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

REPORT OF TEST

FR 4008

on

Pilot-Scale Fire-Endurance Tests of Fire-Barrier Panels and Panel/Blanket Combinations

by

Kenneth D. Steckler

August 20, 1996

Submitted to:

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

Table of Contents

Page

Executive Summary 3

Objective 6

Definitions 6

Significance of Pilot-Scale Fire Endurance Test Results 6

Scope of Test Series 7

Test Details and Results 7

I. Laboratory Test Facility and Uncertainty Associated with Test Results 7
- A. Furnace Specifications and Test Assembly Mounting 7
- B. Thermocouples 8
- C. Unexposed-Surface Thermocouple Insulation Pads 8
- D. Experimental Uncertainty 9

(Brief descriptions of test assemblies are presented in Table ES1, pp. 4-5)

PANEL MATERIALS

II. Test H1-1 16
- A. Description of Test Assembly 16
- B. Fire Test Procedures and Results 17
- C. Analysis of Test Results 17

III. Test H3-1 41
- A. Description of Test Assembly 41
- B. Fire Test Procedures and Results 42
- C. Analysis of Test Results 42

WRAPPING MATERIAL/"SUBLIMING" PANEL COMBINATIONS

IV. Test TJ1-1 70
- A. Description of Test Assembly 70
- B. Fire Test Procedures and Results 71
- C. Analysis of Test Results 71

V. Test TJ3-1 95
- A. Description of Test Assembly 95

B. Fire Test Procedures and Results 96
C. Analysis of Test Results 97

VI. Test TU3-1 125
A. Description of Test Assembly 125
B. Fire Test Procedures and Results 126
C. Analysis of Test Results 127

References 153

APPENDIX. Uncertainty Analysis 154

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 three fire-barrier systems when tested as horizontal planar units in a pilot-scale furnace. These systems are or will be installed to protect cable trays and electrical raceways in one or more U.S. nuclear power plants.

For reasons presented later in this report, pilot-scale fire-endurance testing is limited to assessing the thermal-transmission characteristics of fire barrier materials, often under non-conservative edge-loss conditions. Furthermore, since the tests in this 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 test assemblies exposed to the furnace on more than one surface, 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 fire barriers.** Indeed, the reduced-scale results of this test series are intended for first-cut screening purposes only.

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 five tests were conducted: two tests involving semi-rigid fire-barrier boards and three tests involving "subliming" panels with wrapping-material upgrades.

Procedures specified in American Society for Testing and Materials (ASTM) E 119-88 [1] 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 thermocouples).

The test results are summarized in Table ES1 on pages 4 and 5. The primary results are:

1. Four test assemblies, H3-1, TJ1-1, TJ3-1, and TU3-1, met all ASTM E 119 temperature and flame passage criteria for the expected period of either 1 or 3 hours. Indeed, these systems exceeded their expected periods by 0.5 to 1.5 hours.

2. The remaining test assembly, H1-1, produced average unexposed-surface temperatures that reached the E-119 average-temperature criterion about 5 minutes prior to the expected 1-hour fire-endurance period. No flame passage or burnthrough occurred during the 1-hour test period.

TABLE ES1. SUMMARY OF PILOT-SCALE FIRE-ENDURANCE RESULTS	
PANEL MATERIALS	Fire-endurance period by E-119 criteria (hr:min)[1]
1-hour Assembly	
Test H1-1: Semi-rigid board system; 2 layers of nominal 18 mm (0.70 in) -thick board over nominal 0.51 mm -thick abrasion-resistant cloth, supported only on perimeter by furnace sample-support lip (no 13 mm [0.5 in] -wide stainless steel supports).	**0:55.3** (+0:/01.5 -0:01.4)
3-hour Assembly	
Test H3-1: Semi-rigid board system; 4 layers of nominal 18 mm (0.70 in) -thick board over nominal 0.51 mm -thick abrasion-resistant cloth, supported only on perimeter by furnace sample-support lip (no 13 mm [0.5 in] -wide stainless steel supports).	**3:32.5** (+0:04.6/ -0:04.5)
WRAPPING MATERIAL/"SUBLIMING" PANEL COMBINATIONS	
1-hour Assembly	
Test TJ1-1: panel/blanket system; one layer of nominal 12.7 mm (0.50 in.) -thick[2], 1-hr "subliming" fire-barrier panel over one ~ 25 mm (1 in.)-thick mineral-wool blanket, with blanket sandwiched between two layers of 0.41 mm (0.016 in.) glass-fiber cloth, supported only on perimeter by furnace sample-support lip (no 13 mm [0.5 in] -wide stainless steel supports).	**1:30.6** (+0:03.0/ -0:02.9)
3-hour Assemblies	
Test TJ3-1: panel/blanket system; one layer of nominal 25.4 mm (1.0 in.) -thick[2], 3-hr "subliming" fire-barrier panel over two ~ 25 mm (1 in.)-thick mineral-wool blankets, with blanket combination sandwiched between two layers of 0.41 mm (0.016 in.) glass-fiber cloth, supported only on perimeter by furnace sample-support lip (no 13 mm [0.5 in] -wide stainless steel supports).	**4:29.2** (+0:09.5/ -0:09.3)
Test TU3-1: panel/blanket system; one layer of nominal 25.4 mm (1.0 in.) -thick[2], 3-hr "subliming" fire-barrier panel over a nominal 9 mm (0.35 in.) -thick fire-barrier blanket (flexible mat), supported by 13 mm (0.5 in)-wide stainless steel supports, 0.30 m (12 in) on center (O.C.).	**3:56.8** (+0:07.6/ -0:07.4)

[1]Parenthetical values are the range of uncertainty of the reported fire-endurance period due to uncertainties associated with instruments used in the test (see Sec. I.D.).

[2]The thickness of the board is intended by the manufacturer to have a certain "plus" tolerance, but a zero "minus" tolerance with respect to this nominal thickness.

TABLE ES1. (Cont.).		
Times at which E-119 unexposed-surf.-temp. criteria were exceeded. (hr:min:s)		Unexposed surface observations during and after fire test
Avg.Temp.[3]	Peak Temp.[4]	
"1-hour" Assembly		
0:55:06	not reached at shutdown (1:16:00)	No changes to unexposed surface during test. Post-test inspect. revealed unexposed surface was discolored only beneath thermocouple pads. No burnthrough.
3-hour Assembly		
3:31:34	not reached at shutdown (3:35:00)	No changes to unexposed surface during test. Post-test inspect. revealed unexposed surface was discolored only beneath thermocouple pads. No burnthrough.
1-hour Assembly		
1:30:01	2:04:30 (extrap. from conditions at shutdown at 2:04:00)	No changes to unexposed surface during test. Post-test inspect. revealed unexposed surface was discolored only beneath thermocouple pads. No burnthrough.
3-hour Assemblies		
4:28:14	5:39:41	No changes to unexposed surface during the first 3.6 hours. Subsequently, some slight browning developed in a limited area, and crystals appeared over much of the exposed area. Post-test inspec. revealed unexposed surface was moderate brown to black beneath thermocouple pads. No burnthrough.
3:55:53	5:05:45	No changes to unexposed surface during first 4 hrs. of test. Subsequently, a few small crystals appeared and brown areas formed. Post-test inspec. revealed unexposed surface was moderate to very dark brown beneath thermocouple pads. No burnthrough.

[3]Average temperature rise exceeded 139°C (250°F) above initial temperature.

[4]Temperature rise of any thermocouple exceeded 181°C (325°F) above initial temperature.

Objective

These tests were carried out at the request of the U.S. Nuclear Regulatory Commission (NRC) to obtain information on the fire resistance characteristics of "1-hour" and "3-hour" fire-barrier materials when tested as horizontal planar units in a pilot-scale furnace. The test materials, number and order of layers are the same as those currently installed or soon to be installed in one or more U.S. nuclear power plants to protect cable trays and electrical raceways. The results of these tests are intended for screening purposes only.

Definitions

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

Fire Resistance --- is *"the property of a material or assemblage to withstand fire or give protection against it."* [2] *"As applied to the elements of buildings, it is characterized by the ability to confine a fire or to continue to perform a given structural function, or both"*. [2]

Fire endurance --- is *"a measure of the elapsed time during which a material or assemblage continues to exhibit fire resistance."* [2] For the class of fire-barrier assemblies examined in the present study, fire endurance is measured per ASTM E 119-88, Standard Methods for Fire Tests of Building Materials [1]. 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. If the furnace were shifted suddenly to positive pressure, flame and/or hot gases would be expected to pass immediately through the assembly at burnthrough areas.

Constrained --- indicates that the panel, mat, or blanket extended over the sample-support lip (which is 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 in the region above the lip, thereby fixing the perimeter of the test assembly.

Significance of Pilot-Scale Fire-Endurance Test Results

It is important to note that pilot-scale fire-endurance tests on "planar" assemblies (e.g., walls, floor/ceilings), including those reported herein, generally produce longer fire-endurance periods than tests conducted on full-scale assemblies in a full-scale furnace. This is a consequence of 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 are a factor in pilot-scale fire-endurance tests that may affect the fire endurance period. For these reasons, pilot-scale fire-endurance testing is limited to assessing the thermal-transmission characteristics of fire-barrier materials, 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.

Consequently, based on 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 and electrical raceway fire barriers. Indeed, the test results are intended for NRC screening purposes only.

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 five tests was conducted: two tests involving fire-barrier panels and three test involving a fire-barrier panel and blanket combination.

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).

Hose-stream tests were not conducted.

Test Details and Results

I. Laboratory Test Facility and Uncertainty Associated with Test Results

A. Furnace Specifications and Test Assembly 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 test assembly during a test.

The top of the furnace is equipped with a frame for supporting horizontal test assemblies 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).

During one test, two 13 mm (0.5 in)-wide stainless steel angle supports, 0.30 m (12 in) O.C., were added as shown in Fig. I.3 to approximate the support from metal bands or wires used in actual plant installations. The cross-sectional dimensions of the supports were 13 x 19 x 3 mm (0.5 x 0.75 x 0.125 in).

For all of the tests in this series, nominally square test assemblies were constructed 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 test-assembly frame and centered, 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 in]) were then placed side-by-side, with the 115 mm (4.5 in) dimension at or near vertical, along the perimeter of the unexposed surface of the test assembly, within the area of the supporting lip. Half-bricks were placed in spaces too small to accommodate a full brick. This arrangement constrained the perimeter of the assembly and prevented the upturn of layer edges and attendant flow of ambient air into the furnace along the breaches.

B. Thermocouples

Furnace temperatures were measured with three chromel-alumel thermocouples (designated TC1, TC2, and TC3) 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 349 $\pm$ 6 mm (13.75 $\pm$ 0.25in). Governed by furnace construction details and arrangements, the thermocouples were located at distances of 260 to 310 mm (10.2 to 12.2 in) beneath the exposed surface of the test assembly which are 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[5,6] pipe per the recommendation in paragraph 5.1, ASTM E 119-88. Employing the method set forth in ASTM RR:E05-1001, the time constants of furnace thermocouples were found to be 3.95 $\pm$ 0.15 minutes, which is outside the range 5.0 to 7.2 minutes required by ASTM E 119-88. This results in a **less severe exposure** during the early highly-transient period of the test than would occur with thermocouples with time constants in the specified range.

Unexposed surface temperatures were measured at 5 locations during each test using 0.8 mm (0.031 in) diameter, stainless-steel sheathed, ungrounded, chromel-alumel thermocouples. The thermocouple junctions were installed beneath the centers of insulation pads (described below) per E 119 requirements.

All thermocouple outputs were recorded once every 10 seconds. Temperature-time plots in this report present all these data, whereas tables of temperature-time data only list data taken on the minute.

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 [3]:

---

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

[6]Certain commercial equipment, instruments, or materials are identified in this report in order to adequately specify the experimental procedure. In no case does such identification imply recommendation or endorsement by NIST, nor does it imply that the material or equipment identified is necessarily the best available for the purpose.

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 thermal performance.**

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 a bead of high-temperature RTV sealant (having a maximum continuous operating temperature of 315°C (600°F)) placed on the lower side along the perimeter of the pad. The RTV was allowed to cure for at least 24 hours prior to the test.

D. Experimental Uncertainty

The ASTM E 119 standard states that

> *"No comprehensive test program has been conducted to develop data on which to derive statistical measures of repeatability (within-laboratory variability) and reproducibility (among-laboratory variability). The limited data suggest that there is a degree of repeatability and reproducibility for some types of assemblies. Results depend on factors such as the type of assembly and materials being tested, the characteristics of the furnace, the type and level of applied load, the nature of the boundary conditions (restraint and end fixity), and details of workmanship during assembly."* [1]

Most of this statement applies to the current series of reduced-scale tests. Since only one test assembly (one sample) of each fire-barrier system was tested, a statistical measure of repeatability was not established. Furthermore, no other data exist to indicate reproducibility of results obtained from the NIST reduced-scale furnace. Consequently, uncertainty statements had to be limited to **instrument uncertainty** during a given test.

The two measured quantities that determine fire endurance are time and temperature. The uncertainty of the fire-endurance period is related explicitly to the uncertainty in the time measurement and implicitly to the uncertainties associated with the unexposed-surface and furnace temperatures.

The following factors were judged to be relevant for assessing the effect of instrument uncertainty on the results of a given test:

<u>time measurement</u>

* basic accuracy of computer clock

* delay between reading clock and reading thermocouple output during data-acquisition scan

<u>temperature measurement</u>

* inherent accuracy of thermocouple materials
* accuracy of voltage-to-temperature conversion polynomial
* accuracy of digital voltmeter used to measure thermocouple voltages

Uncertainties associated with the attachment of thermocouples to the unexposed surface of the test assembly were judged to be small since they were mounted beneath insulation pads (see sections I.B and I.C below) as required by ASTM E 119.

Details of the analysis are presented in the Appendix. For this test series, the percent maximum uncertainty of the fire-endurance period associated with instrument uncertainty during a single test was found to be within the range 2.2 to 3.5 percent.

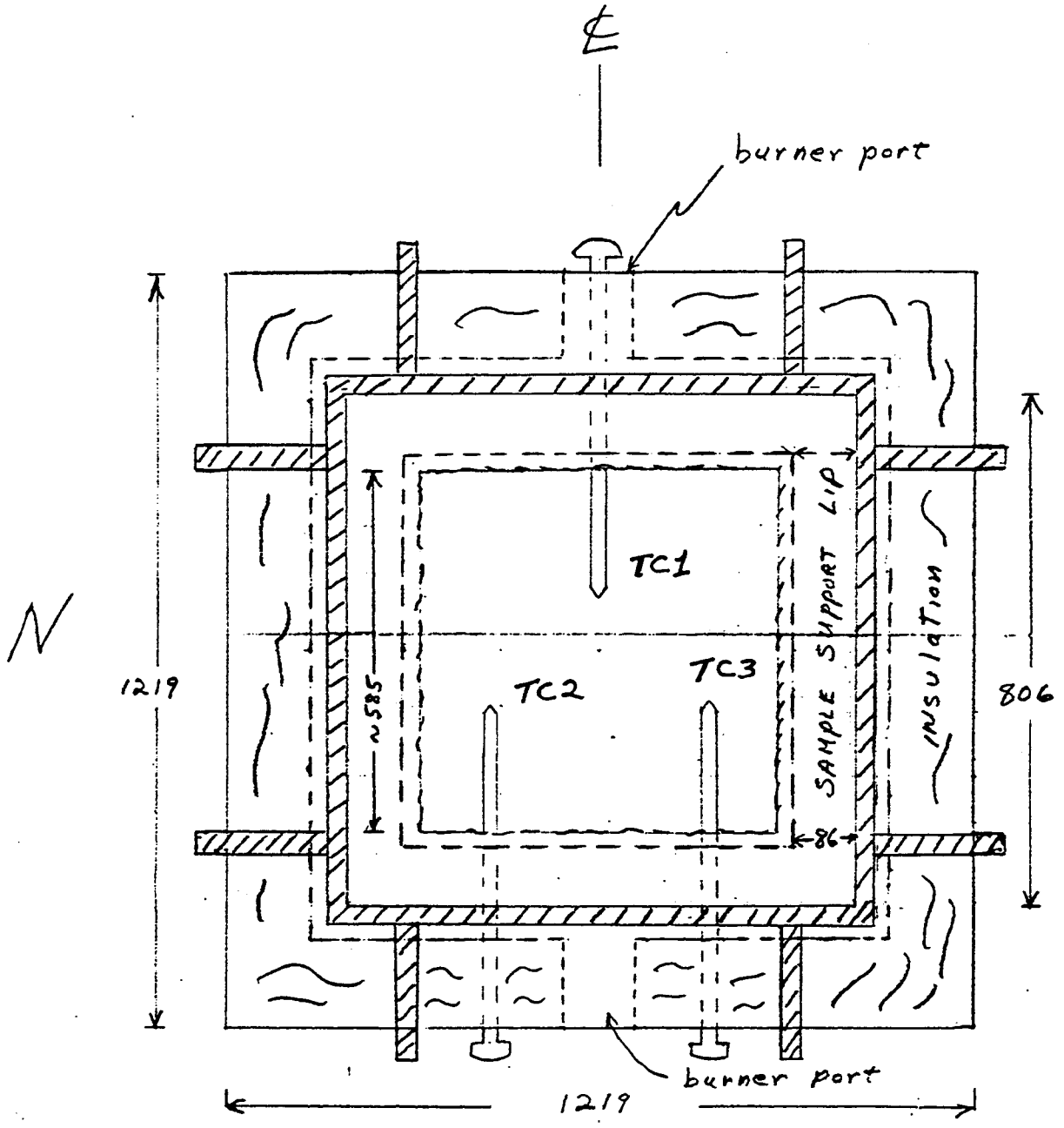


Fig. I.1. Furnace plan. All dimensions in millimeters (1 in = 25.4 mm).

