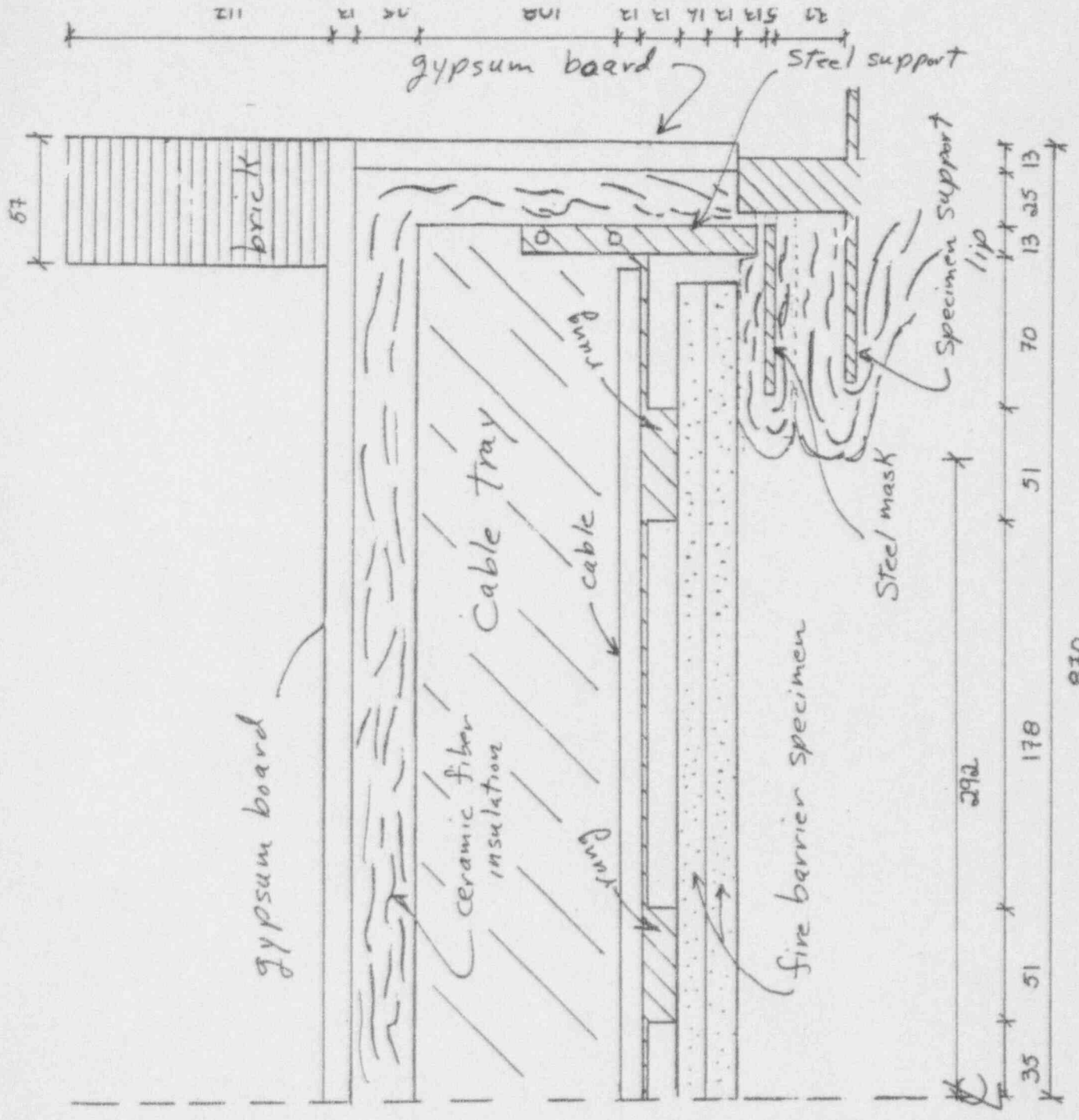

Fig. IX.8. Mounting detail, elevation in north-south plane. Dimensions in millimeters.

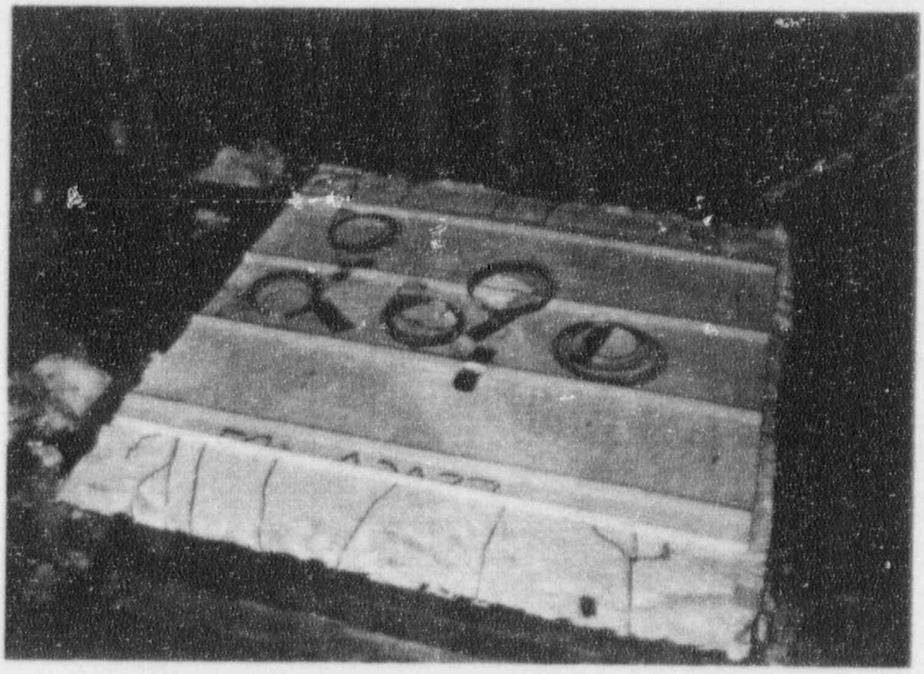

Fig. IX.9. Pre-test view of fire-barrier specimen on furnace, test 1T-1.

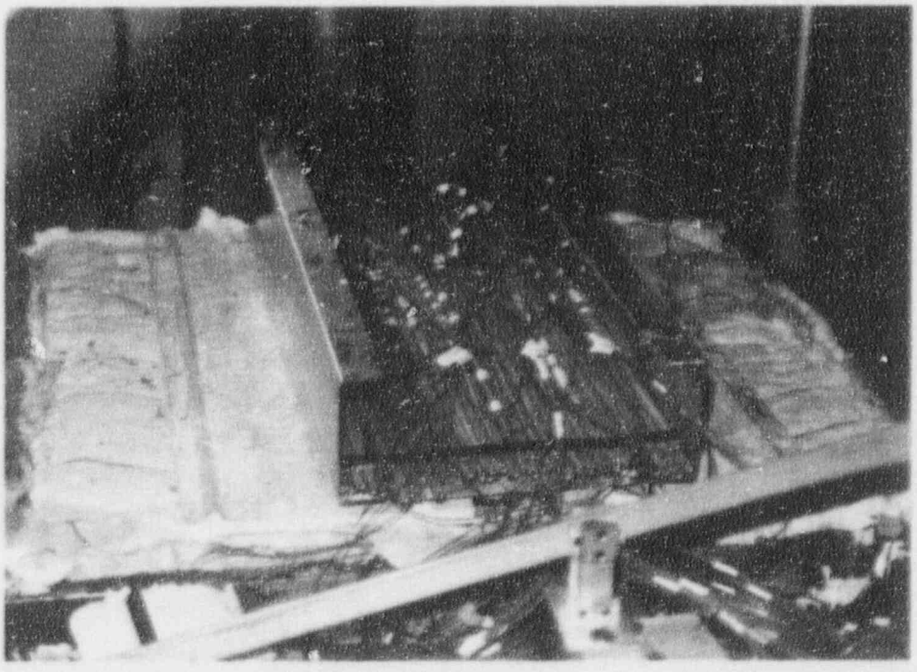

Fig. IX.10. Pre-test view of cable tray atop fire-barrier specimen, test 1T-1.