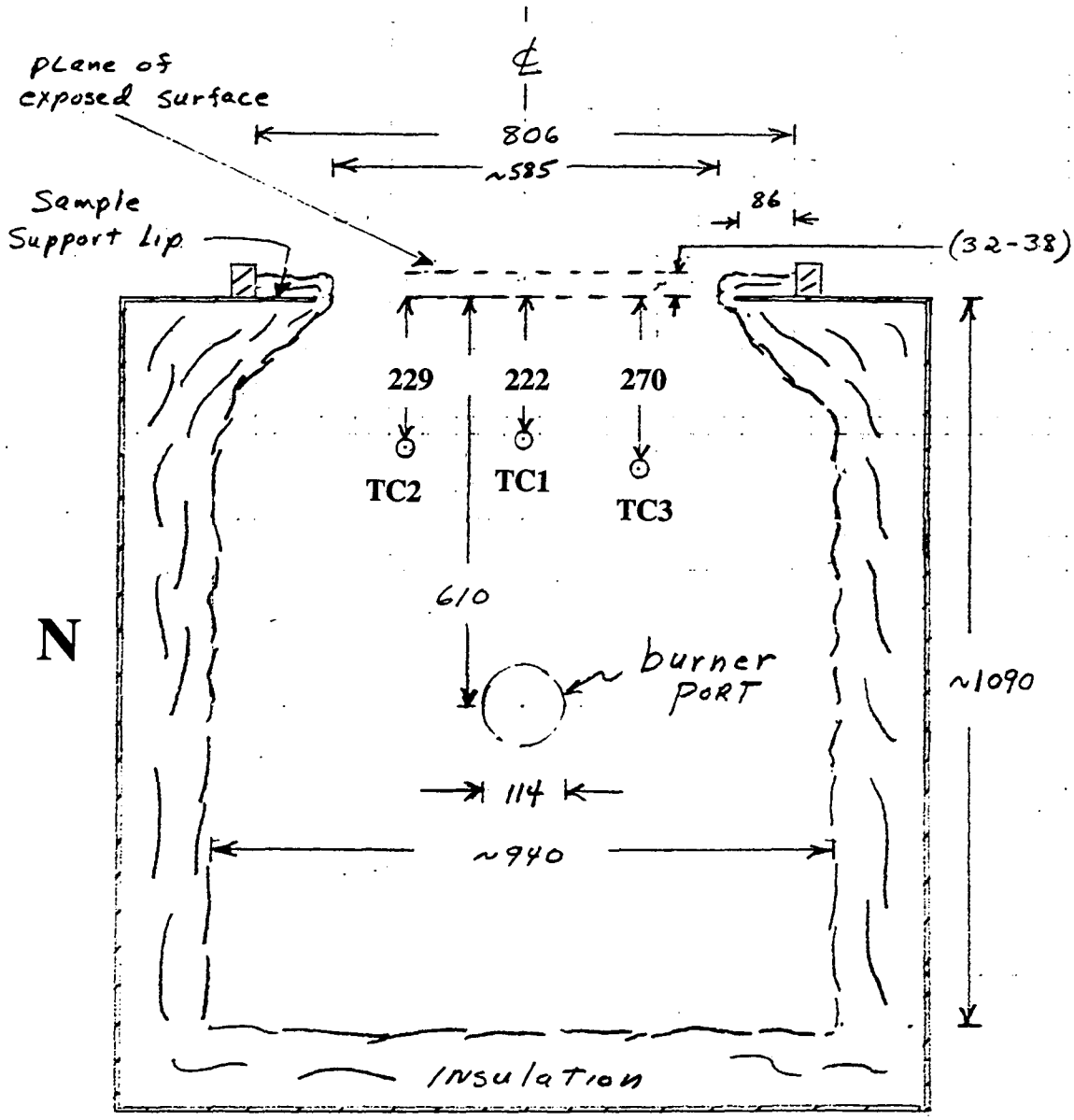


Fig. I.2. Furnace elevation. All dimensions in millimeters (1 in = 25.4 mm).

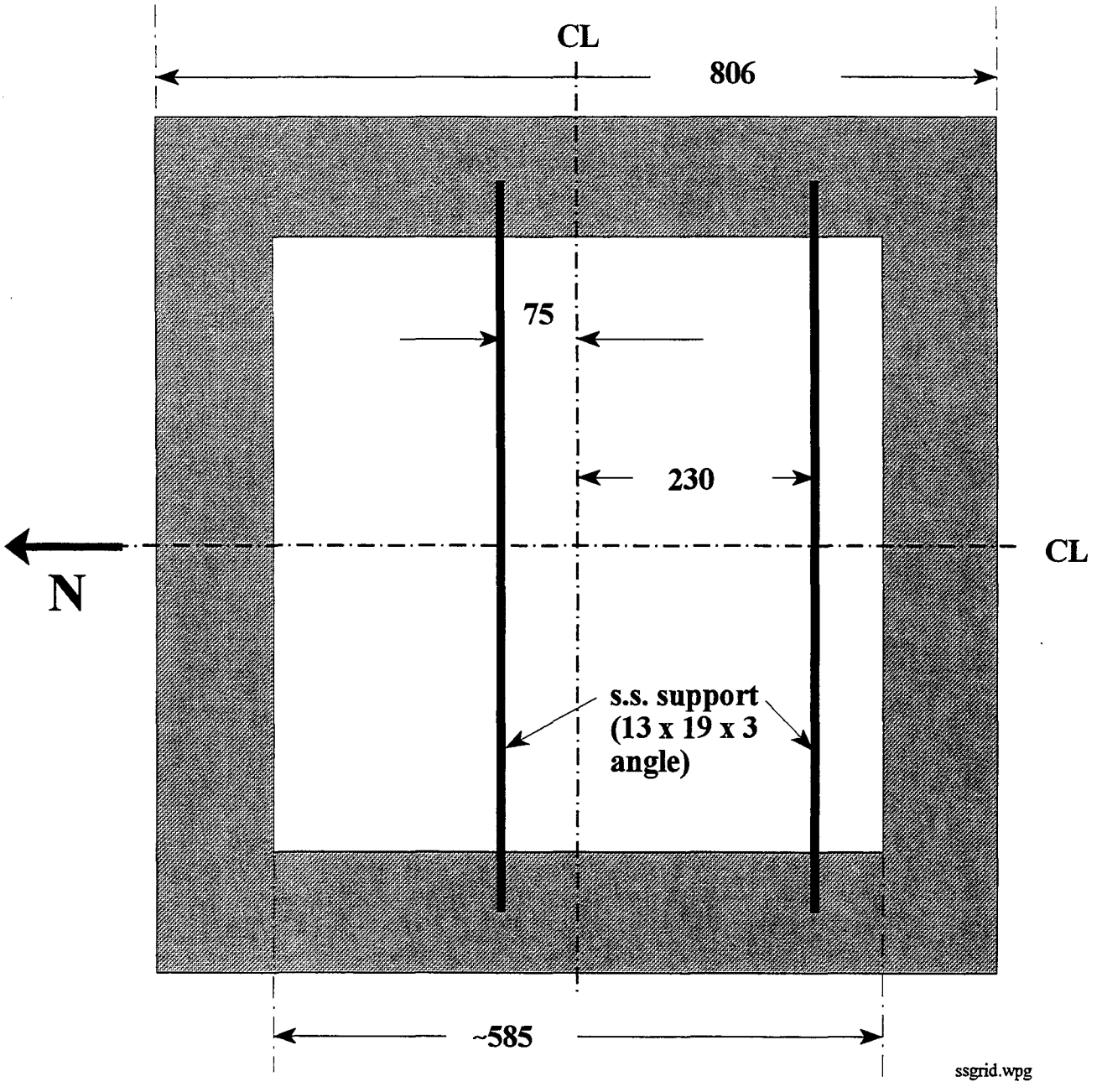


Fig. I.3. Furnace plan. Locations of 13 mm (0.5 in)-wide stainless steel supports (dimensions in mm).

PANEL MATERIALS

II. Test H1-1

A. Description of Test Assembly

The test assembly consisted of 2 layers of semi-rigid fire-barrier board with one layer of abrasion-resistant silicone-impregnated cloth on the exposed face. The manufacturer reports that the board consists of a suspension of hydrated magnesium carbonate in bulk ceramic fiber bound with an aqueous synthetic resin and faced with a polyester scrim.

The layers were cut by the manufacturer to the dimensions shown in Fig. II.1 and identified as H.D. SN 8/47 (upper board) and H.D. SN 17/44 (lower board).

The arrangement, designations, thicknesses, and masses of the layers were as follows:

Test H1-1: Test Assembly			
Arrangement	Thickness in mm [in]	Pre-test Mass in kg ± 0.01 [lb ± 0.02]	Post-test Mass in kg ± 0.01 [lb ± 0.02]
layer A, upper board	18 (nominal) [0.70]	9.26 [20.4]	17.39 [38.31]
layer B, lower board	18 (nominal) [0.70]	9.58 [21.1]	
layer C, abrasion-resistant cloth	0.51 (nominal) [0.020]		

Layer C was closest to the furnace and layer A was farthest away.

Pre-test photographs of the unexposed and exposed surfaces of layer A are shown in Figs. II.2 and II.3, respectively. The unexposed surface of layer B and the exposed surface of layer C are shown in Figs. II.4 and II.5, respectively. Twenty "quilting pins" with fender washers were installed along the perimeter of the stack of layers to hold the test assembly together (Fig. II.6).

The stainless steel supports described in section I.A were <u>not</u> in place for this test. After positioning the assembly on the furnace, nominal 25.4 mm (1 in) thick ceramic-fiber insulation was wrapped around its edges and the exterior of this insulation was covered with aluminum foil. The lower edge of the foil was taped to the furnace with glass-cloth tape. The upper edges of the insulation and foil were held in place by the bricks (described in sec. I.A) which loaded the perimeter of the assembly.

B. Fire Test Procedures and Results

The test was conducted on June 5, 1995 and was witnessed by the following official observer: Patrick M. Madden (NRC).

The test assembly 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.7 and tabulated in Table II.1. The average furnace temperatures and the standard temperature-time curve are shown in Fig. II.8.

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

Figures II.10 and II.11 show the unexposed surface during the test. The surface did not discolor and neither flame passage nor glowing were observed during the test period.

Following termination of the test, no flaming was observed on the exposed surface of the test assembly when the west edge of the assembly was lifted and propped (Fig. II.12). The abrasion-resistant cloth was bulging slightly but free from tears. There was no debris from the test assembly at the bottom of the furnace. The assembly was allowed to cool overnight in the propped position and was removed from the furnace the following day.

A log of observations is presented in Table II.2.

The exposed surface of layer B and the unexposed surface of Layer A on June 6, 1995, the day after the test, are shown in Figs. II.13 and II.14, respectively. The photograph in Fig. II.13 was taken subsequent to cutting and folding-back the abrasion-resistant cloth (layer C). Specimens of layers B and A from a "core sample" taken near the center of the assembly are shown in Figs. II.15 and II.16. The unexposed surface of layer A (Fig. II.14) was discolored only beneath the thermocouple pads. The color varied from light brown under TC pad 31 to dark brown/black under TC pad 33. There was no burnthrough beneath the TC pads or elsewhere.

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 during the test neither flame nor hot gases capable of igniting cotton waste held against the unexposed surface pass through the assembly. In addition to these criteria, NRC requests monitoring the time at which any of the unexposed-surface thermocouples exceeds 139°C (250°F) above the initial temperature.

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

Test H1-1: 1-hour Test Assembly			
Condition	Location	Time	
		(sec)	[hr:min:sec]
E 119 avg. unexposed surf. temp. criterion (164°C) [327°F]		3306	[0:55:06]
E 119 peak unexposed surf. temp. criterion (206°C) [403°F]		not reached; peak temp. was 201°C at shutdown.	
NRC unexposed surf. temp., 1st occurrence (164°C) [327°F]	TC33	3086	[0:51:26]

Concerning E 119 criteria, the average temperature was the controlling factor and the E 119 fire-endurance period was 3306 seconds (55.1 minutes). 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 +14 s and **the corrected fire-endurance period was 3320 s (55.3 minutes)**. The attendant maximum uncertainty was +91/-86 s (+1.5/-1.4 minutes) (see Appendix).

Neither flame nor hot gas passage through the unexposed face of the assembly were observed during the test. No glowing was observed at any time during the test. The post-test inspection revealed no burnthrough at the unexposed surface of the assembly.

TABLE II.1. Temperatures (°C), Test H1-1.

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
-120	23	23	23	23	24	24	24	24	24	24
-60	23	23	23	23	24	24	24	24	24	24
0	23	23	23	23	25	24	24	24	25	25
60	75	53	53	61	25	24	24	25	25	25
120	230	172	180	194	25	24	24	24	25	25
180	378	322	325	342	25	24	24	25	25	25
240	466	424	418	436	25	24	24	25	25	25
300	510	482	468	487	25	24	24	25	26	25
360	559	540	524	541	25	24	25	25	26	25
420	611	607	589	602	25	25	25	25	26	25
480	657	661	642	653	26	25	26	25	26	26
540	677	677	662	672	27	26	27	26	27	26
600	689	684	675	683	28	27	28	27	28	28
660	712	707	698	706	30	28	31	28	29	29
720	733	729	720	727	32	30	33	30	31	31
780	747	741	733	741	35	32	36	32	33	34
840	758	748	743	750	38	34	39	34	35	36
900	768	754	751	758	41	37	42	37	37	39
960	778	764	762	768	44	39	45	39	40	41
1020	787	773	770	776	47	42	49	42	42	44
1080	795	781	779	785	50	44	53	45	45	47
1140	801	786	785	791	54	48	56	48	48	51
1200	808	792	791	797	57	51	60	51	51	54
1260	815	799	798	804	61	54	64	54	54	57
1320	819	804	804	809	64	58	67	57	57	61
1380	823	809	808	813	67	61	71	60	60	64
1440	828	814	813	818	70	64	74	63	63	67
1500	833	819	818	823	73	68	77	66	66	70
1560	838	824	823	828	76	71	79	69	69	73
1620	841	827	827	832	78	74	82	71	71	75
1680	843	830	830	834	80	76	84	74	73	77
1740	848	834	834	838	82	79	86	76	76	80
1800	851	838	838	842	84	81	87	78	78	82
1860	856	842	842	847	86	83	89	80	80	83
1920	860	846	846	851	88	85	90	82	82	85
1980	863	851	851	855	90	87	93	83	83	87
2040	868	855	855	859	94	88	97	85	86	90
2100	872	859	859	863	97	91	102	88	88	93
2160	876	863	863	867	101	93	106	91	90	96
2220	877	865	865	869	105	97	111	94	93	100
2280	880	868	868	872	109	100	115	98	96	104
2340	886	873	872	877	113	104	119	102	100	108
2400	888	875	876	880	117	108	123	105	103	111
2460	891	878	879	883	121	112	127	109	107	115
2520	894	882	882	886	125	116	131	113	111	119
2580	898	885	885	889	128	120	135	117	114	123
2640	899	887	887	891	132	123	138	120	118	126

TEST: NRC H1-1 6/05/95

TABLE II.1. Temperatures (°C), Test H1-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
2700	899	888	888	892	136	127	142	124	121	130
2760	902	891	891	894	139	131	146	127	125	133
2820	905	894	894	898	143	134	149	131	128	137
2880	908	897	897	901	146	138	153	134	132	141
2940	912	900	900	904	150	141	156	138	135	144
3000	915	903	903	907	153	145	160	141	138	147
3060	917	906	906	910	157	148	163	144	142	151
3120	919	907	908	911	160	152	166	148	145	154
3180	920	909	910	913	164	155	170	151	148	158
3240	922	912	912	915	167	159	173	154	151	161
3300	924	914	914	917	170	162	177	157	155	164
3360	927	916	917	920	174	165	180	161	158	168
3420	929	918	918	922	178	169	184	164	161	171
3480	931	920	920	924	182	172	187	167	164	174
3540	933	923	923	926	186	176	191	170	167	178
3600	935	925	925	928	193	179	196	174	170	182
3660	937	927	927	930	200	183	201	177	174	187

TABLE II.2. Observations, Test H1-1.

The following observations were made during and after the test:

Time	
0:10:00	No change in the appearance of the unexposed surface.
0:11:00	Slight outgassing along the west edge of test assembly.
0:30:00	No change in appearance, no outgassing.
0:40:00	No change.
0:46:00	Some outgassing along outer edge of aluminum foil on east side.
0:55:00	No change.
1:00:00	No change.
1:01:00	Shutdown.
1:16:00	Lifted and propped the west edge of the assembly. Silicone is burned out of layer C, which is slightly bulged but not torn.

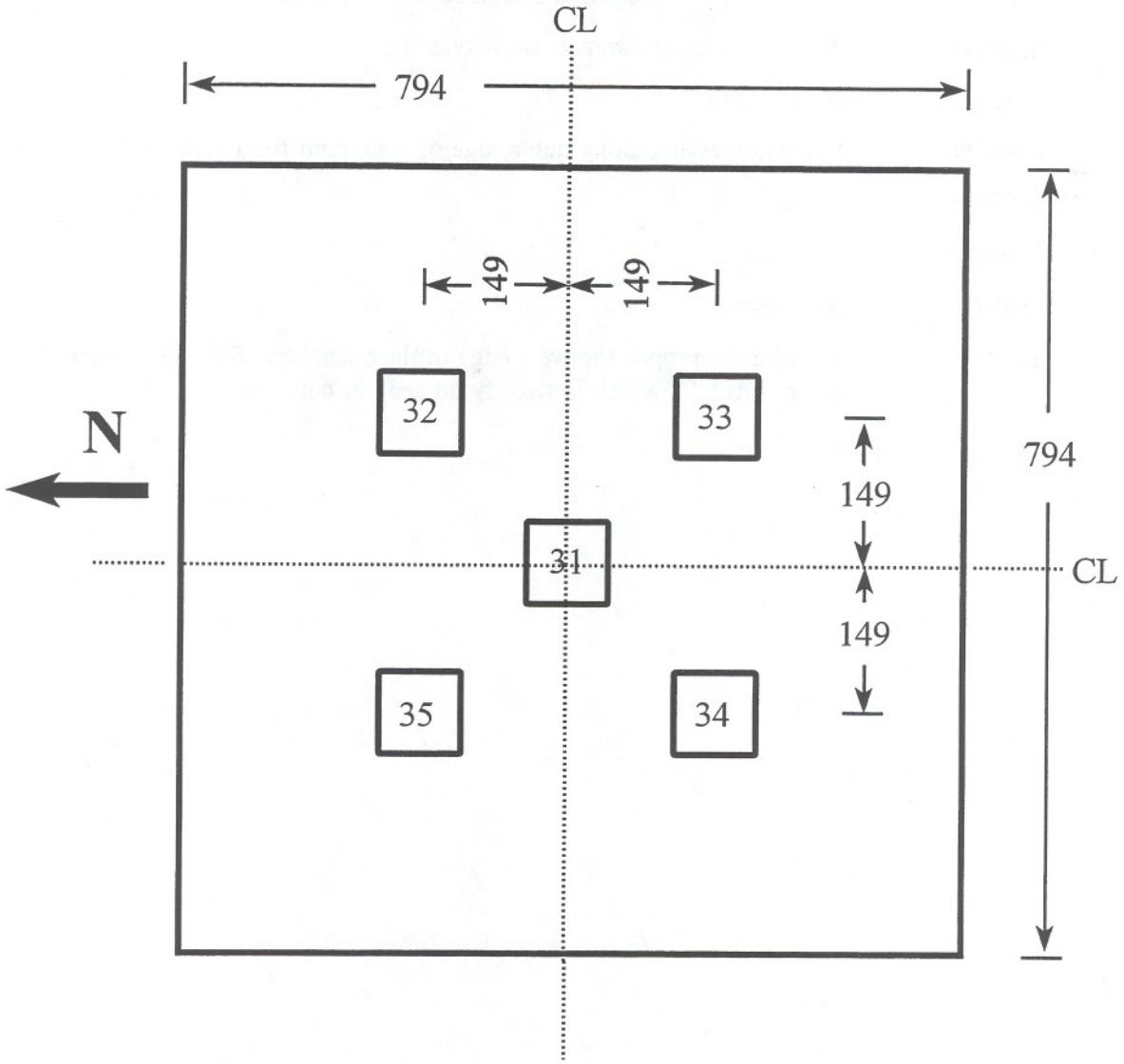


Fig. II.1. Layer dimensions, Test H1-1. All dimensions in millimeters (1 in = 25.4 mm). Numbered squares denote unexposed-surface thermocouple pads.

Fig. II.2. Pre-test unexposed surface, layer A, Test H1-1.

Fig. II.3. Pre-test exposed surface, layer A, Test H1-1.

Fig. II.4. Pre-test unexposed surface, layer B, Test H1-1.

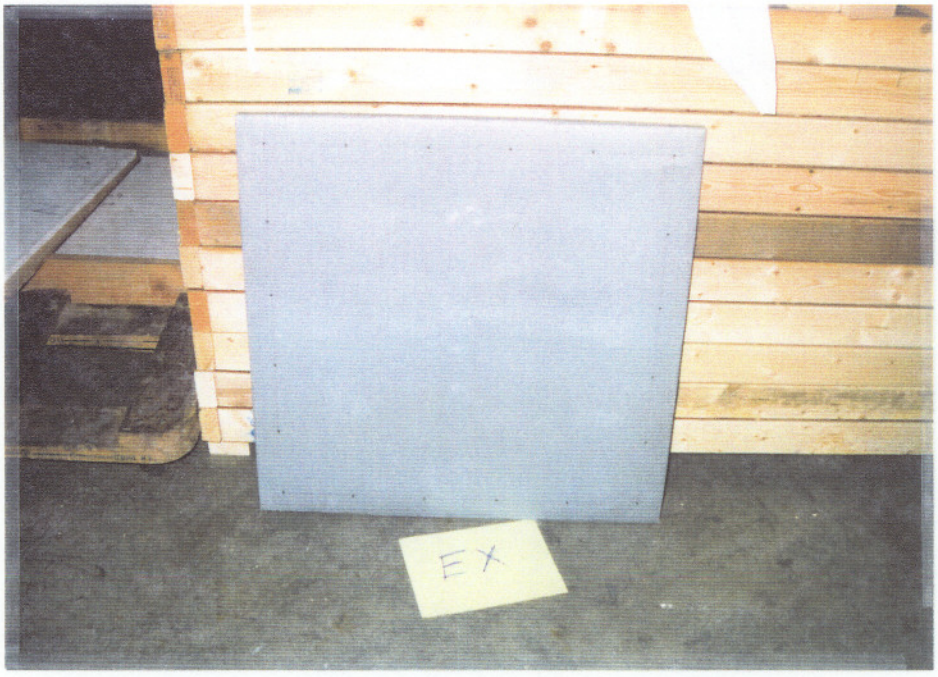


Fig. II.5. Pre-test exposed surface, layer C, Test H1-1.

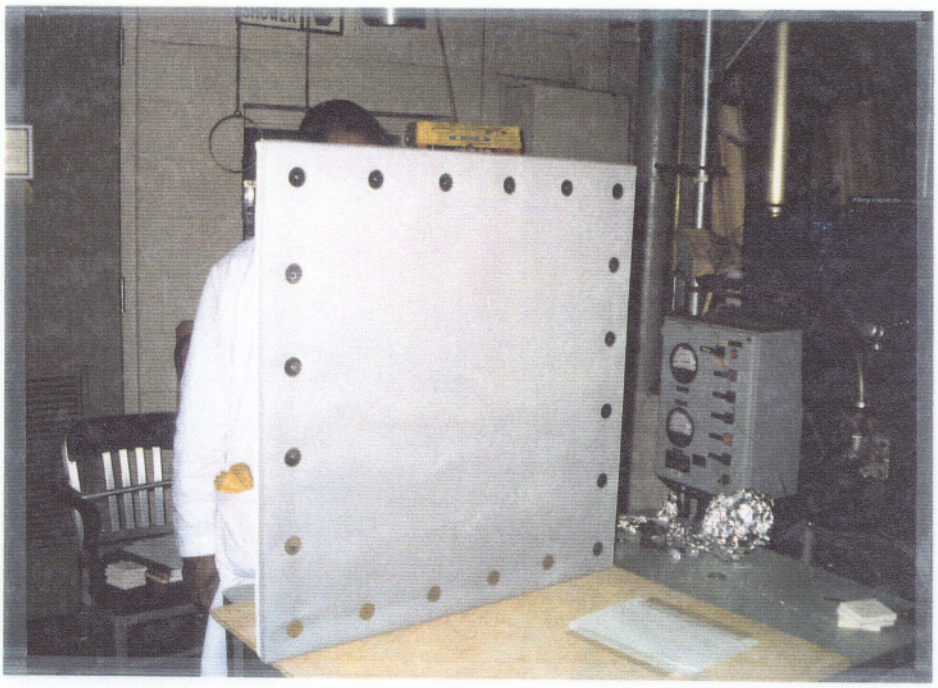


Fig. II.6. Photograph showing "quilting pins" with fender washers, Test H1-1.

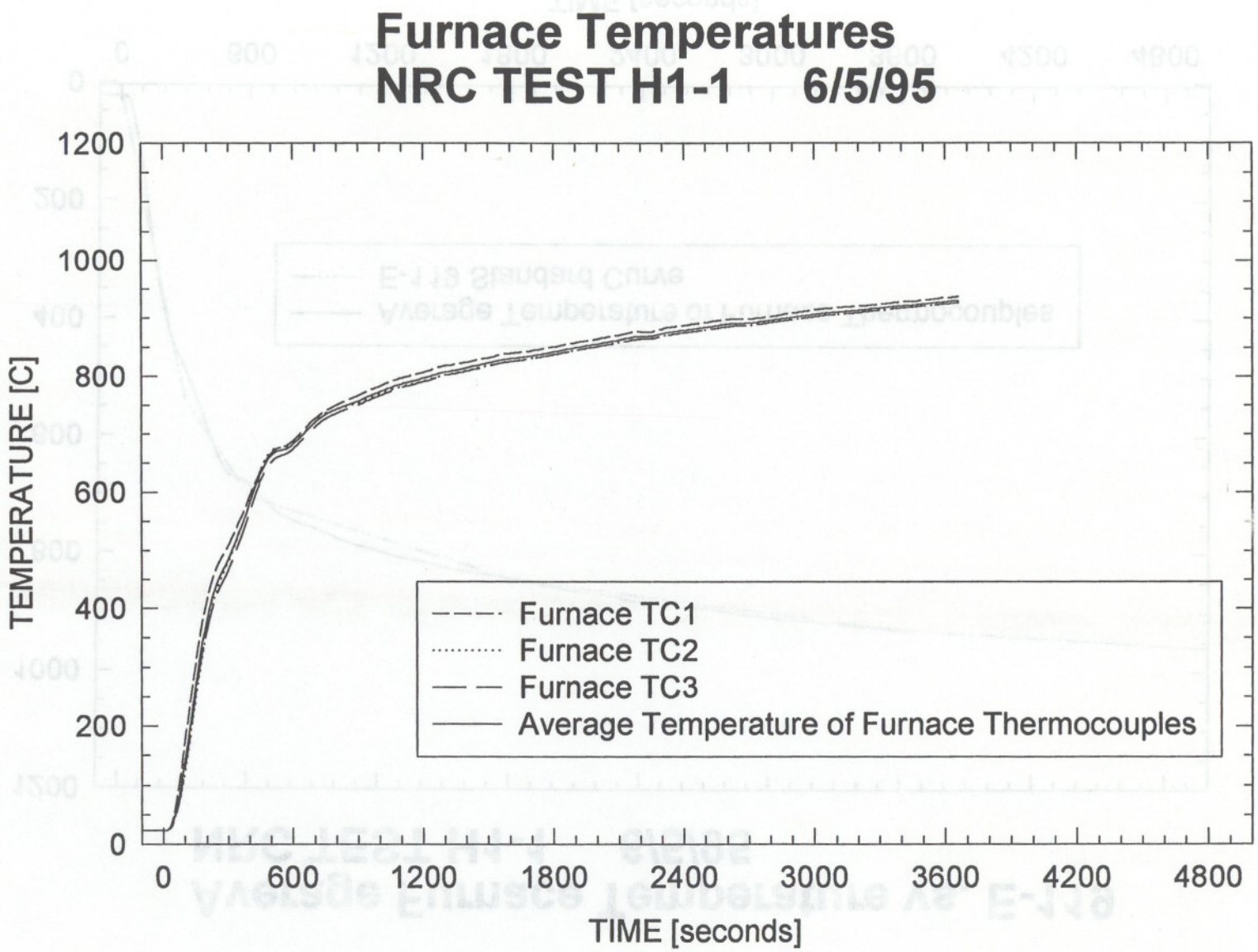


Fig. II.7. Furnace temperature, Test H1-1.

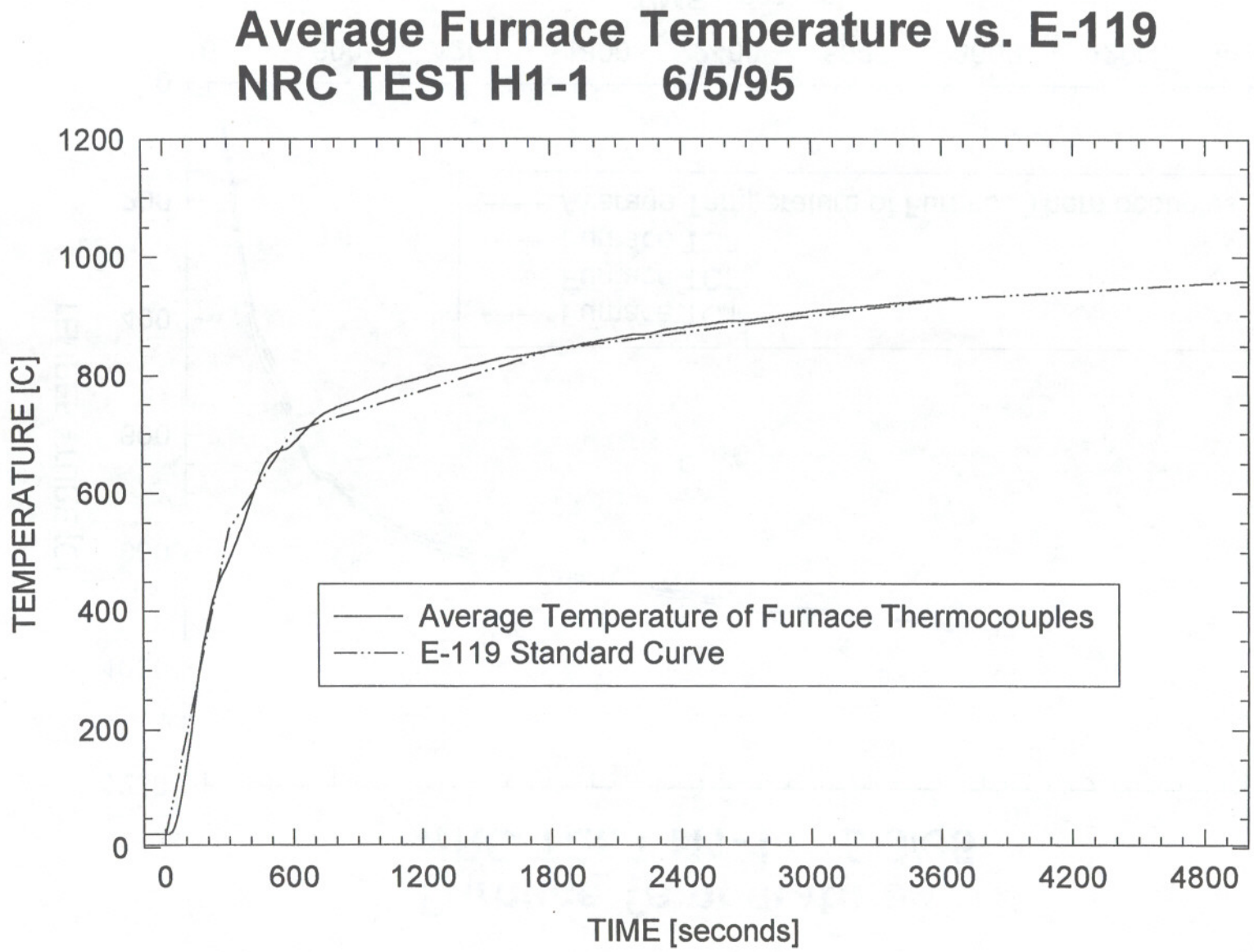


Fig. II.8. Furnace temperature, Test H1-1.