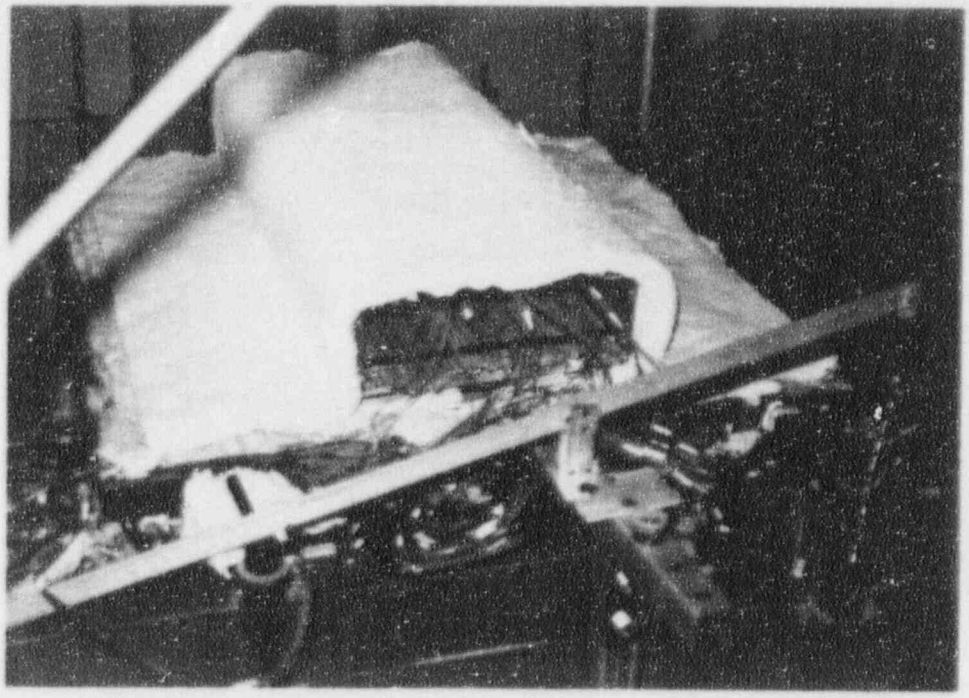

Fig. IX.11. Pre-test view of insulation blanket on sides and top of cable tray, test 1T-1.

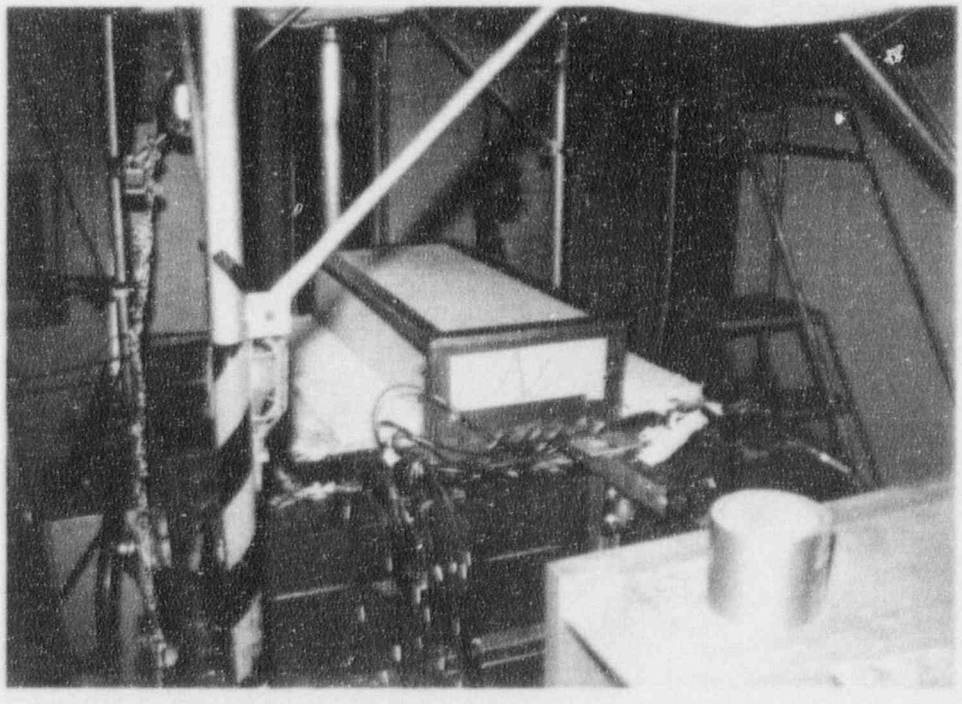

Fig. IX.12. Pre-test view of assembly with gypsum-board cover in place, test 1T-1.