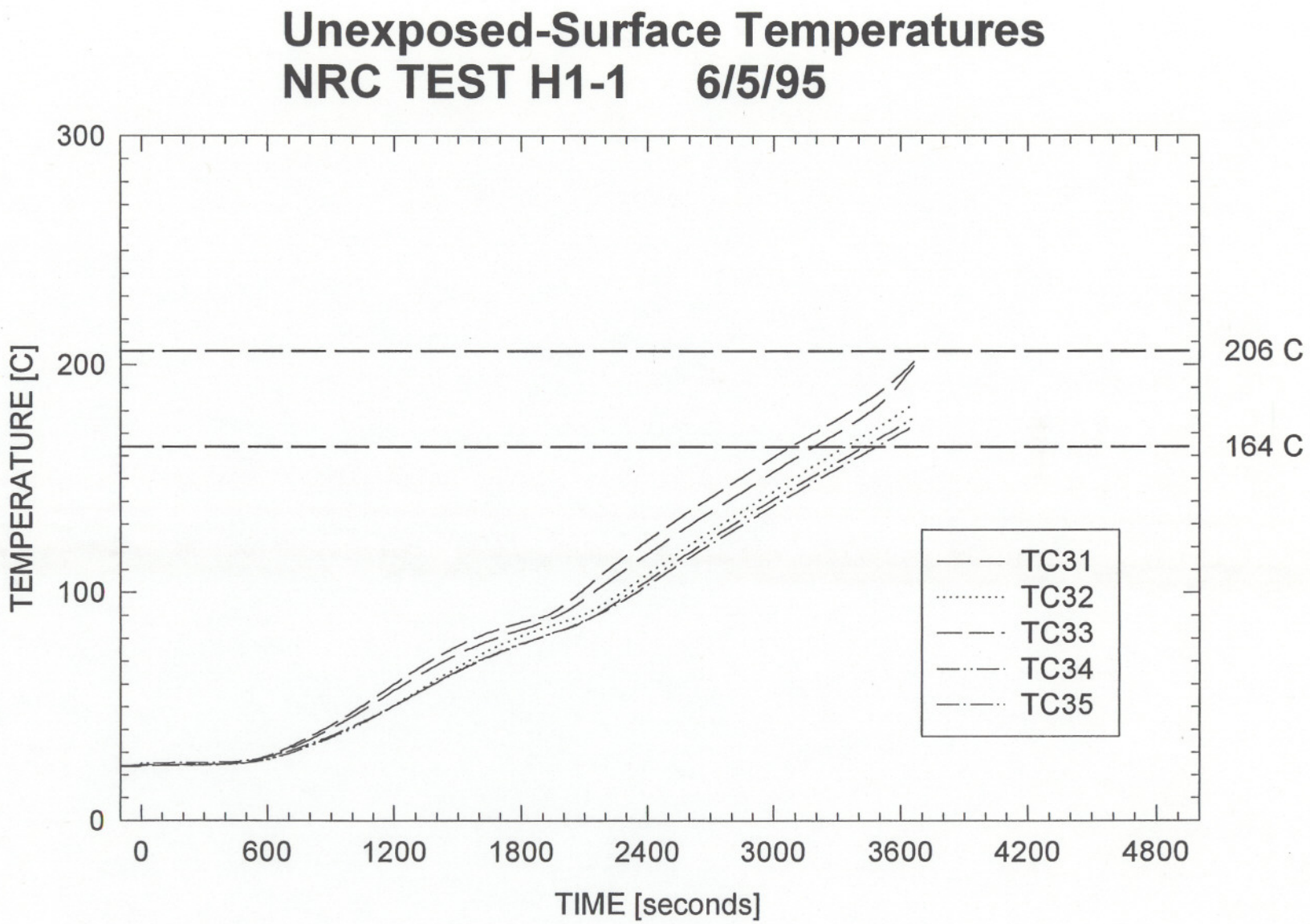


Fig. II.9. Unexposed-surface temperatures, Test H1-1.

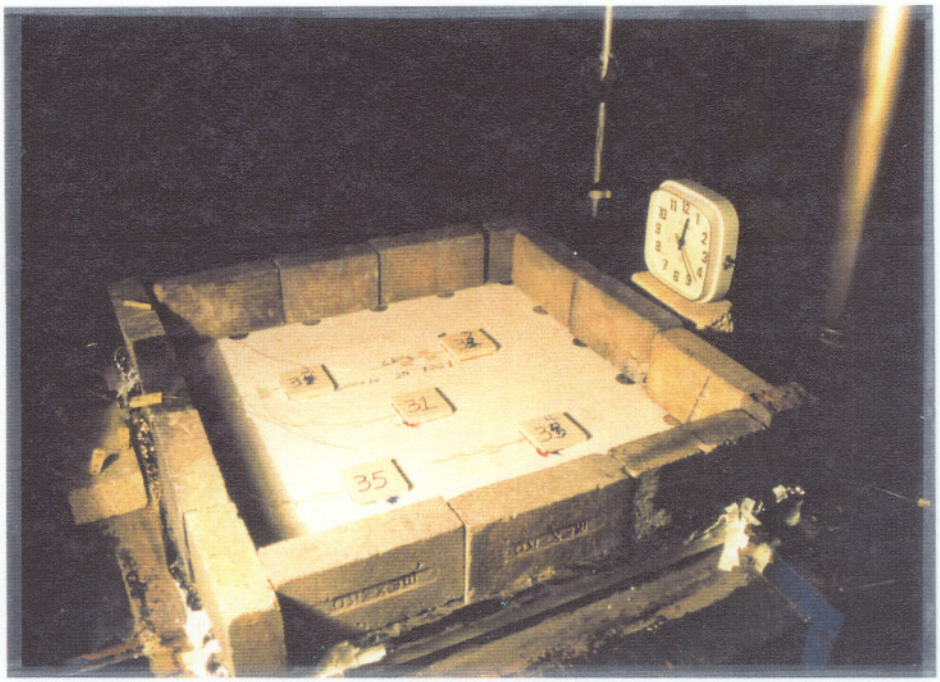


Fig. II.10. Photograph of unexposed surface during Test H1-1.

Fig. II.11. Photograph of unexposed surface during Test H1-1.

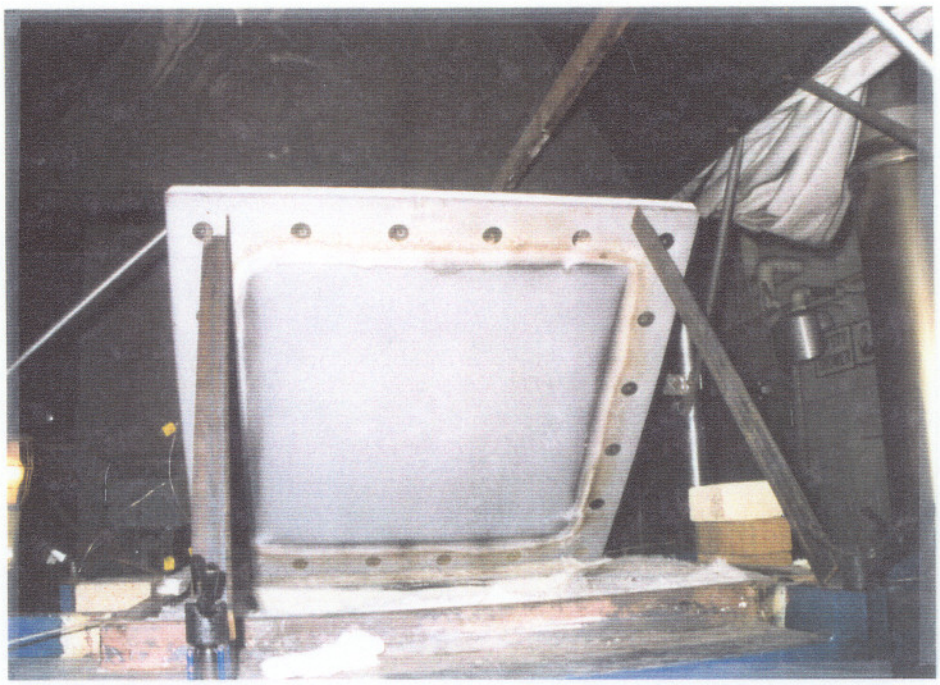


Fig. II.12. Post-test photograph of exposed surface, layer C, Test H1-1.

Fig. II.13. Post-test photograph of exposed surface, layer B, Test H1-1.

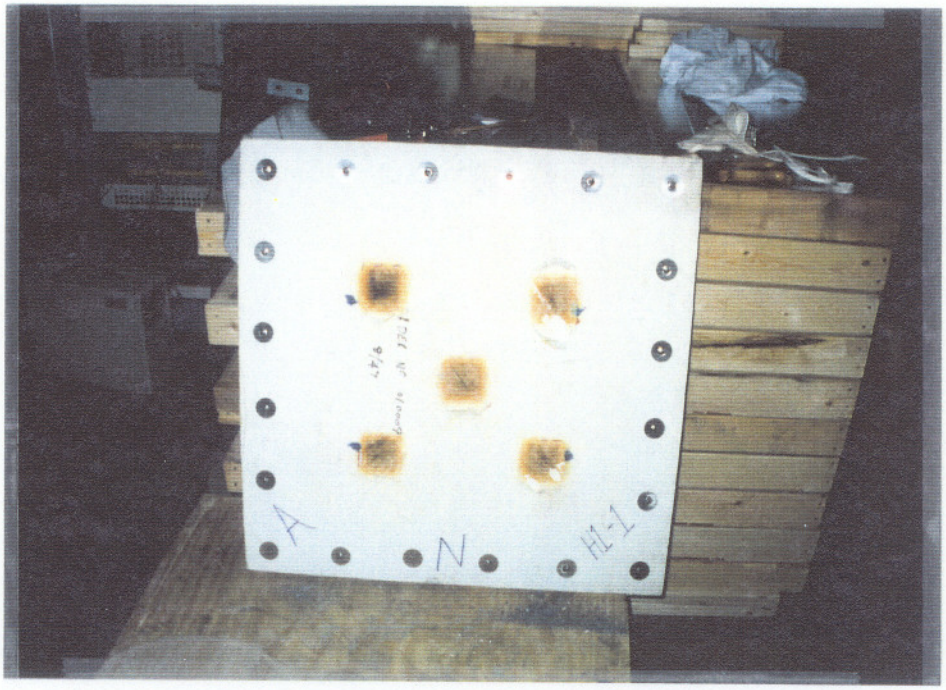


Fig. II.14. Post-test photograph of unexposed surface, layer A, Test H1-1.

Fig. II.15. Post-test photograph of unexposed surfaces of specimens from layers A and B, Test H1-1.

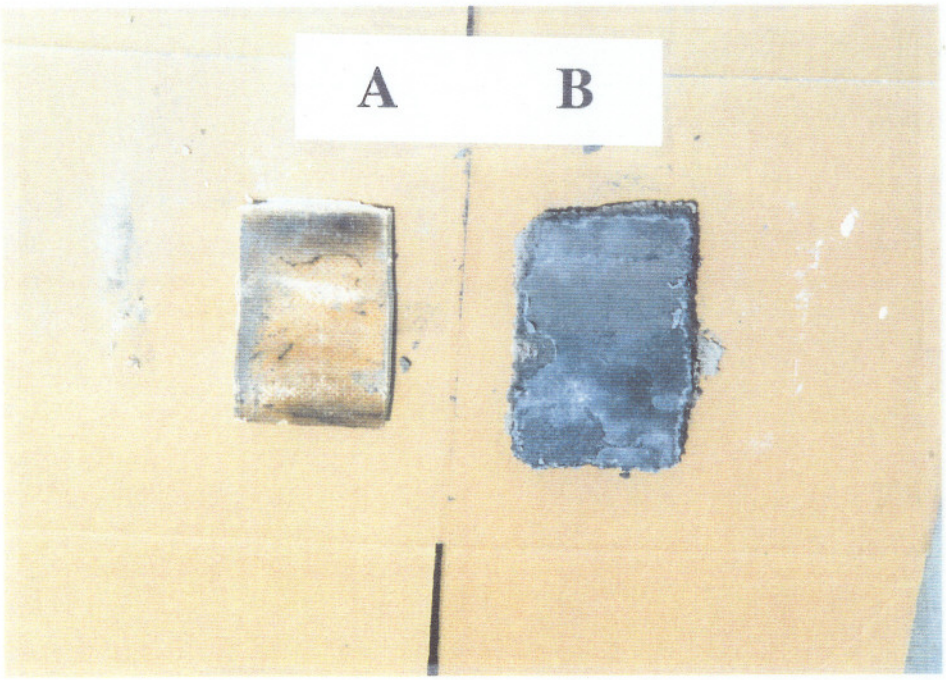


Fig. II.16 Post-test photograph of exposed surfaces of specimens taken from layers A and B, Test H1-1.

III. Test H3-1

A. Description of Test Assembly

The test assembly consisted of 4 layers of fire-barrier semi-rigid board with an abrasion-resistant silicone-impregnated cloth on the exposed face. The manufacturer reports that the board consists of a suspension of hydrated magnesium carbonate in bulk ceramic fiber bound with an aqueous synthetic resin and faced with a polyester scrim.

The layers were cut by the manufacturer to the dimensions shown in Fig. III.1 and identified as SN 12/79 (upper board, layer A. See table below), SN 17/44 (layer B), SN 8/47 (layer C), and SN 12/79 (layer D).

The arrangement, designations, thicknesses, and masses of the layers were as follows:

Test H3-1: Test Assembly			
Arrangement	Thickness in mm [in]	Pre-test Mass in kg ± 0.01 [lb ± 0.02]	Post-test Mass in kg ± 0.01 [lb ± 0.02]
layer A, upper board	avg. = 17.9 [0.706] std. dev. = 0.74 [0.029] (6 measurements)	9.61 [21.2]	
layer B, next lower board	avg. = 17.7 [0.697] std. dev. = 0.61 [0.024] (6 measurements)	9.14 [20.1]	
layer C, next lower board	avg. = 17.9 [0.705] std. dev. = 0.33 [0.013] (6 measurements)	9.32 [20.5]	32.95 [72.59]
layer D, lowest board	avg. = 16.8 [.662] std. dev. = 0.66 [0.026] (6 measurements)	9.56 [21.1]	
layer E, abrasion-resistant cloth	0.51 (nominal) [0.020]		

Layer E was closest to the furnace and layer A was farthest away.

Pre-test photographs of the unexposed and exposed surfaces of layer A are shown in Figs. III.2 and III.3, respectively. Layers B and C had the same appearance. Photographs of the unexposed surface of D and the exposed surface of layer E are shown in Figs. III.4 and III.5, respectively. Twenty "quilting pins" with fender washers were installed along the perimeter of the stack of layers to hold the assembly together (Fig. III.6).

The stainless steel supports described in section I.A were <u>not</u> in place for this test. After positioning the assembly on the furnace, nominal 25.4 mm (1 in) thick ceramic-fiber insulation was wrapped around its edges and the exterior of this insulation was covered with aluminum foil. The lower edge of the foil was

taped to the furnace with glass-cloth tape. The upper edges of the insulation and foil were held in place by the bricks (described in sec. I.A) which loaded the perimeter of the assembly.

B. Fire Test Procedures and Results

The test was conducted on June 6, 1995 and was witnessed by the following official observer: Patrick M. Madden (NRC).

The test assembly was subjected to a 3.5-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. III.7 and tabulated in Table III.1. The average furnace temperatures and the standard temperature-time curve are shown in Fig. III.8.

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

Figures III.10 and III.11 show the unexposed surface during the test. No discoloring was observed on the unexposed surface and neither flame passage nor glowing were observed during the test period.

A log of observations is presented in Table III.2.

Following termination of the test, no exposed-surface flaming was observed when the west edge of the assembly was lifted and propped (Fig. III.12). The abrasion-resistant cloth was bulging slightly but free of tears. There was no debris from the test assembly at the bottom of the furnace. The assembly was allowed to cool overnight in the propped position and was removed from the furnace the following day.

The exposed surface of layer D and the unexposed surface of Layer A on June 7, 1995, the day after the test, are shown in Figs. III.13 and III.14, respectively. The photograph in Fig. III.13 was taken subsequent to cutting and folding-back the abrasion-resistant cloth (layer E) and removing a small specimen from layer D. Layer D was bowed, forming a hollow area between it and layer C. Specimens of layers A through D from a "core sample" taken near the center of the assembly are shown in Figs. III.15 and III.16. The unexposed surface of layer A (Fig. III.14) was discolored a light to medium brown beneath the thermocouple pads. Based on the log presented in Table III.2, it is believed that the remaining yellow sections in Fig. III.14 also were present before the test (see Fig. III.2) but less obvious in the pre-test photograph because of the camera/flash angle. There was no burnthrough beneath the thermocouple pads or elsewhere.

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 during the test neither flame nor hot gases capable of igniting cotton waste held against the unexposed surface pass through the assembly. In

addition to these criteria, NRC requests monitoring the time at which any of the unexposed-surface thermocouples exceeds 139°C (250°F) above the initial temperature.

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

Test H3-1: 3-hour Test Assembly			
Condition	Location	Time	
		(sec)	[hr:min:sec]
E 119 avg. unexposed surf. temp. criterion (163°C) [325°F]		12694	[3:31:34]
E 119 peak unexposed surf. temp. criterion (205°C) [401°F]		not reached; peak temp. was 173°C at shutdown.	
NRC unexposed surf. temp., 1st occurrence (163°C) [325°F]	TC35	11596	[3:13:16]

Concerning E 119 criteria, the average temperature was the controlling factor and the E 119 fire-endurance period was 12694 seconds (3 hours and 31.6 minutes). 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 +54 s and **the corrected fire-endurance period was 12748 s (3 hours and 32.5 minutes)**. The attendant maximum uncertainty was +279/-268 s (+4.6/-4.5 minutes) (see Appendix).

Neither flame nor hot gas passage through the unexposed face of the assembly were observed during the test. No glowing was observed at any time during the test. The post-test inspection revealed no burnthrough at the unexposed surface of the assembly.

TABLE III.1. Temperatures (°C), Test H3-1.

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
-120	24	24	24	24	24	23	23	23	23	23
-60	24	24	24	24	24	24	24	24	24	24
0	24	24	24	24	24	24	24	24	24	24
60	82	58	57	66	24	24	24	24	24	24
120	247	180	179	202	24	24	24	24	24	24
180	398	338	331	356	24	24	24	24	25	24
240	498	457	443	466	24	24	24	24	25	24
300	549	519	506	524	24	24	24	24	25	24
360	586	562	549	566	24	24	24	24	25	24
420	618	605	586	603	24	24	24	25	25	24
480	648	645	622	638	24	24	24	25	25	24
540	673	674	653	667	24	24	24	25	25	25
600	695	695	677	689	25	24	24	25	25	25
660	718	718	704	713	25	24	24	25	25	25
720	740	735	726	734	25	24	24	25	25	25
780	754	746	740	746	25	25	24	25	25	25
840	762	750	746	753	25	25	24	25	25	25
900	769	757	754	760	25	25	24	25	25	25
960	776	764	761	767	25	25	25	25	25	25
1020	784	772	769	775	25	25	25	25	26	25
1080	792	779	777	783	25	25	25	25	26	25
1140	800	786	784	790	25	25	25	25	26	25
1200	807	793	791	797	25	25	25	25	26	25
1260	814	799	797	804	25	25	25	25	26	25
1320	818	803	802	807	25	25	25	25	26	25
1380	822	807	806	812	25	25	25	26	26	25
1440	826	812	811	816	25	25	25	26	26	26
1500	832	817	816	821	26	25	25	26	26	26
1560	836	821	821	826	26	26	25	26	27	26
1620	841	826	826	831	26	26	25	26	27	26
1680	847	831	830	836	26	26	26	26	27	26
1740	851	836	835	841	26	26	26	26	27	26
1800	856	841	840	846	26	26	26	27	27	26
1860	859	845	844	849	27	27	26	27	28	27
1920	861	846	846	851	27	27	26	27	28	27
1980	864	849	849	854	27	27	27	27	28	27
2040	867	852	852	857	28	27	27	28	29	28
2100	871	857	856	861	28	28	27	28	29	28
2160	876	862	862	867	28	28	27	28	30	28
2220	881	867	867	871	29	29	28	29	30	29
2280	883	870	869	874	29	29	28	29	31	29
2340	885	871	871	876	30	29	28	30	31	30
2400	888	874	874	878	30	30	29	30	32	30
2460	891	877	877	881	31	30	29	31	33	31
2520	894	880	880	885	31	31	30	31	33	31
2580	897	883	883	888	32	31	30	32	34	32
2640	900	886	886	891	33	32	31	32	35	33

TEST: NRC H3-1 6/06/95

TABLE III.1. Temperatures (°C), Test H3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
2700	903	890	890	895	33	33	31	33	36	33
2760	907	893	894	898	34	33	32	34	36	34
2820	907	895	895	899	35	34	33	34	37	35
2880	908	896	896	900	36	34	33	35	38	35
2940	910	898	898	902	36	35	34	36	39	36
3000	913	901	901	905	37	36	35	36	40	37
3060	916	904	904	908	38	36	35	37	40	37
3120	918	907	907	910	39	37	36	38	41	38
3180	921	909	909	913	39	38	37	39	42	39
3240	923	911	912	915	40	38	37	40	43	40
3300	926	914	914	918	41	39	38	40	44	40
3360	928	916	916	920	42	40	39	41	45	41
3420	930	918	919	922	42	40	40	42	45	42
3480	932	920	920	924	43	41	40	43	46	43
3540	934	922	922	926	44	42	41	43	47	43
3600	935	924	924	928	44	42	42	44	48	44
3660	937	926	926	929	45	43	43	45	49	45
3720	939	927	928	931	46	44	43	46	50	46
3780	941	930	930	933	47	45	44	46	50	46
3840	943	931	932	935	47	45	45	47	51	47
3900	945	934	934	938	48	46	46	48	52	48
3960	947	936	936	940	49	47	46	49	53	49
4020	949	938	938	942	50	48	47	50	54	50
4080	952	940	941	944	50	48	48	50	55	50
4140	954	943	943	946	51	49	49	51	56	51
4200	956	945	945	949	52	50	49	52	57	52
4260	958	947	947	951	53	51	50	53	58	53
4320	958	948	948	952	53	51	51	54	58	54
4380	958	948	948	952	54	52	52	54	59	54
4440	959	949	949	952	55	53	53	55	60	55
4500	960	950	950	953	56	54	54	56	61	56
4560	962	951	952	955	56	54	54	57	62	57
4620	965	954	954	958	57	55	55	58	63	58
4680	968	958	958	961	58	56	56	59	64	58
4740	971	961	961	964	59	57	57	59	64	59
4800	973	962	962	966	59	58	58	60	65	60
4860	970	960	961	964	60	58	58	61	66	61
4920	971	961	961	964	61	59	59	62	66	61
4980	975	964	964	968	61	60	60	63	67	62
5040	977	966	967	970	62	60	61	63	67	63
5100	978	968	968	971	63	61	61	64	68	63
5160	979	969	969	972	63	62	62	65	68	64
5220	980	970	970	973	64	63	63	65	69	65
5280	983	973	973	976	64	63	63	66	69	65
5340	986	975	976	979	65	64	64	66	70	66
5400	987	977	977	980	65	65	64	67	70	66
5460	986	977	977	980	66	65	65	67	71	67

TEST: NRC H3-1 6/06/95

TABLE III.1. Temperatures (°C), Test H3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
5520	987	978	978	981	66	66	65	67	71	67
5580	989	978	979	982	66	67	65	68	71	67
5640	990	980	980	983	67	67	66	68	72	68
5700	993	982	983	986	67	68	66	68	72	68
5760	995	985	985	988	67	68	66	69	73	69
5820	996	986	986	990	68	69	67	69	73	69
5880	998	987	988	991	68	70	67	69	74	70
5940	997	987	987	990	69	70	67	70	74	70
6000	998	989	989	992	69	71	68	70	75	71
6060	1001	991	991	994	70	72	68	70	75	71
6120	1002	993	993	996	71	72	68	71	76	72
6180	1004	994	994	997	71	73	69	71	76	72
6240	1005	995	995	999	72	74	69	72	77	73
6300	1004	995	995	998	73	75	70	73	78	73
6360	1004	995	995	998	73	75	70	73	78	74
6420	1005	996	996	999	74	76	71	74	79	75
6480	1006	997	997	1000	75	77	71	75	80	75
6540	1007	998	998	1001	76	78	72	75	81	76
6600	1009	999	999	1002	76	79	73	76	81	77
6660	1009	1000	1000	1003	77	80	73	77	82	78
6720	1011	1001	1001	1004	78	81	74	78	83	79
6780	1011	1002	1002	1005	79	81	75	79	84	80
6840	1012	1003	1003	1006	80	82	76	79	85	81
6900	1013	1004	1004	1007	81	83	77	80	86	82
6960	1014	1005	1005	1008	82	84	78	81	87	82
7020	1015	1006	1006	1009	83	85	79	82	88	83
7080	1016	1007	1007	1010	84	86	80	83	89	84
7140	1017	1008	1008	1011	84	87	81	84	90	85
7200	1016	1007	1008	1010	85	88	82	85	91	86
7260	1016	1008	1008	1011	86	89	83	86	92	87
7320	1017	1008	1008	1011	87	90	84	87	93	88
7380	1018	1009	1009	1012	88	91	84	87	94	89
7440	1019	1010	1010	1013	89	91	85	88	95	90
7500	1020	1011	1011	1014	90	92	86	89	96	91
7560	1021	1012	1012	1015	91	93	87	90	97	92
7620	1021	1013	1013	1016	92	94	88	91	98	93
7680	1022	1013	1013	1016	93	95	89	92	99	94
7740	1023	1014	1014	1017	94	96	90	93	100	95
7800	1024	1015	1015	1018	95	97	91	94	101	95
7860	1025	1016	1016	1019	96	98	92	95	102	96
7920	1026	1017	1017	1020	97	99	93	96	103	97
7980	1026	1017	1017	1020	97	100	94	97	104	98
8040	1027	1018	1018	1021	98	101	95	97	105	99
8100	1028	1019	1019	1022	99	102	96	98	106	100
8160	1028	1020	1020	1023	100	102	97	99	107	101
8220	1029	1020	1020	1023	101	103	98	100	108	102
8280	1030	1021	1021	1024	102	104	99	101	109	103

TEST: NRC H3-1 6/06/95

TABLE III.1. Temperatures (°C), Test H3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
8340	1031	1022	1021	1025	103	105	100	102	109	104
8400	1031	1022	1022	1025	104	106	101	103	110	105
8460	1032	1023	1023	1026	105	107	102	104	111	106
8520	1033	1024	1023	1027	106	108	103	105	112	107
8580	1033	1025	1024	1027	107	109	104	106	113	108
8640	1034	1025	1025	1028	108	110	105	107	114	109
8700	1034	1026	1026	1029	109	111	106	108	115	110
8760	1035	1027	1026	1029	109	112	106	109	116	111
8820	1036	1027	1027	1030	110	113	107	110	117	111
8880	1036	1028	1028	1031	111	114	108	111	118	113
8940	1037	1029	1029	1031	112	115	109	112	119	113
9000	1038	1030	1029	1032	113	116	110	113	120	114
9060	1039	1030	1030	1033	114	117	111	114	121	115
9120	1039	1031	1031	1033	115	117	112	115	122	116
9180	1040	1031	1031	1034	116	118	113	116	123	117
9240	1040	1032	1032	1035	117	119	114	117	124	118
9300	1041	1032	1033	1035	118	120	115	118	125	119
9360	1042	1033	1033	1036	119	121	116	119	126	120
9420	1042	1034	1034	1037	120	122	117	120	127	121
9480	1043	1034	1034	1037	121	123	118	121	129	122
9540	1043	1035	1035	1038	122	124	119	122	130	123
9600	1044	1035	1035	1038	123	125	120	123	131	124
9660	1044	1036	1036	1039	124	126	121	124	132	125
9720	1045	1036	1036	1039	125	127	122	125	133	126
9780	1045	1037	1036	1039	126	128	124	126	134	128
9840	1046	1037	1037	1040	127	129	125	127	135	129
9900	1047	1038	1038	1041	128	130	126	128	137	130
9960	1047	1038	1038	1041	129	131	127	129	138	131
10020	1048	1039	1039	1042	130	132	128	130	139	132
10080	1050	1041	1041	1044	131	133	129	131	140	133
10140	1051	1042	1042	1045	132	134	130	132	141	134
10200	1052	1043	1043	1046	133	135	131	133	143	135
10260	1052	1044	1043	1046	134	136	132	134	144	136
10320	1053	1044	1044	1047	135	137	133	135	145	137
10380	1054	1045	1045	1048	136	138	134	136	147	138
10440	1054	1046	1046	1048	136	138	135	137	148	139
10500	1055	1047	1046	1049	137	139	136	138	149	140
10560	1056	1047	1047	1050	138	140	137	139	150	141
10620	1057	1048	1048	1051	139	141	138	140	152	142
10680	1057	1048	1048	1051	140	142	139	140	153	143
10740	1058	1049	1049	1052	141	143	140	141	154	144
10800	1058	1050	1049	1052	142	143	141	142	155	145
10860	1059	1050	1050	1053	143	144	142	143	156	146
10920	1059	1051	1050	1053	143	145	143	144	157	146
10980	1060	1051	1051	1054	144	146	143	145	158	147
11040	1061	1052	1052	1055	145	147	144	146	159	148
11100	1062	1053	1053	1056	146	147	145	147	159	149

TEST: NRC H3-1 6/06/95

TABLE III.1. Temperatures (°C), Test H3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
11160	1063	1054	1054	1057	147	148	146	147	160	150
11220	1063	1055	1054	1057	147	149	147	148	161	150
11280	1064	1056	1055	1058	148	149	148	149	161	151
11340	1064	1056	1056	1059	149	150	148	150	161	152
11400	1065	1056	1056	1059	149	151	149	150	162	152
11460	1066	1057	1057	1060	150	151	150	151	163	153
11520	1066	1058	1057	1060	151	152	151	152	163	154
11580	1066	1058	1058	1061	152	153	151	152	163	154
11640	1067	1059	1058	1061	152	153	152	153	164	155
11700	1068	1059	1059	1062	153	154	152	153	164	155
11760	1070	1061	1061	1064	153	154	153	154	165	156
11820	1071	1062	1062	1065	154	155	154	155	165	156
11880	1073	1064	1063	1067	155	156	154	155	165	157
11940	1074	1065	1064	1068	155	156	155	156	166	158
12000	1074	1065	1065	1068	156	156	155	156	166	158
12060	1075	1066	1066	1069	156	157	156	157	167	159
12120	1076	1067	1067	1070	157	158	156	157	167	159
12180	1076	1067	1066	1070	157	158	156	158	168	160
12240	1075	1066	1066	1069	158	159	157	158	168	160
12300	1075	1066	1066	1069	158	159	157	159	168	160
12360	1075	1067	1066	1069	159	160	158	159	169	161
12420	1076	1068	1067	1070	159	160	158	160	169	161
12480	1077	1069	1069	1072	160	161	158	160	170	162
12540	1079	1070	1070	1073	160	161	159	161	170	162
12600	1079	1071	1070	1073	161	162	159	161	171	163
12660	1080	1071	1071	1074	162	162	160	162	171	163
12720	1080	1072	1071	1074	162	163	160	162	172	164
12780	1081	1072	1072	1075	163	163	160	163	172	164
12840	1081	1073	1073	1076	163	164	161	163	172	165
12900	1082	1073	1073	1076	164	164	161	164	173	165

TABLE III.2. Observations, Test H3-1.