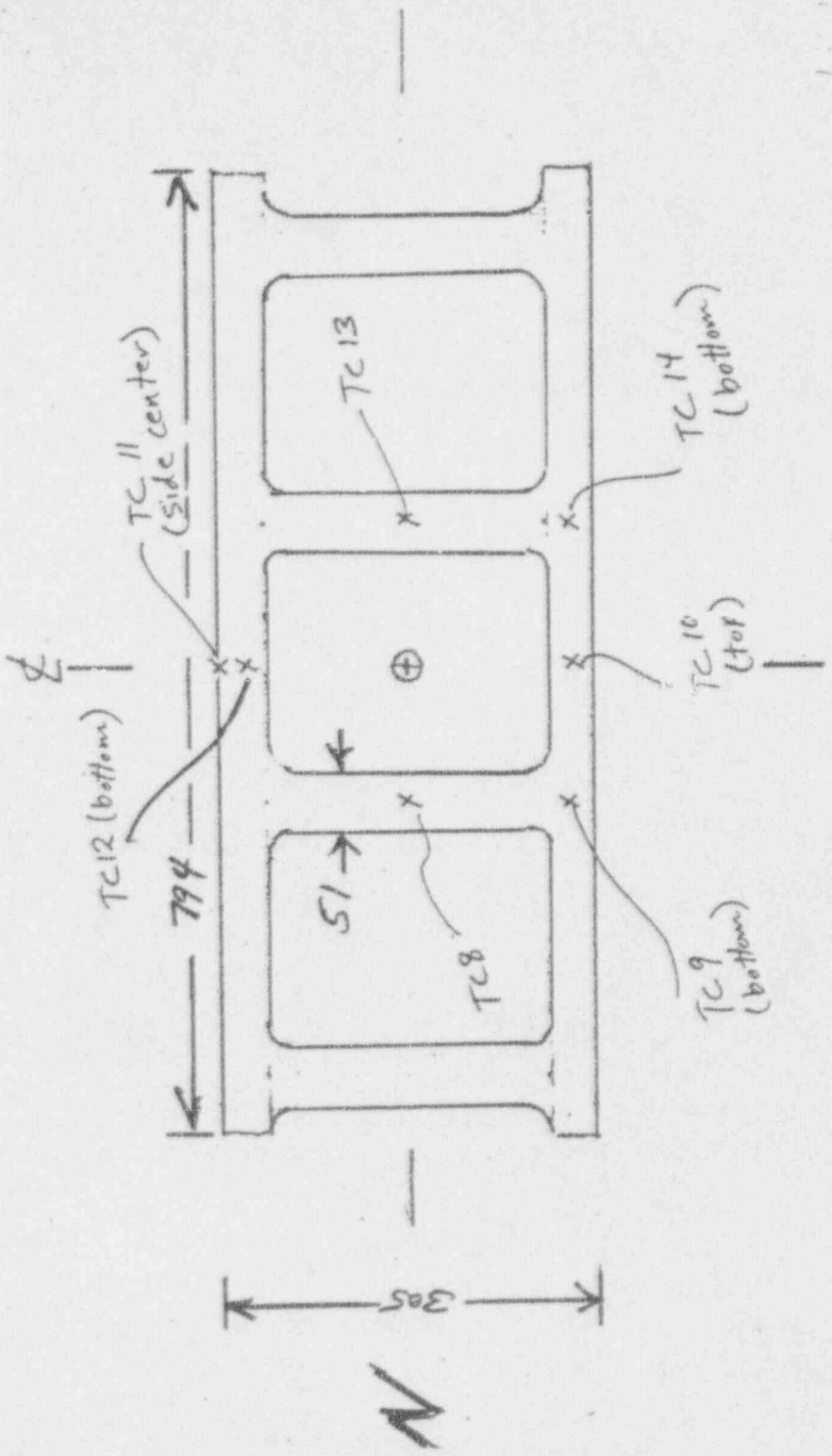

Fig. IX.13. Key to thermocouple locations on tray, test 1T-1. Dimensions in millimeters.

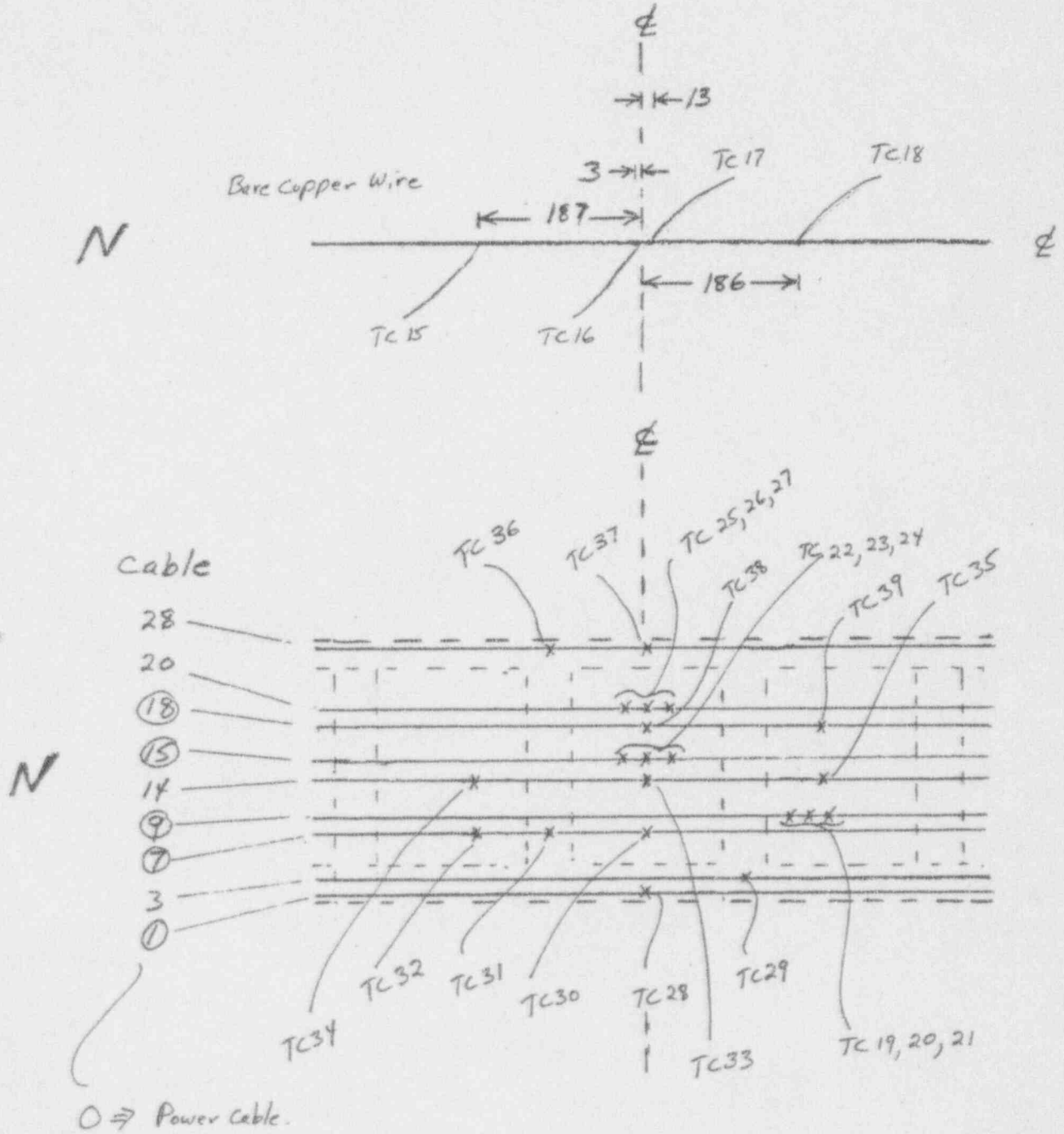

Fig. IX.14. Key to thermocouple locations on wire and cable, test 1T-1. Dimensions in millimeters.