The following observations were made during and after the test:

Time	
0:50:00	No change in the appearance of the unexposed surface.
0:56:00	Some outgassing along east edge of aluminum foil.
1:00:00	No change.
1:15:00	No change in the appearance of unexposed surface. Light outgassing along the perimeter of the foil.
1:30:00	No change.
1:45:00	No change in the appearance of unexposed surface. Light outgassing along the perimeter of the foil.
2:00:00	No change.
2:30:00	No change.
3:00:00	No change.
3:35:00	Shutdown. No change in the appearance of unexposed surface.
3:46	Lifted and propped west edge of assembly. Silicone is burned out of layer E, which is slightly bulged but not torn.

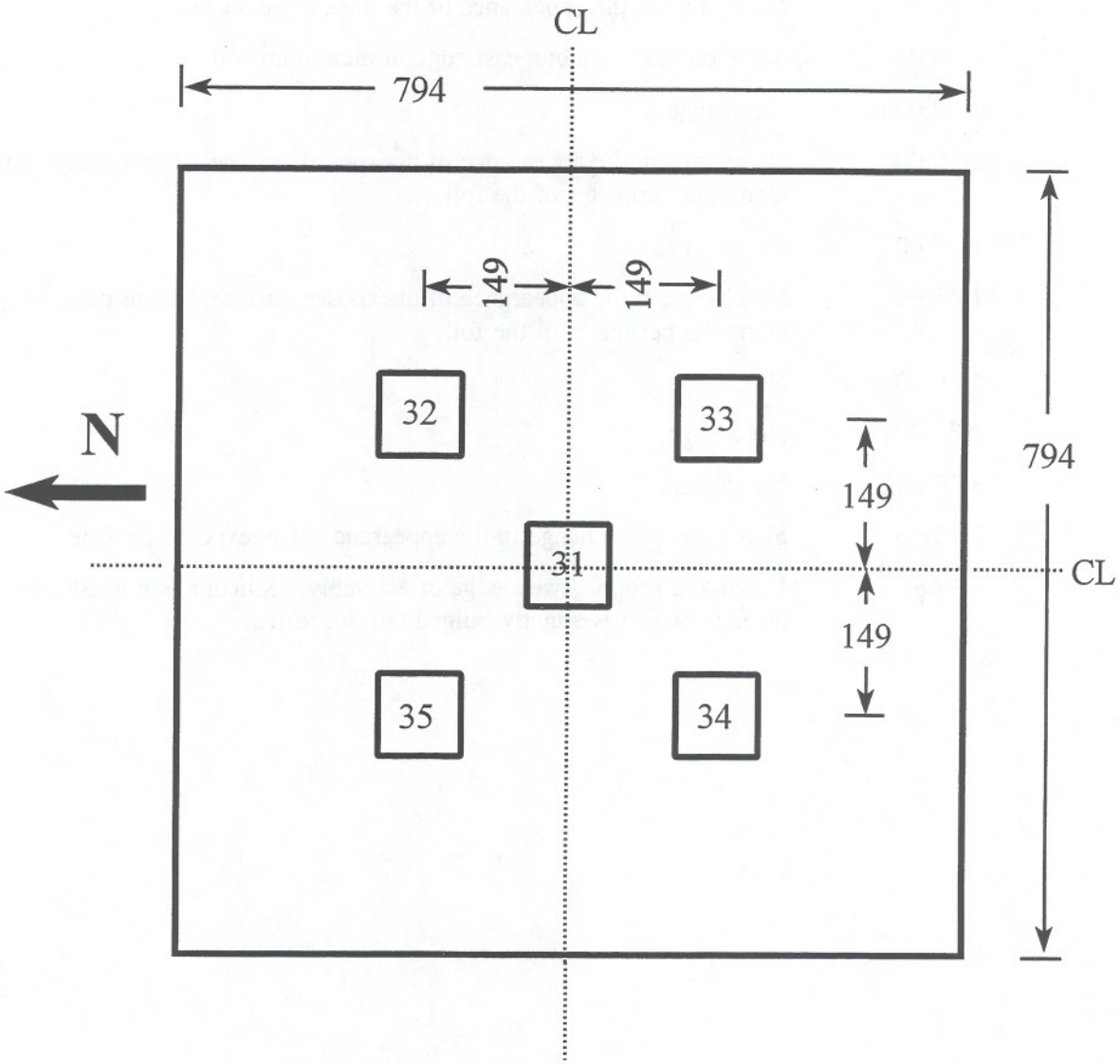


Fig. III.1. Layer dimensions, Test H3-1. All dimensions in millimeters (1 in = 25.4 mm). Numbered squares denote unexposed-surface thermocouple pads.

Fig. III.2. Pre-test unexposed surface, layer A, Test H3-1.

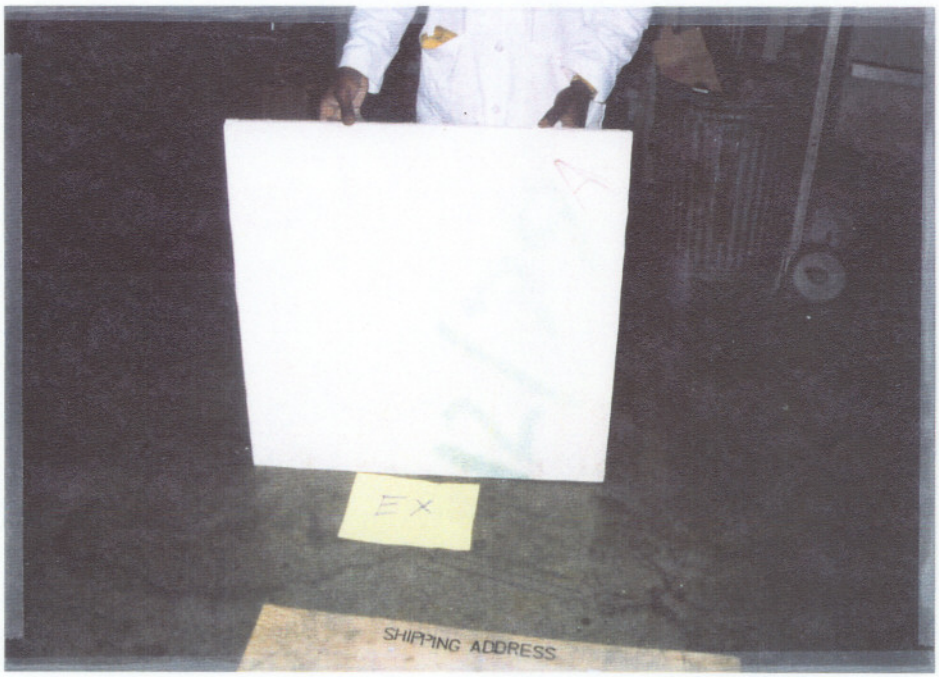


Fig. III.3. Pre-test exposed surface, layer A, Test H3-1.

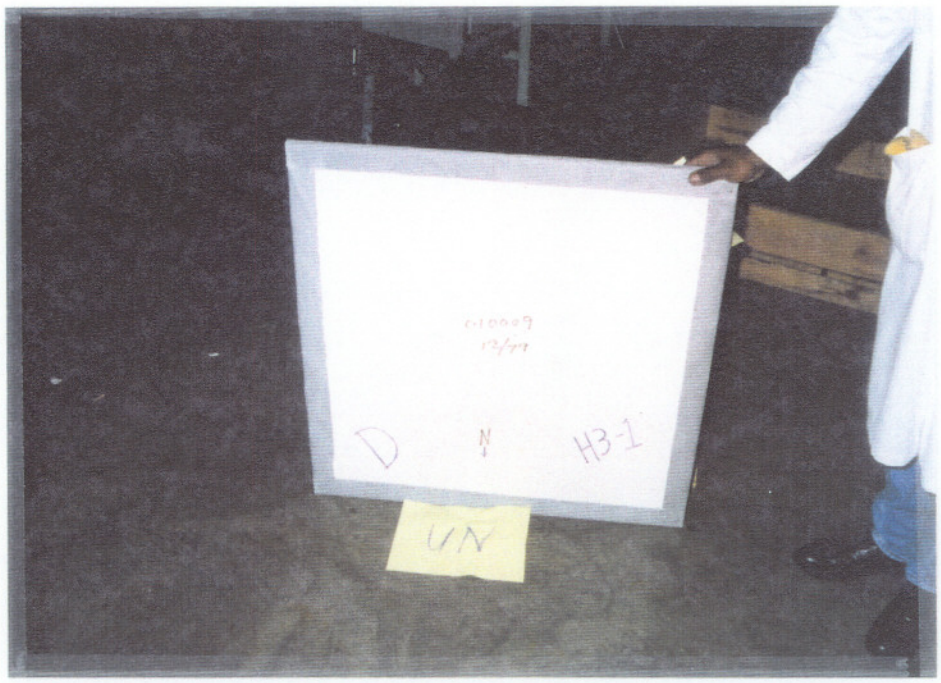


Fig. III.4. Pre-test unexposed surface, layer D, Test H3-1.

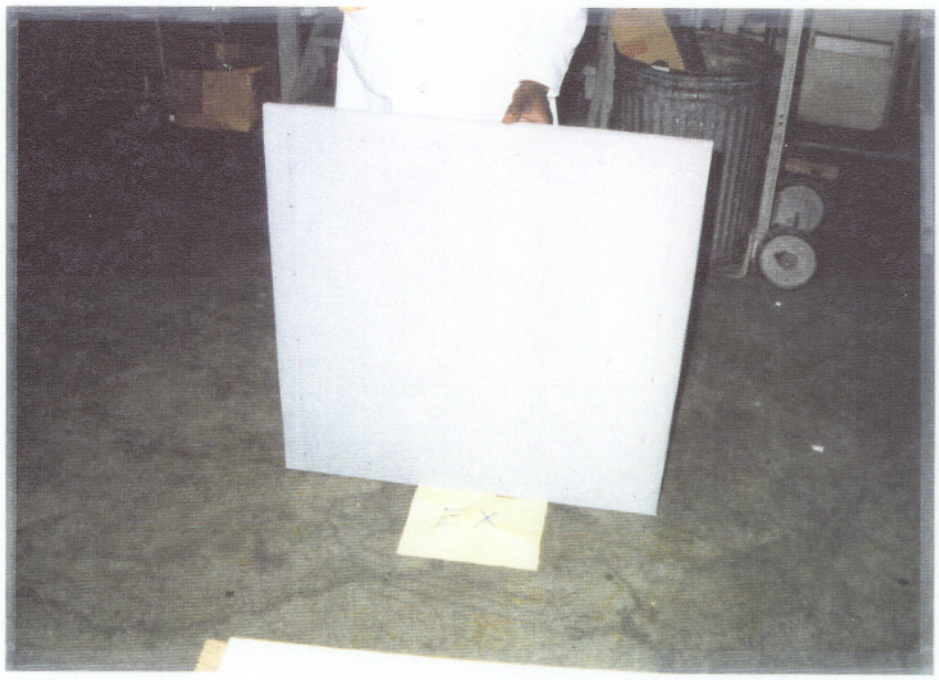


Fig. III.5. Pre-test exposed surface, layer E, Test H3-1.

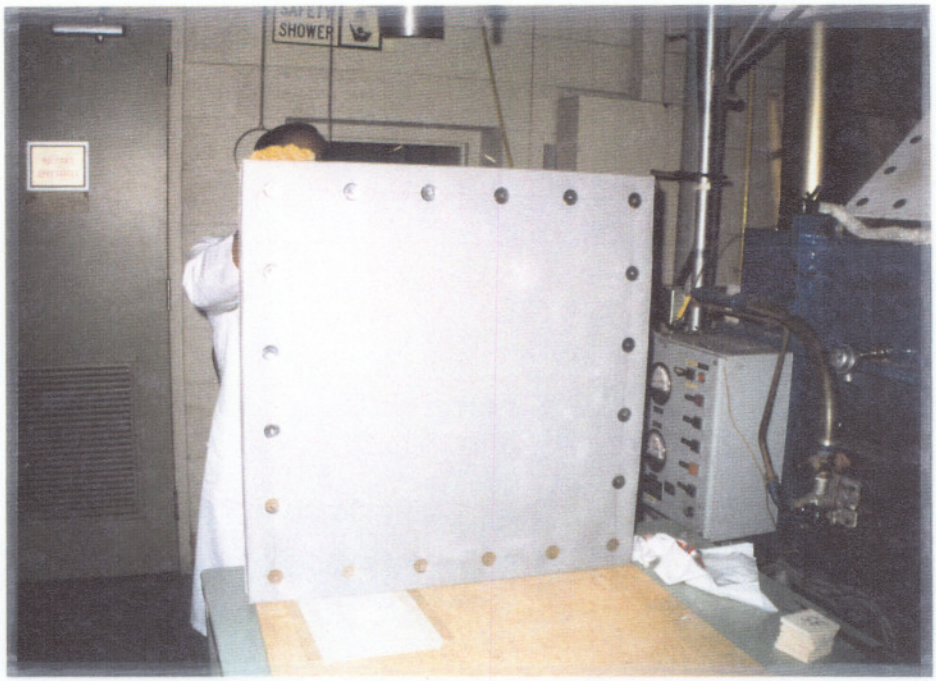


Fig. III.6. Photograph showing "quilting pins" with fender washers, Test H3-1.

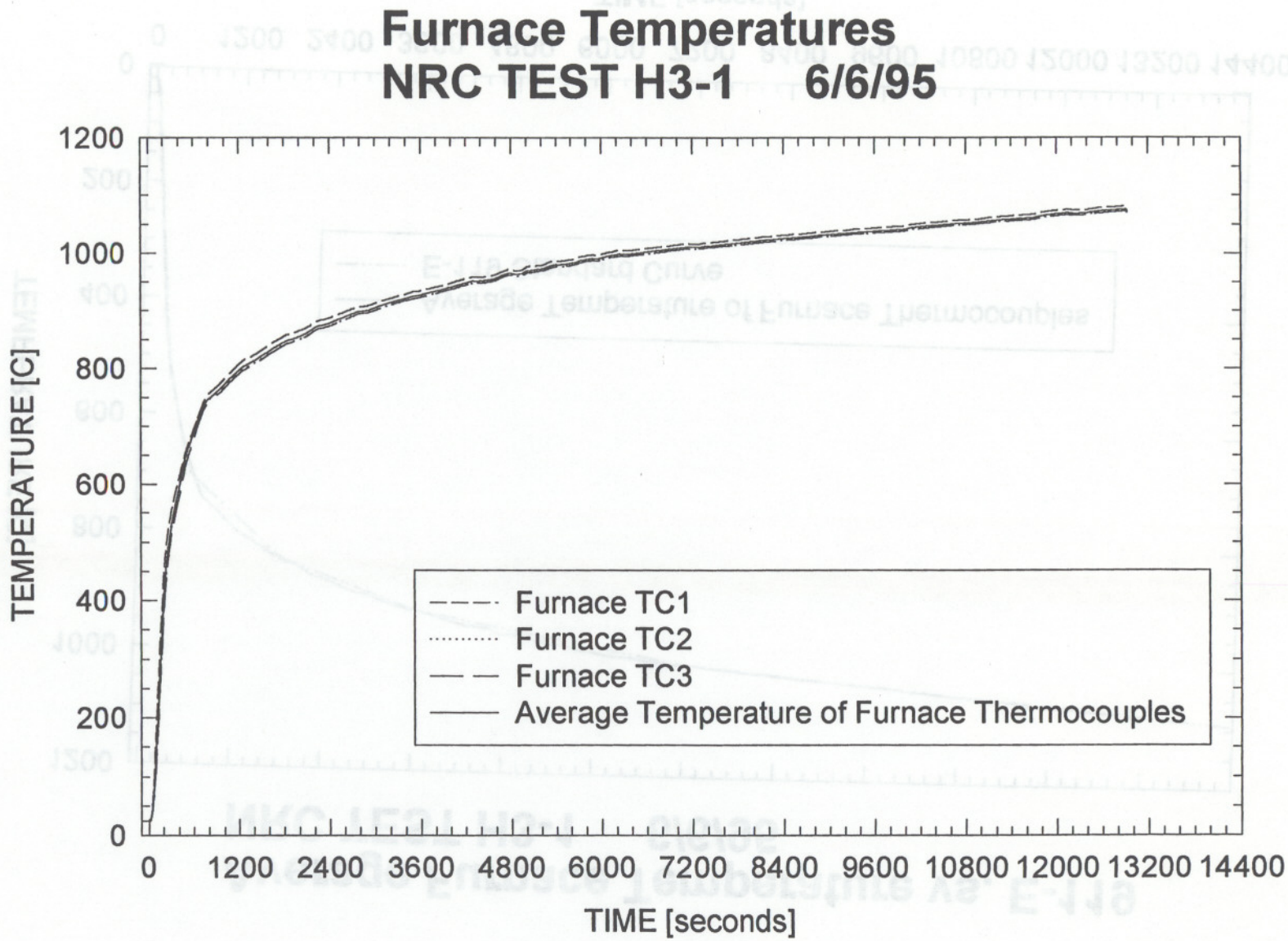


Fig. III.7. Furnace temperature, Test H3-1.

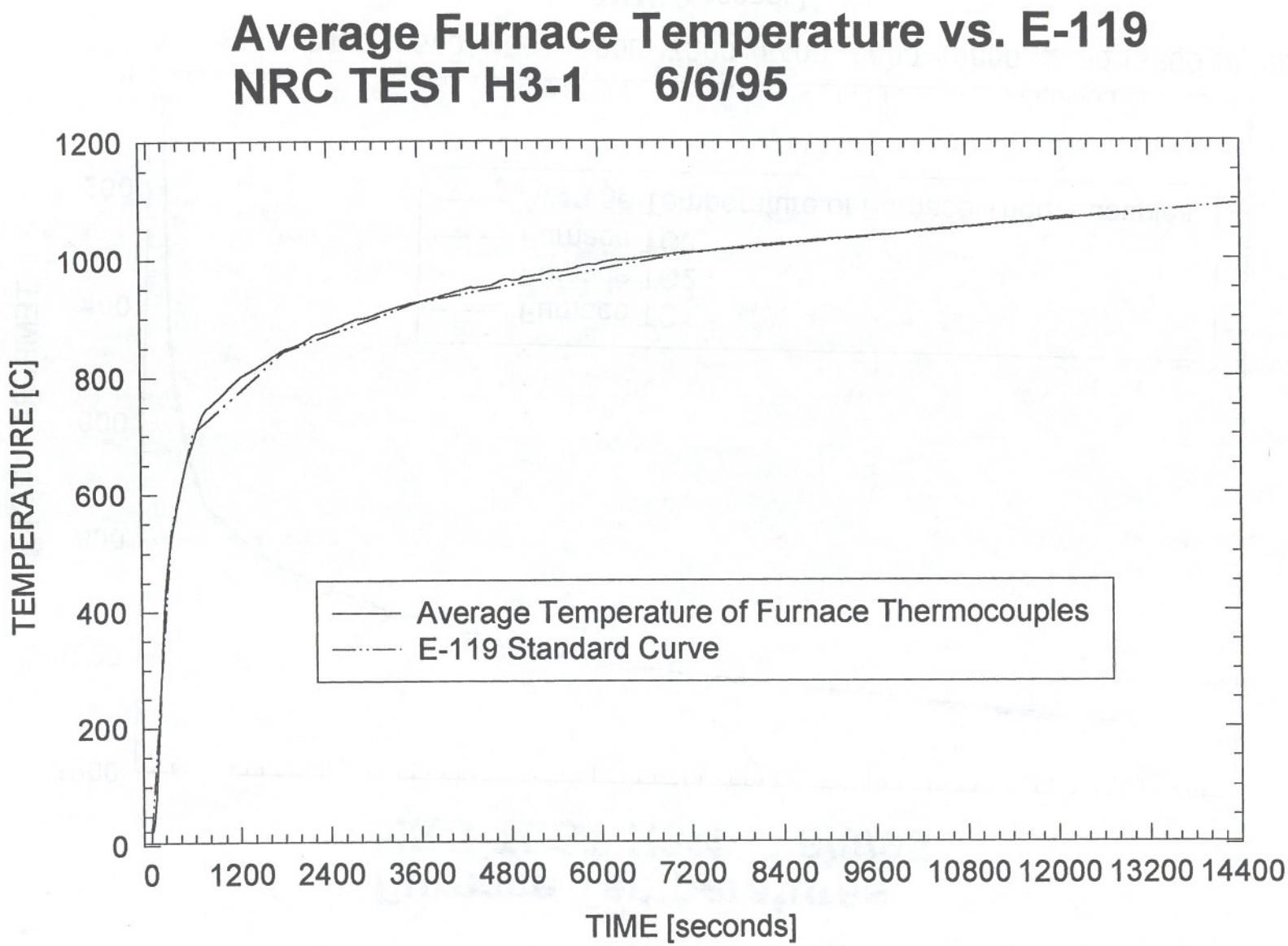


Fig. III.8. Furnace temperature, Test H3-1.

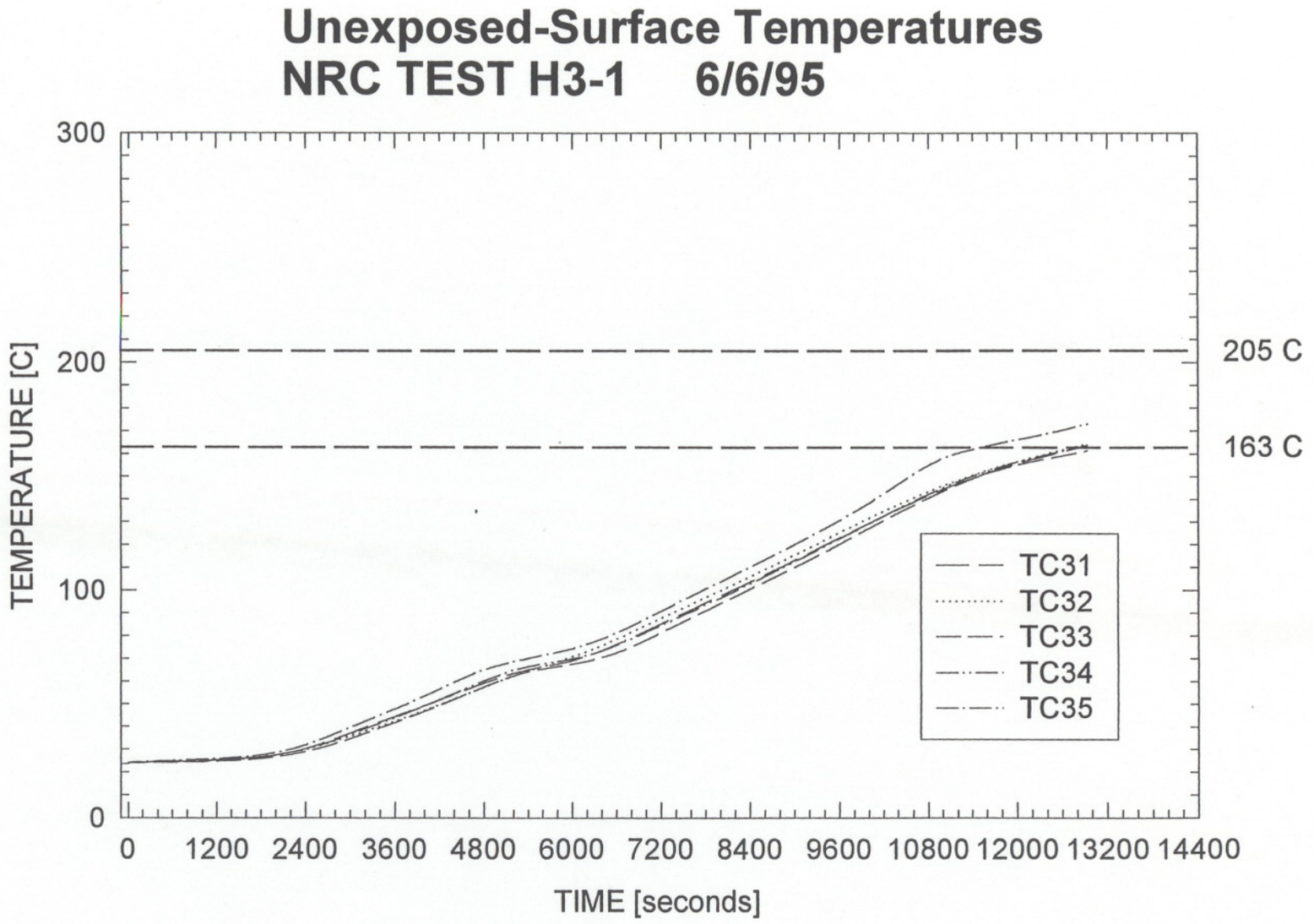


Fig. III.9. Unexposed-surface temperatures, Test H3-1.

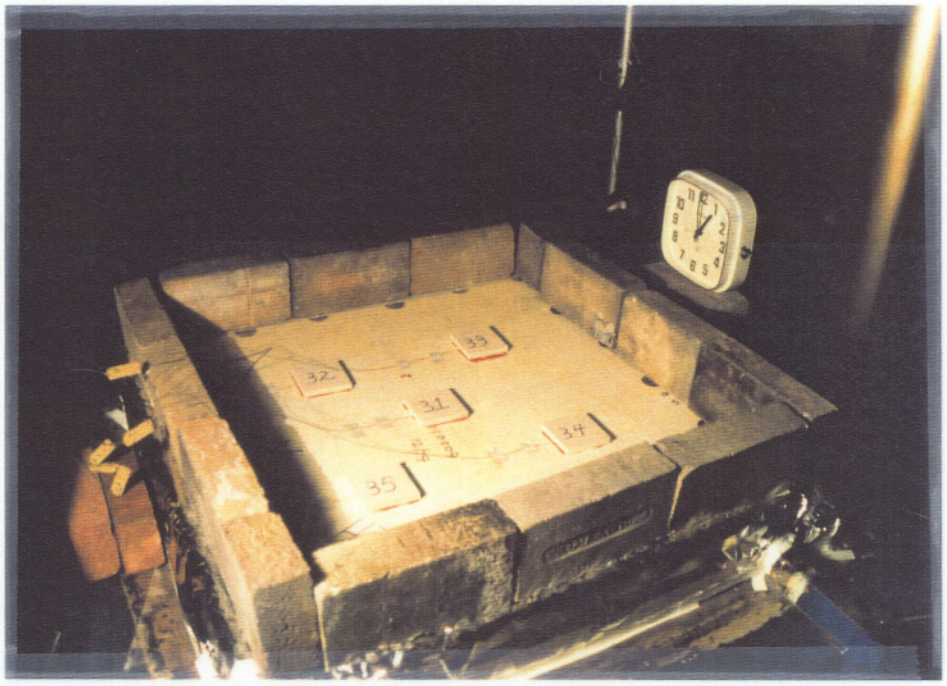


Fig. III.10. Photograph of unexposed surface during Test H3-1.

Fig. III.11. Photograph of unexposed surface during Test H3-1.

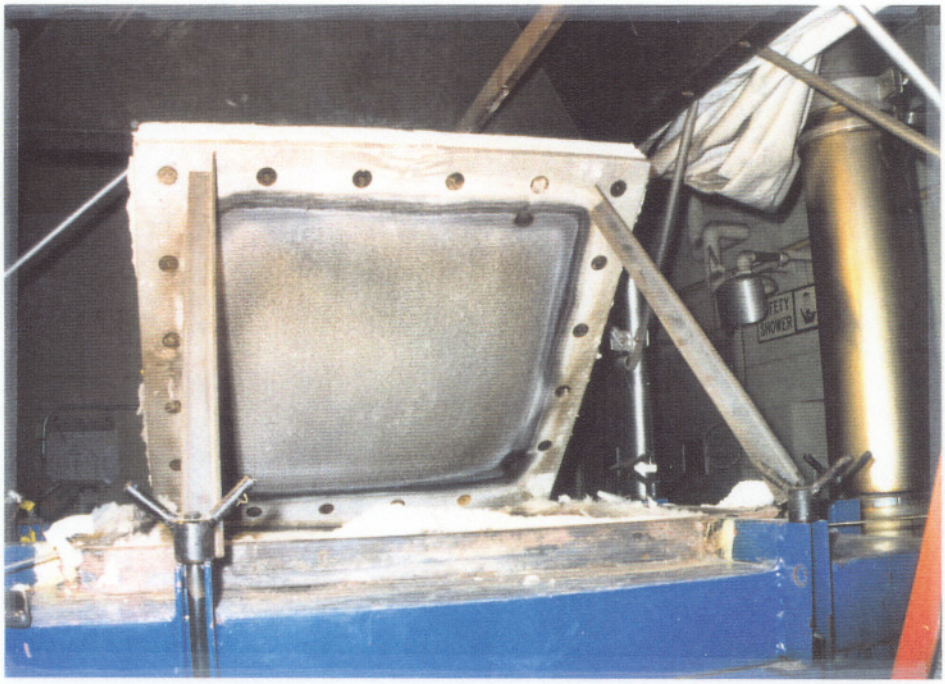


Fig. III.12. Post-test photograph of exposed surface, layer E, Test H3-1.

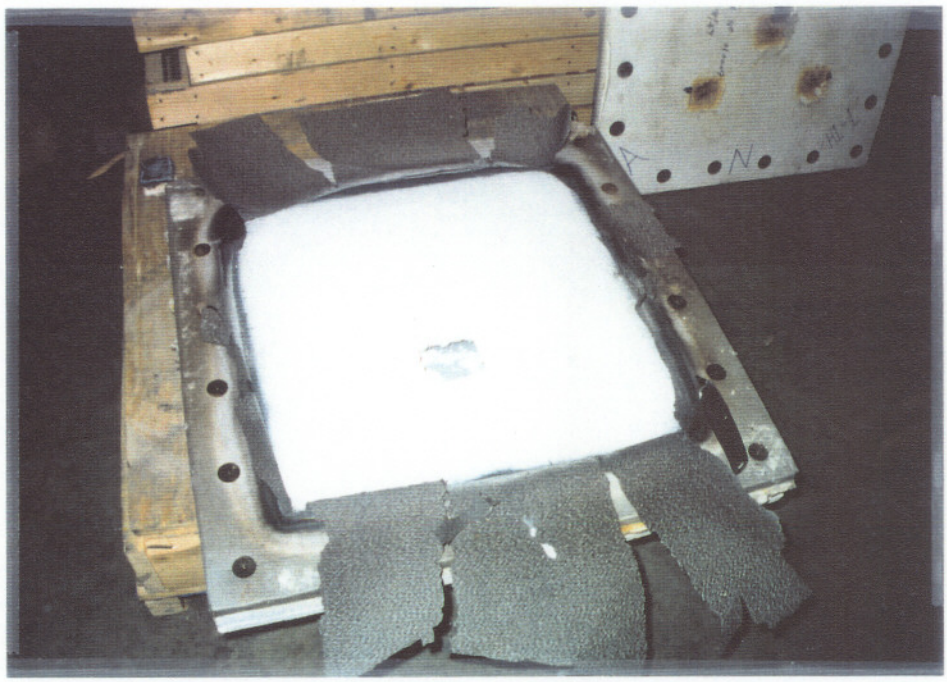


Fig. III.13. Post-test photograph of exposed surface, layer D, Test H3-1.