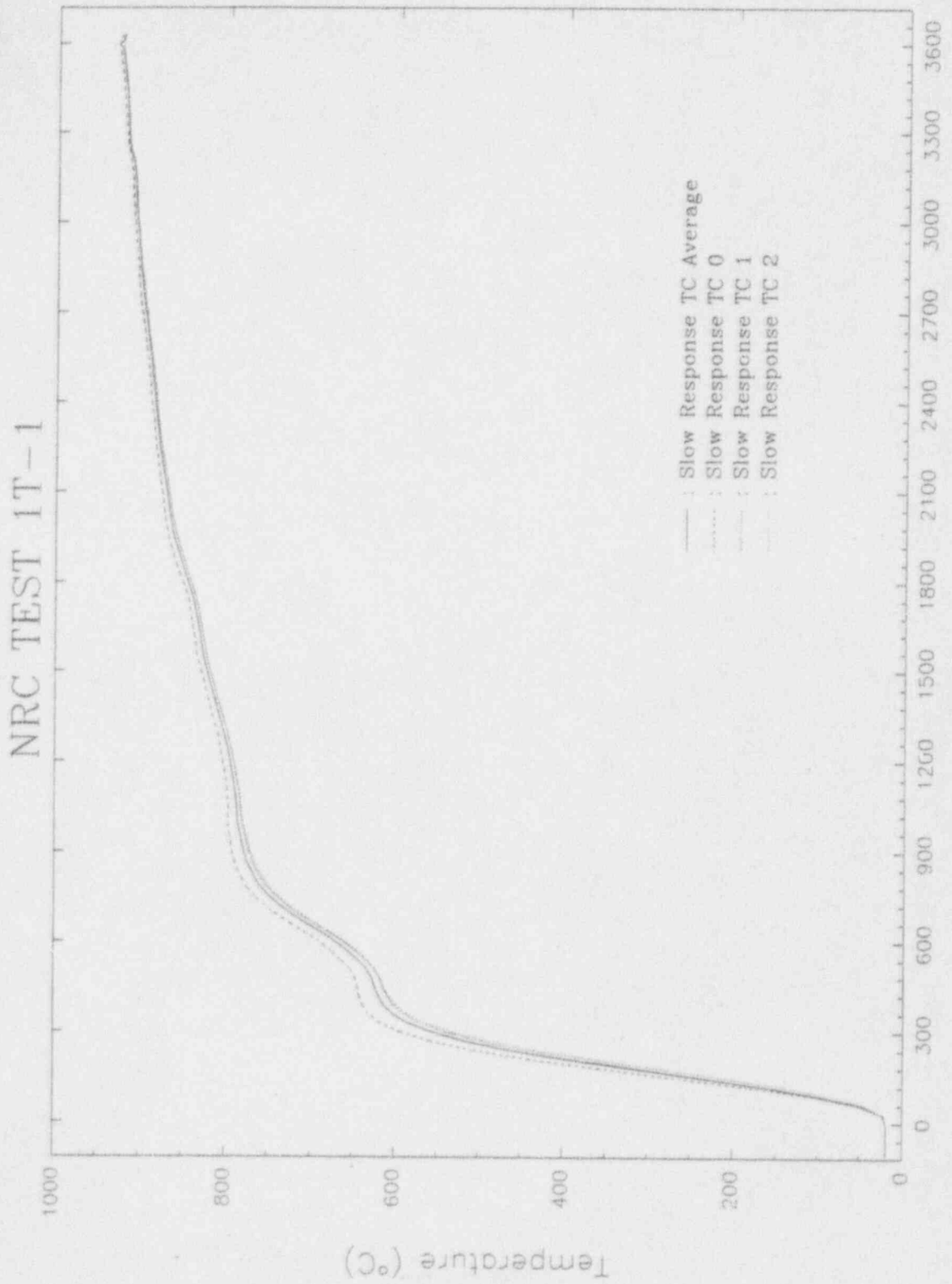

Fig. IX.15. Furnace temperatures, test 1T-1.

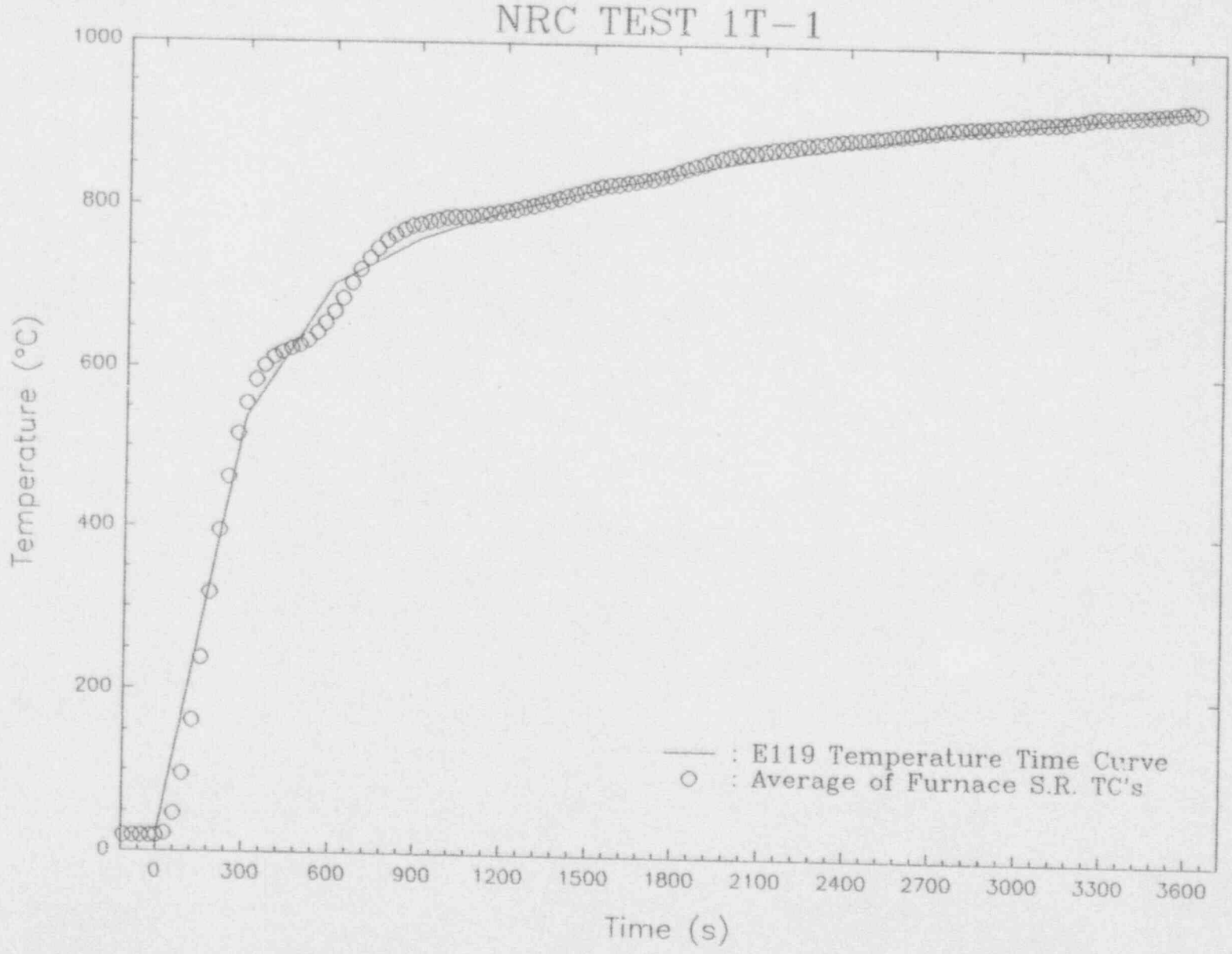

Fig. IX.16. Furnace Temperatures, test 1T-1.

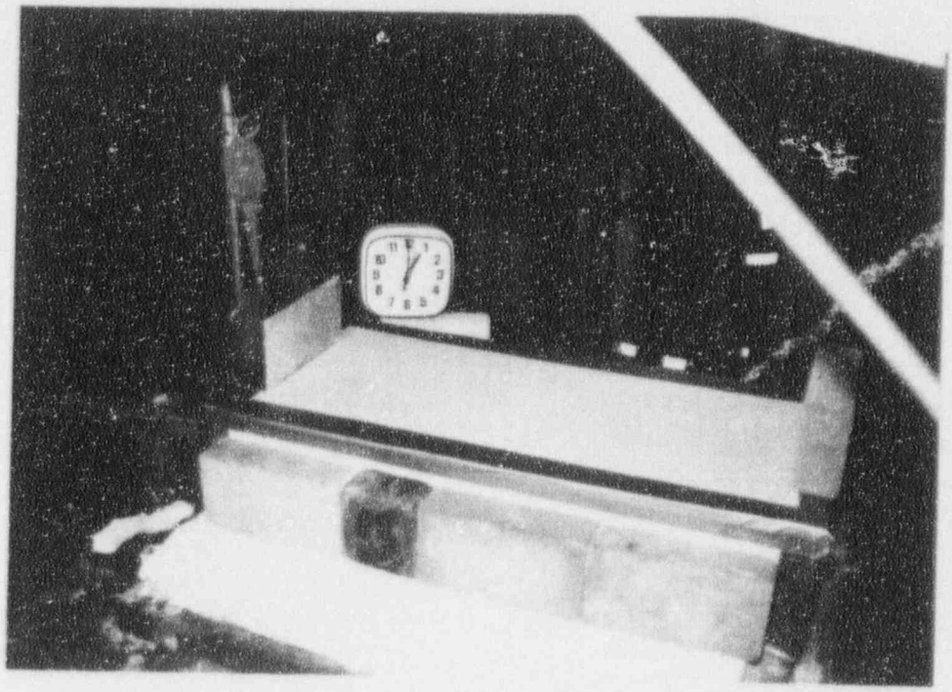

Fig. IX.17. View of test assembly at end of 1-hour test, test 1T-1.

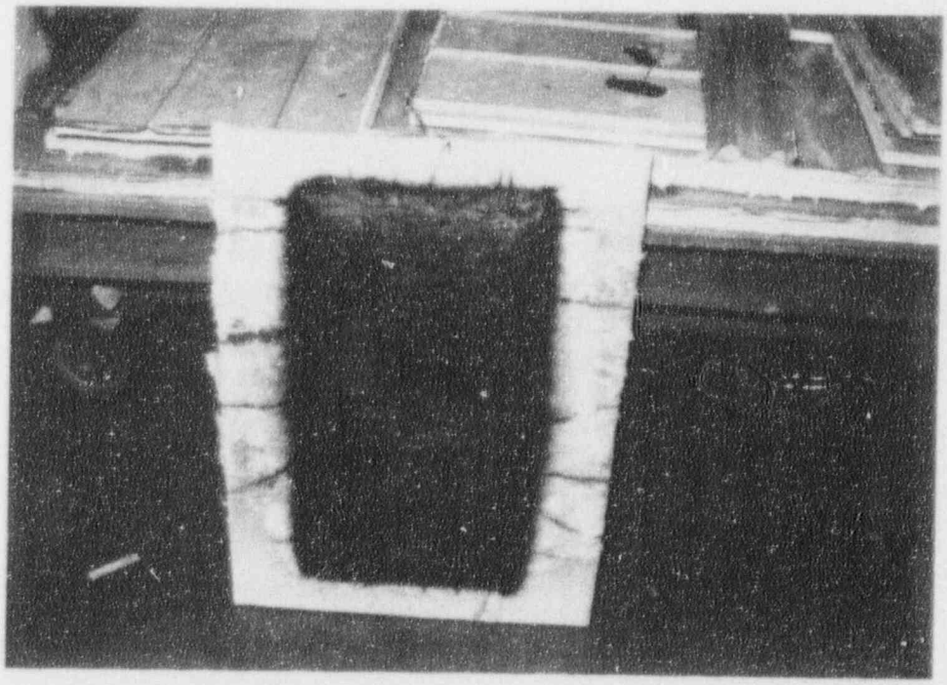

Fig. IX.18. Post-test exposed surface of fire-barrier specimen, test 1T-1.

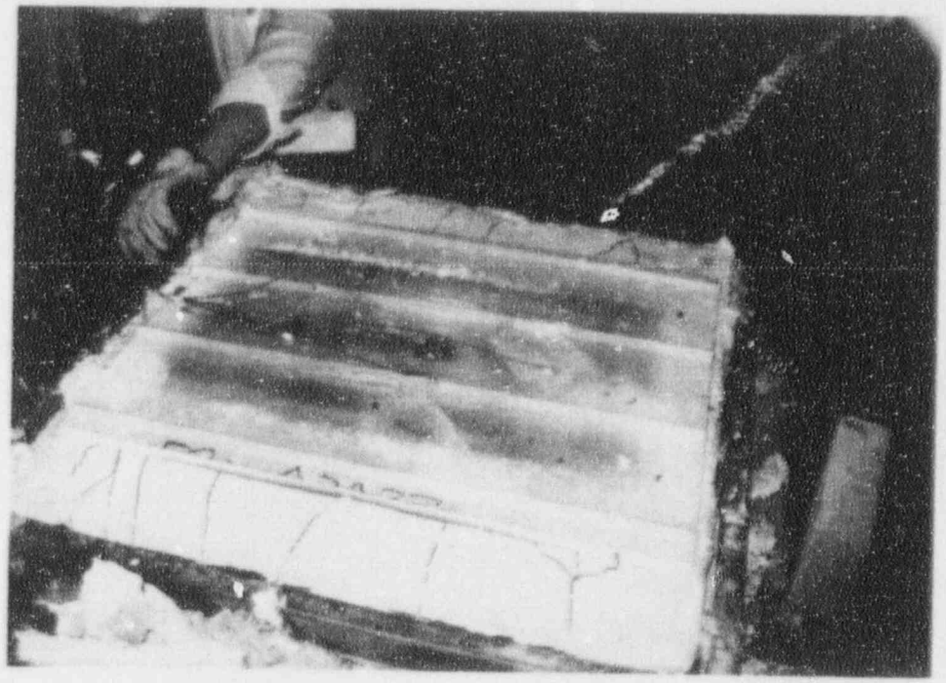

Fig. IX.19. Post-test unexposed surface of fire-barrier specimen, test 1T-1.

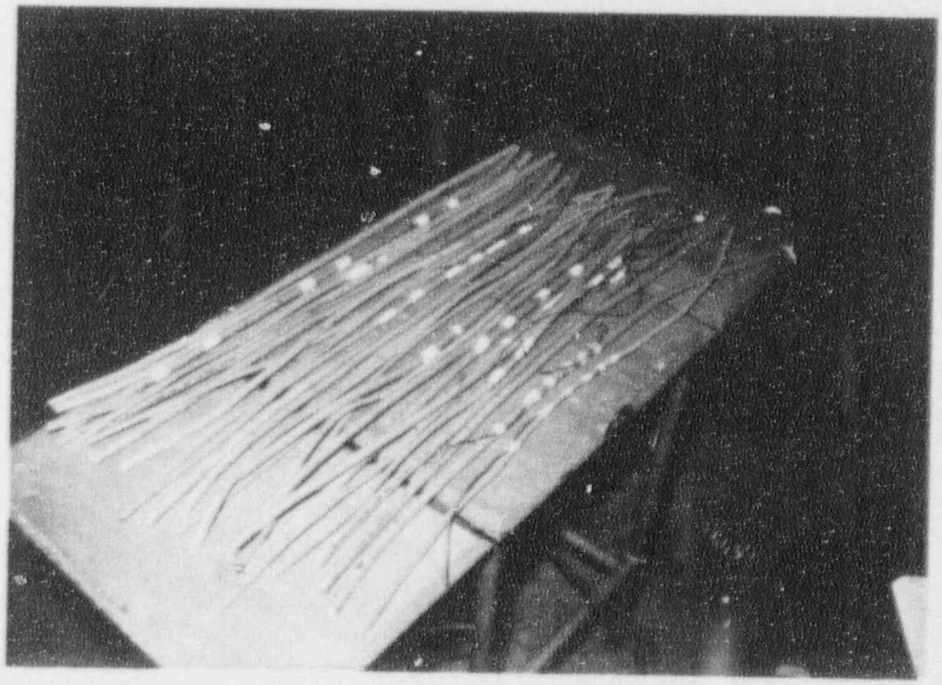

Fig. IX.20. Post-test cables, test 1T-1.0

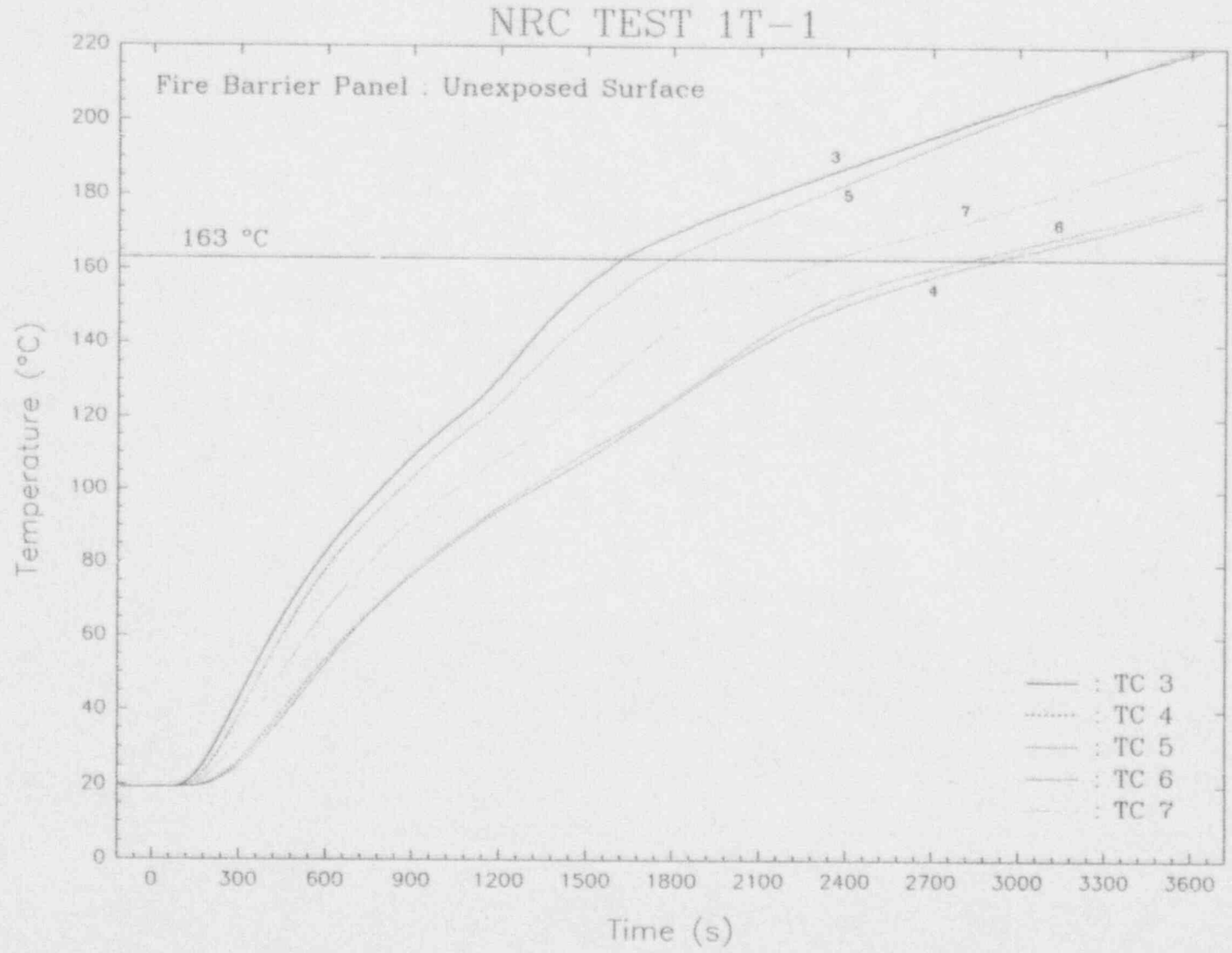

Fig. IX.21. Unexposed-surface temperatures, test 1T-1.

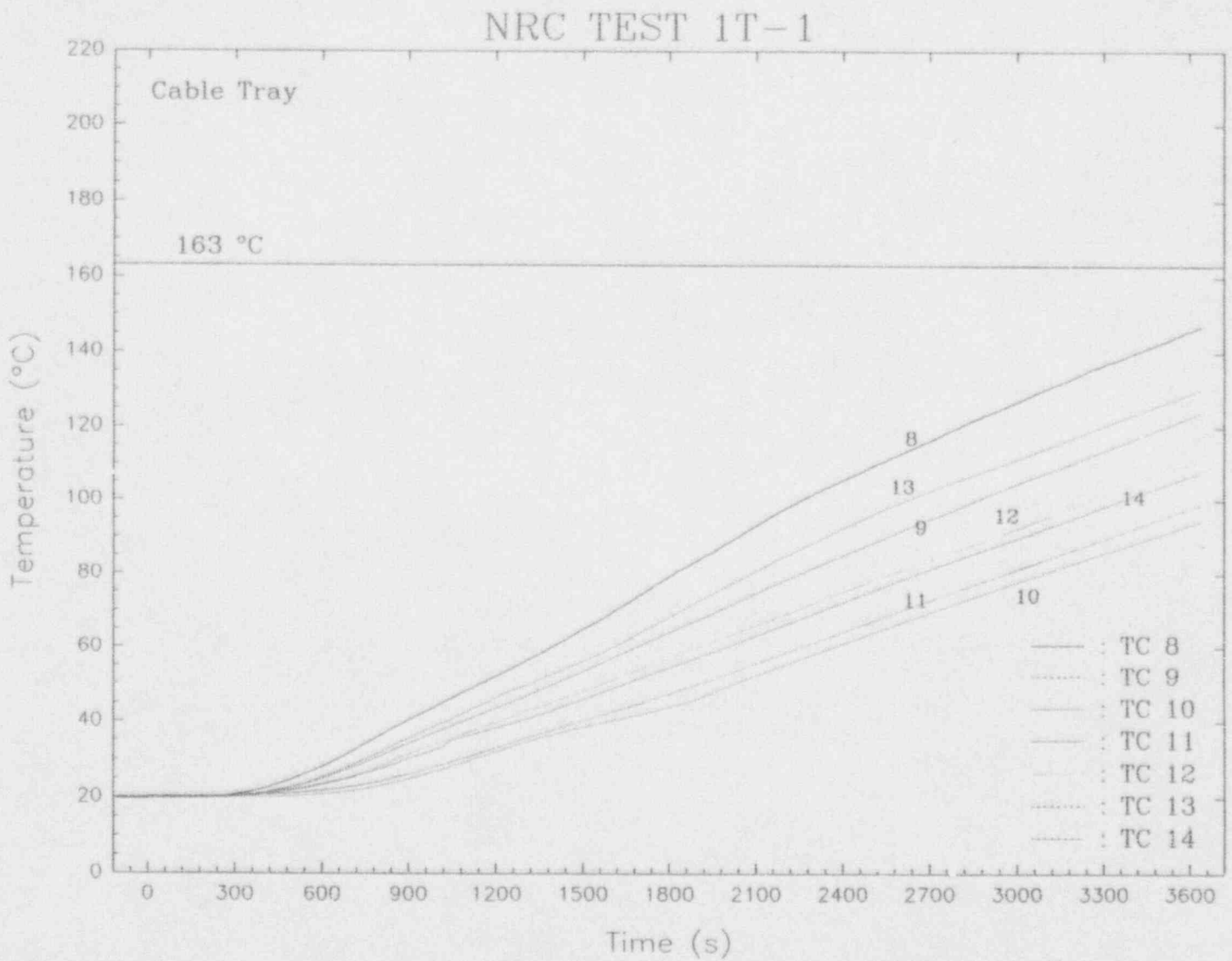

Fig. IX.22. Cable tray temperatures, test 1T-1.

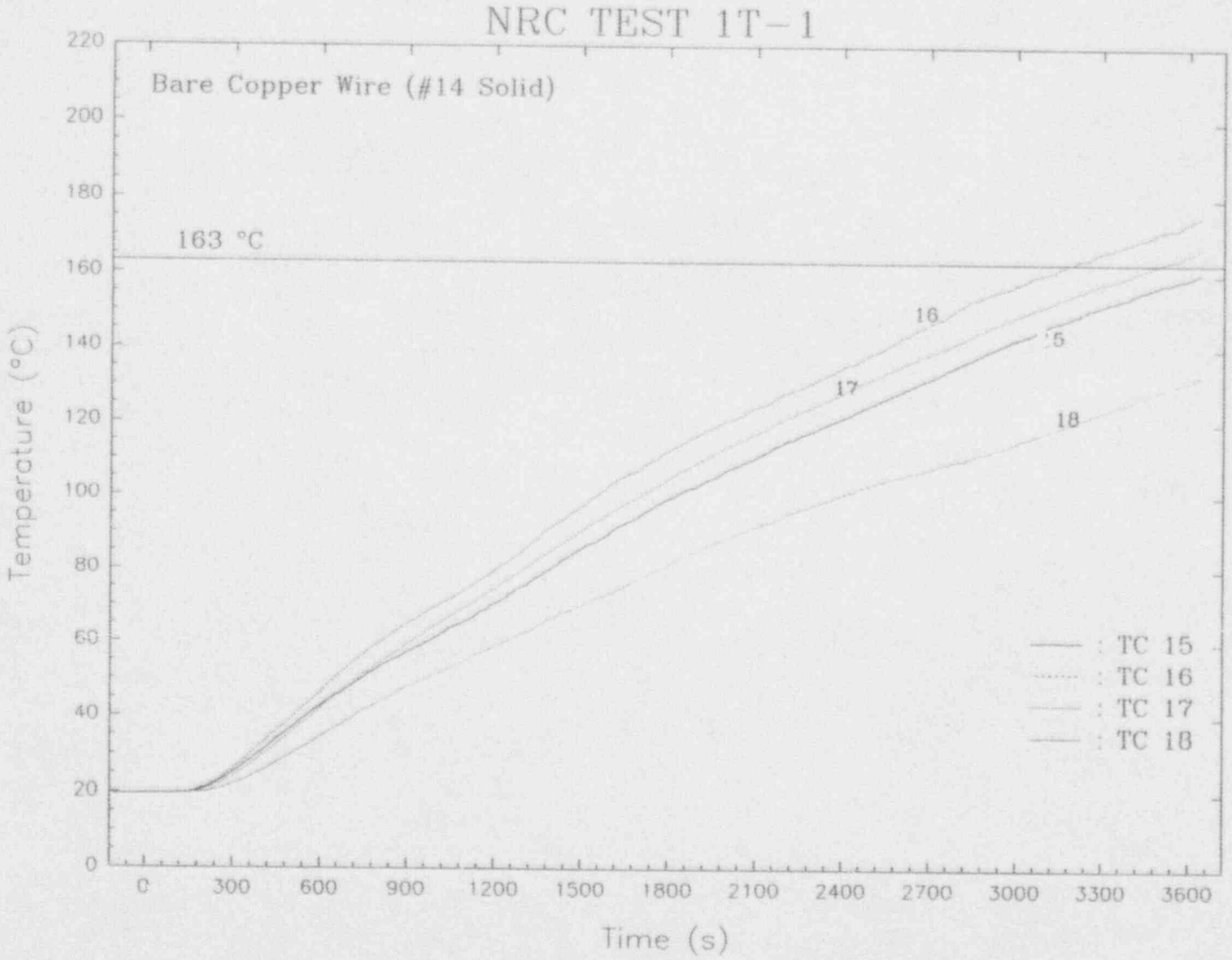

Fig. IX.23. Temperatures of bare 14-gauge wire, test 1T-1.

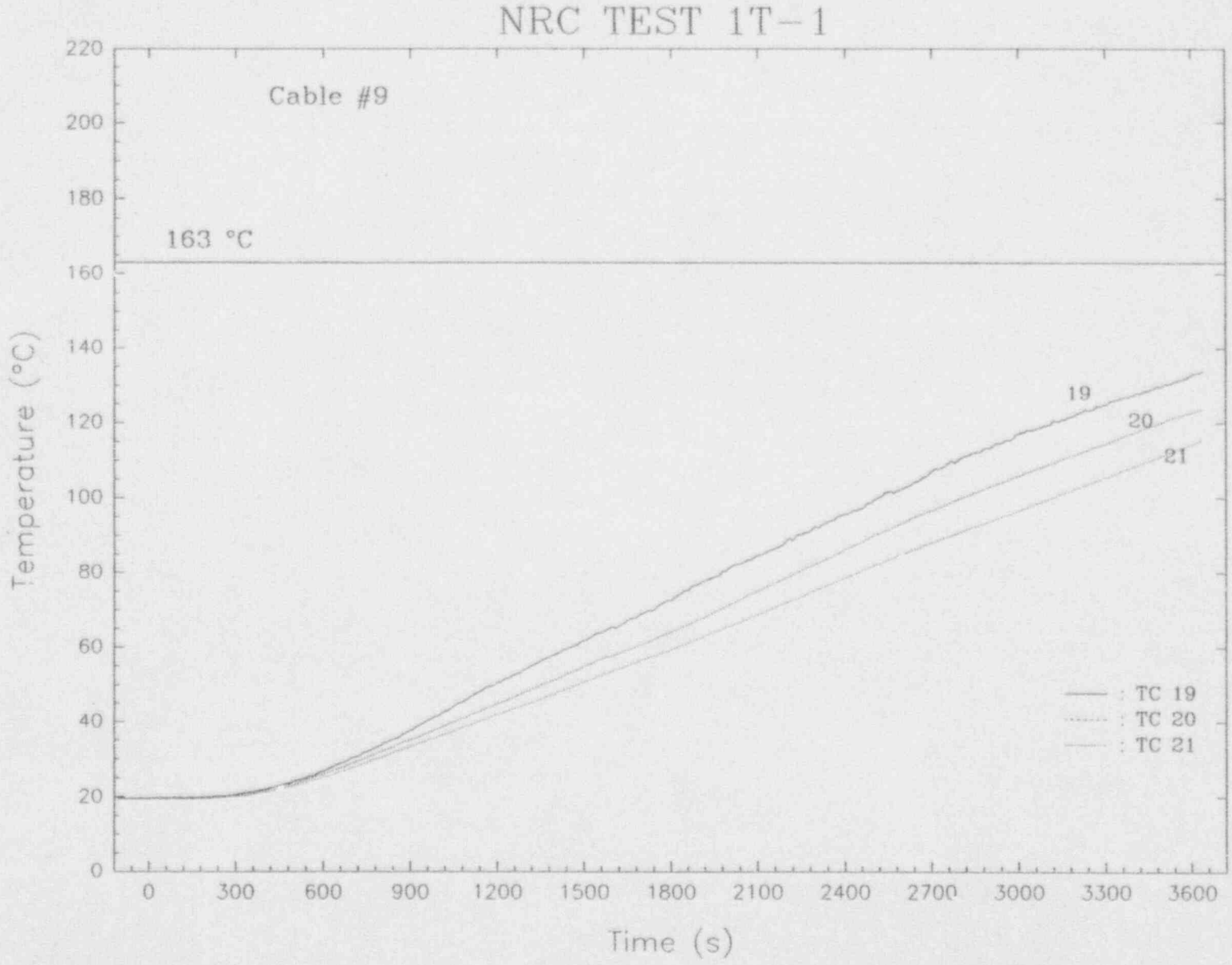

Fig. IX.24. Temperatures on power/control cable #9, test 1T-1.

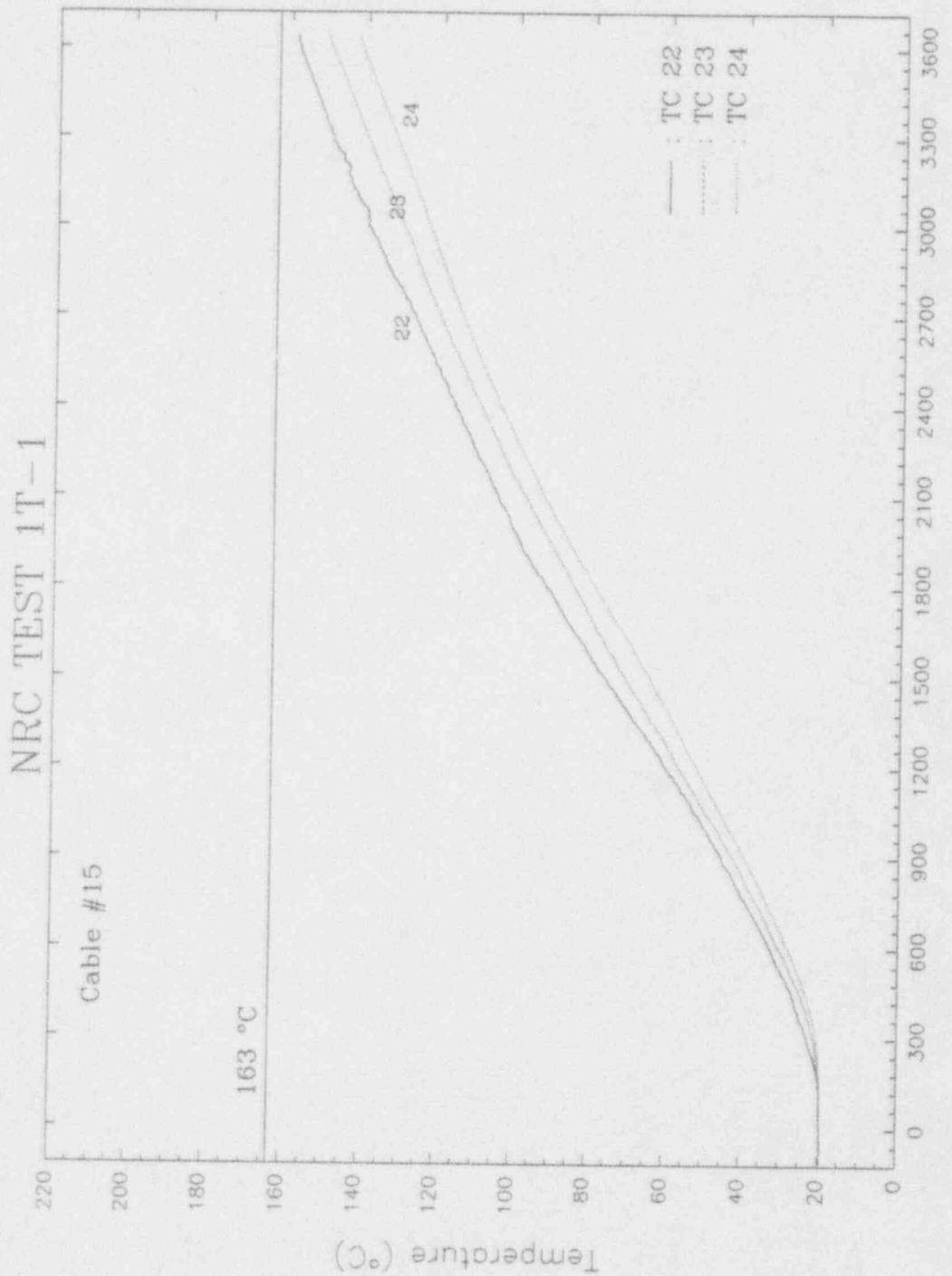

Fig. IX.25. Temperatures on power/control cable #15, test 1T-1.

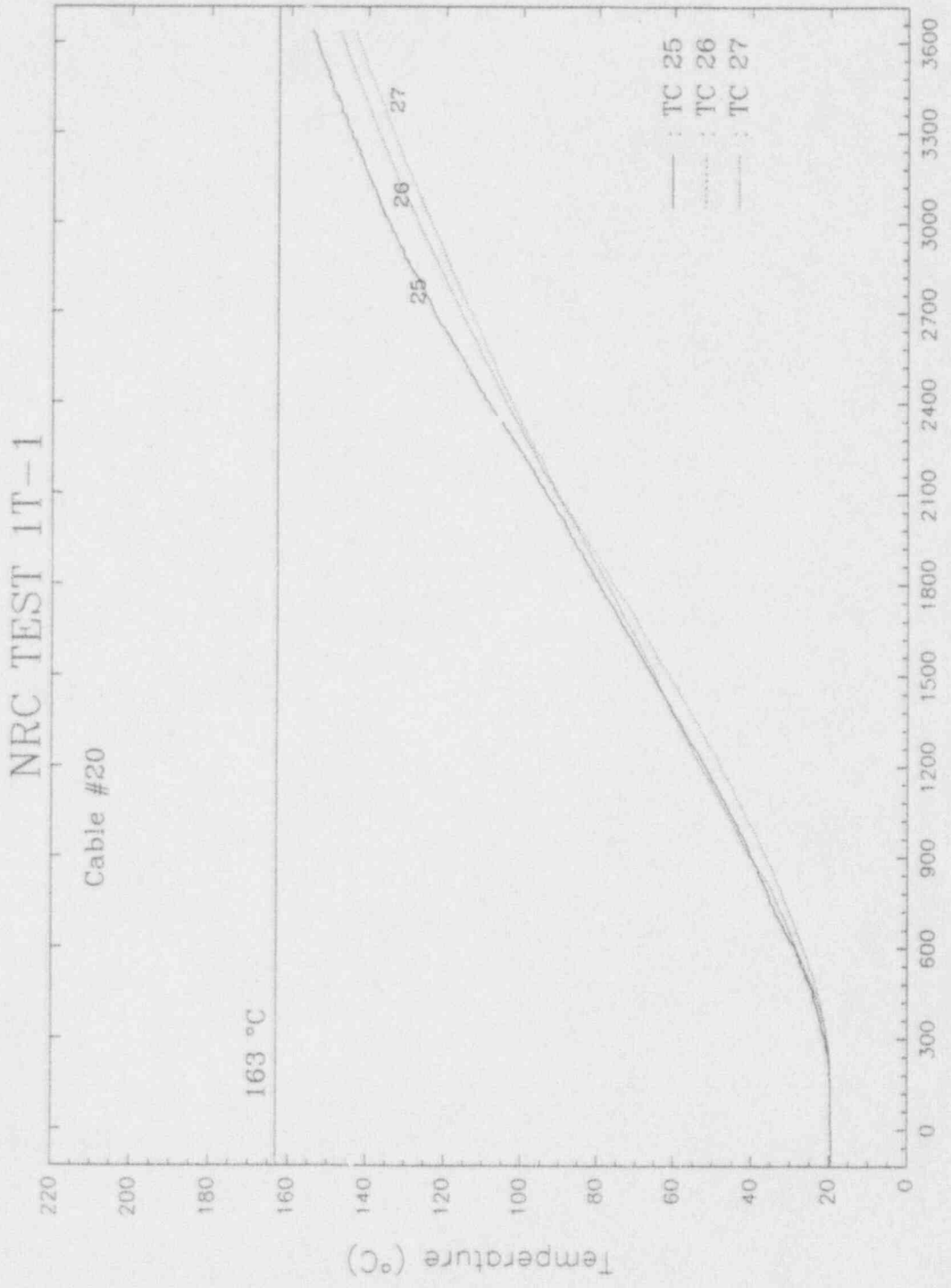

Fig. IX.26. Temperatures on instrumentation cable #20, test 1T-1.

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NIST-114
(REV. 9-92)
ADMAN 4.09

U.S. DEPARTMENT OF COMMERCE
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Report of Test -
FR 3991 on Pilot-Scale Fire-Endurance Tests of Subliming Fire-Barrier Panels

CONTRACT OR GRANT NUMBER | TYPE OF REPORT AND/OR PERIOD COVERED

AUTHOR(S) (LAST NAME, FIRST INITIAL, SECOND INITIAL)

Steckler, Kenneth D.

PERFORMING ORGANIZATION (CHECK (X) ONE BOX)

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Building and Fire Research Laboratory, Fire Science Division

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A series of tests was carried out at the request of the Nuclear Regulatory Commission to obtain information on the fire endurance of several configurations of subliming fire-barrier panels when tested in a pilot-scale furnace.

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