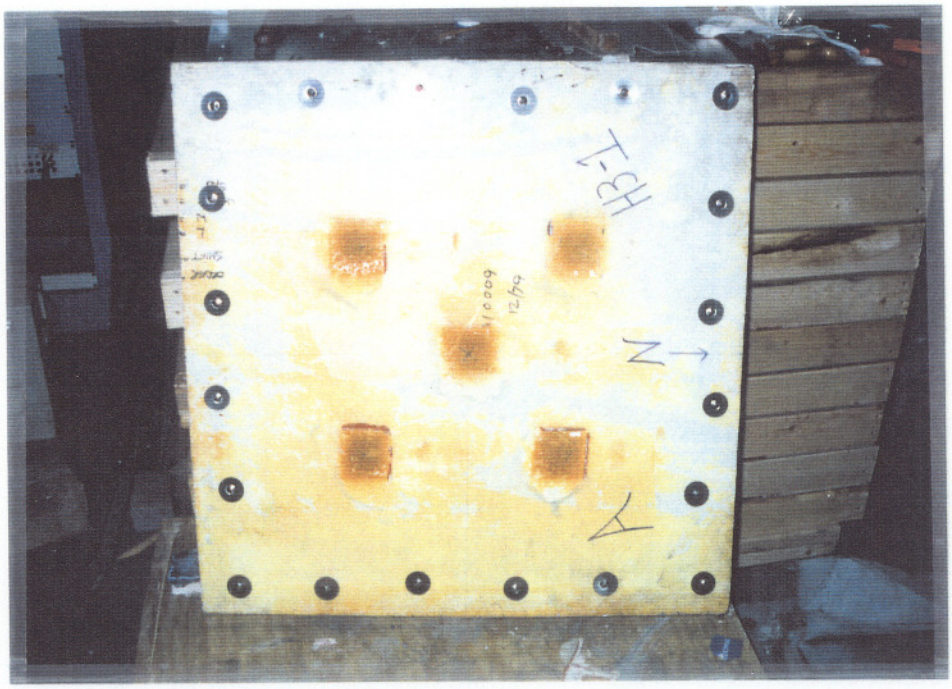


Fig. III.14. Post-test photograph of unexposed surface, layer A, Test H3-1.

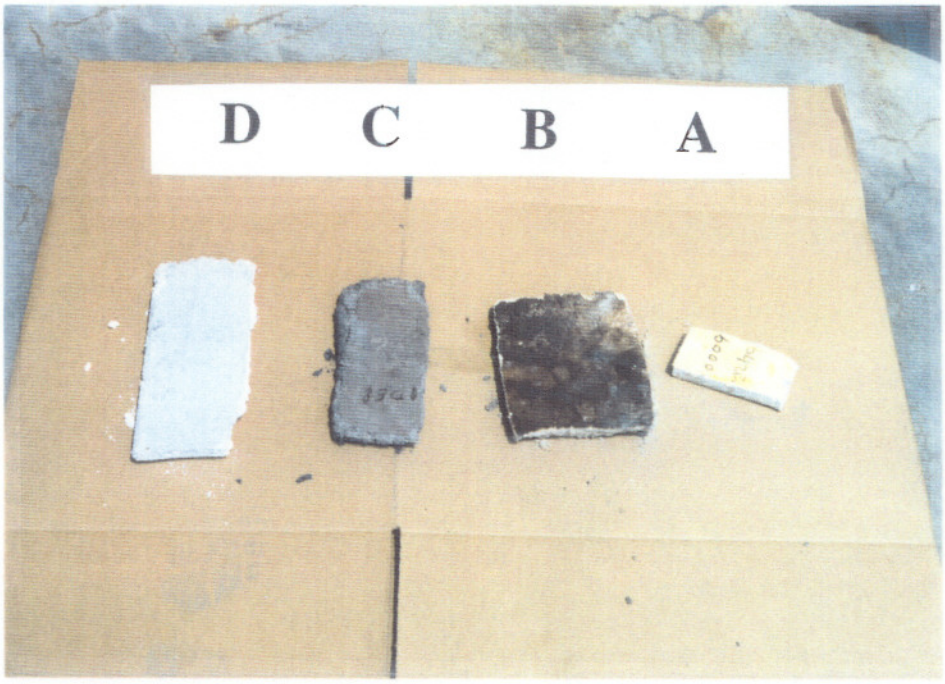


Fig. III.15. Post-test photograph of unexposed surfaces of specimens taken from layers A, B, C, and D; Test H3-1.

Fig. III.16 Post-test photograph of exposed surfaces of specimens taken from Layers A,B,C,and D; Test H3-1.

WRAPPING MATERIAL/"SUBLIMING" PANEL COMBINATIONS

IV. Test TJ1-1

A. Description of Test Assembly

The test assembly, which is shown schematically in Fig. IV.1, consisted of one layer of 1-hr "subliming" fire-barrier panel over one layer of mineral-wool fire-barrier blanket. The blanket was sandwiched between two layers of silicon-impregnated glass-fiber cloth. The adhesives used at layer interfaces are identified in Fig.IV.1. The panel is manufactured with a "flat" face, a ribbed face, and wire mesh covering the ribbed face. The panel used here had a spill-resistant top-coat on its flat face. The ribbed face became the unexposed surface of the test assembly. A galvanized-steel band with steel pins was glued to the flat side of the panel. Fender washers on the lower ends of the pins helped to support the mineral-wool and glass-fiber-cloth layers.

Plan views of the test assembly are shown in Figs. IV.2 and IV.3. The 1-hr "subliming" layer was cut at NIST from a panel labeled by the manufacturer as F92-12046 F100292. The upgrade materials (steel pins, mineral-wool blanket, and glass-fiber cloth) were installed by trained employees of the supplier of the upgrade system.

The arrangement, designations, thicknesses, and masses of the layers were as follows:

Test TJ1-1: Test Assembly			
Arrangement	Thickness in mm [in]	Pre-test Mass in kg ± 0.01 [lb ± 0.02]	Post-test Mass in kg ± 0.01 [lb ± 0.02]
layer A, 1-hr "subliming" panel	off-rib avg.= 17.4 [0.685] std. dev. = 1.13 [0.044] (32 measurements) rib avg.= 24.7 [0.972] std. dev. = 1.22 [0.048] (9 measurements)	12.49 [27.48]	17.14 [37.71] (mass of identified layers plus steel band, pins, and washers; mastic; and glue)
layer B, silicon-impregnated glass-fiber cloth	0.41 (nominal) [0.016]	7.91 [17.40] (mass of identified layers plus steel band, pins, and washers; mastic; and glue)	
layer C, mineral-wool blanket	32 - 38 (nominal) [1.3 - 1.5]		
layer D, silicon-impregnated glass-fiber cloth	0.41 (nominal) [0.016]		

Layer D was closest to the furnace and layer A was farthest away.

Pre-test photographs of the unexposed and exposed surfaces of layer A are shown in Figs. IV.4 and IV.5, respectively. The exposed surface of layer D is shown in Fig. IV.6

The stainless-steel supports described in section I.A were not in place for this test. After positioning the assembly on the furnace, two layers of nominal 25.4 mm (1 in) thick ceramic-fiber insulation were wrapped around its edges and the exterior of this insulation was covered with aluminum foil. The lower edge of the foil was taped to the furnace and the upper edge was taped to the unexposed surface of layer A with glass-cloth tape. Then the upper edges of the foil were loaded with bricks as described section I.A.

B. Fire Test Procedures and Results

The test was conducted on November 30, 1995 with no official observers present.

The test assembly was subjected to a 2-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. IV.7 and tabulated in Table IV.1. Note that data are missing from this table owing to automatic shutdown of the data acquisition system at 1:30. Entries at and after 6300 s were limited in number because they were recorded by hand. Nevertheless, sufficient data were obtained to determine the first instance that an unexposed-surface thermocouple reached the peak-temperature criterion (see C. below).

The average furnace temperatures and the standard temperature-time curve are shown in Fig. IV.8.

Unexposed-surface thermocouples measured surface temperatures beneath insulation pads at 5 locations designated 31 to 35 in Fig. IV.2. The thermocouples at these locations are designated TC31 to TC35, respectively, and their outputs are plotted in Fig. IV.9 and tabulated in Table IV.1. Included in the table are the averages of the unexposed-surface temperatures as a function of time.

Figures IV.10 and IV.11 show the unexposed surface during the test. There was no change in the appearance of the unexposed surface during the test period. Neither flame passage nor glowing were observed during the test.

A log of observations is presented in Table IV.2.

Following termination of the test, flaming was observed in the northwest corner beneath a torn edge of layer D when the west edge of the assembly was lifted and propped (Fig. IV.12). Virtually all of the exposed area of layer D was missing, but layer C was intact. The assembly was allowed to cool in the propped position about 3 hours before removing it from the furnace for inspection.

The exposed surface of layer C and the unexposed surface of layer A are shown in Figs. IV.13 and IV.14, respectively. Figure IV.15 shows a small specimen cut from layer C. The exposed face of this specimen was black to a depth of a millimeter or so, and white through the remainder of the layer.

The overall thickness of layer A was about 25 mm (1 in). In regions away from thermocouple pads,

about 13 mm (0.5 in) of the thickness was a dense char. Not much swelling (intumescence) occurred. The remaining thickness contained a cream-colored material. The thermocouple pads remained attached and had to be pried off to complete inspection of the unexposed surface. Beneath the pads, the unexposed-surface colors varied from gray to light black. There was no burnthrough beneath the pads or elsewhere.

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, 21°C [70°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 during the test neither flame nor hot gases capable of igniting cotton waste held against the unexposed surface pass through the assembly. In addition to these criteria, NRC requests monitoring the time at which any of the unexposed-surface thermocouples exceeds 139°C (250°F) above the initial temperature.

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

Test TJ1-1: 1-hour Test Assembly			
Condition	Location	Time	
		(sec)	[hr:min:sec]
E 119 avg. unexposed surf. temp. criterion (160°C) [320°F]		5401	[1:30:01]
E 119 peak unexposed surf. temp. criterion (202°C) [396°F]	TC35	7470[7]	[2:04:30]
NRC unexposed surf. temp., 1st occurrence (160°C) [320°F]	TC35	5099	[1:24:59]

Concerning E 119 criteria, the average temperature was the controlling factor and the E 119 fire-endurance period was 5401 seconds (1 hour and 30.0 minutes). 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 +35 s and **the corrected fire-endurance period was 5436 s (1 hour and 30.6 minutes)**. The attendant maximum uncertainty was +181/-174 s (+3.0/-2.9 minutes) (see Appendix).

Neither flame nor hot gas passage through the unexposed face of the assembly were observed during the test. No glowing was observed at any time during the test. The post-test inspection revealed no burnthrough at the unexposed surface of the assembly.

[7]Extrapolated from conditions at shutdown, which occurred at 7440 seconds.

TABLE IV.1. Temperatures (°C), Test TJ1-1.

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
-120	20	20	20	20	21	21	21	21	21	21
-60	20	20	20	20	21	21	21	21	21	21
0	20	20	20	20	21	21	21	21	21	21
60	59	53	44	52	21	21	21	21	21	21
120	196	169	155	174	21	21	21	21	21	21
180	369	350	339	352	21	21	21	21	21	21
240	500	491	480	490	21	21	21	21	21	21
300	551	550	535	545	21	21	21	21	21	21
360	582	579	567	576	21	21	21	21	21	21
420	610	601	594	602	22	21	21	21	22	21
480	634	623	618	625	22	21	21	21	22	22
540	661	649	643	651	23	22	22	22	22	22
600	696	682	675	684	24	22	22	22	23	22
660	732	717	711	720	25	22	22	22	24	23
720	746	729	723	733	26	23	23	23	25	24
780	752	735	730	739	27	24	24	24	26	25
840	762	744	739	748	29	25	24	24	28	26
900	783	764	758	768	31	26	26	26	30	28
960	799	779	774	784	33	28	27	27	32	29
1020	804	784	779	789	35	30	28	28	34	31
1080	810	790	786	795	37	32	30	30	36	33
1140	814	796	792	800	39	34	31	31	38	35
1200	816	799	796	804	41	36	33	33	40	36
1260	819	803	801	808	43	38	34	34	42	38
1320	825	809	807	813	45	39	36	36	44	40
1380	831	815	813	820	47	41	37	37	45	41
1440	836	820	818	825	49	43	38	39	46	43
1500	838	823	821	827	51	45	40	40	48	45
1560	839	825	823	829	53	46	41	41	49	46
1620	842	828	827	832	54	47	42	42	50	47
1680	846	832	831	836	56	49	43	44	51	49
1740	850	836	835	840	57	50	44	45	52	50
1800	854	840	839	844	59	51	45	46	53	51
1860	858	844	843	849	61	52	46	47	54	52
1920	862	848	848	853	62	53	47	48	55	53
1980	867	852	852	857	64	54	48	49	56	54
2040	871	857	856	861	66	55	49	50	57	56
2100	875	861	860	865	67	56	50	51	58	57
2160	877	863	862	867	69	57	52	52	59	58
2220	878	865	864	869	71	58	53	53	60	59
2280	880	867	867	872	73	59	54	54	61	60
2340	885	872	871	876	75	60	56	55	62	62
2400	889	876	875	880	77	61	58	56	63	63
2460	892	878	878	883	79	62	60	57	65	65
2520	893	880	880	884	81	63	63	58	67	66
2580	895	883	882	887	83	65	66	59	70	69
2640	897	885	884	889	85	66	69	61	73	71

TEST: NRC TJ1-1 11/30/95

TABLE IV.1. Temperatures (°C), Test TJ1-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
2700	901	889	888	893	88	68	71	62	76	73
2760	905	893	892	897	90	70	74	64	79	75
2820	909	897	896	901	92	73	77	66	82	78
2880	909	898	897	901	94	75	79	68	84	80
2940	910	898	898	902	97	77	82	70	87	83
3000	914	902	901	906	99	79	84	73	89	85
3060	917	905	904	909	101	81	87	75	91	87
3120	920	908	907	912	104	83	89	78	93	89
3180	920	907	908	912	106	85	92	80	95	91
3240	923	906	911	913	108	87	94	82	97	94
3300	927	908	914	916	110	89	96	85	98	96
3360	926	909	915	917	112	91	98	87	100	98
3420	928	911	916	918	114	93	101	89	102	100
3480	932	916	920	923	116	94	103	91	104	102
3540	935	922	923	927	117	96	105	93	106	104
3600	937	926	926	929	119	98	108	95	108	106
3660	938	927	927	931	120	99	110	97	110	107
3720	940	929	930	933	122	101	112	99	113	109
3780	943	932	932	936	123	103	115	101	115	111
3840	944	934	934	937	125	105	117	103	117	113
3900	944	935	935	938	126	106	119	105	119	115
3960	946	937	937	940	127	108	121	108	121	117
4020	949	940	940	943	129	110	123	110	123	119
4080	952	943	944	946	130	112	126	112	126	121
4140	952	944	944	947	132	114	128	114	128	123
4200	953	946	946	949	133	116	130	116	130	125
4260	956	949	949	952	135	118	132	117	132	127
4320	959	952	952	954	136	120	134	119	135	129
4380	960	954	953	956	138	123	136	121	137	131
4440	960	954	953	956	139	125	138	123	139	133
4500	960	955	954	956	141	127	140	125	142	135
4560	962	958	955	958	142	129	143	127	144	137
4620	965	960	958	961	144	131	144	129	146	139
4680	966	961	960	962	145	134	146	131	148	141
4740	966	961	960	962	147	136	148	133	150	143
4800	967	963	961	964	148	138	150	135	152	145
4860	969	964	962	965	150	140	152	137	154	147
4920	972	966	965	968	151	143	153	139	156	148
4980	974	967	966	969	153	145	155	141	157	150
5040	976	969	969	971	154	147	156	143	159	152
5100	978	970	971	973	155	149	158	144	161	153
5160	979	971	971	974	157	151	159	146	162	155
5220	980	974	973	976	158	152	160	148	163	156
5280	982	975	975	978	159	154	162	150	164	158
5340	983	976	976	979	160	156	163	151	166	159
break										
6300		1000	998	999						

TEST: NRC TJ1-1 11/30/95

TABLE IV.1. Temperatures (°C), Test TJ1-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
6360		1004	1003	1001						
6420		1006	1004	1005						
6480		1005	1003	1004						
6540		1003	1001	1002						
6600	1002	1000	1007	1003						
6660	1001	1000	1005	1002						
6720	1001	1000	1003	1001						
6780	1002	1000	1003	1002	183	182	186	176	191	
6840	1004	1001	1004	1003						
6900	1005	1003	1006	1005	185	185	188	177	193	
6960	1007	1005	1007	1006					194	
7020	1008	1006	1009	1008					195	
7080	1008	1008	1010	1009					196	
7140	1009	1009	1013	1010					197	
7200	1010	1010	1015	1012					198	
7260	1012	1011	1016	1013					199	
7320	1013	1012	1018	1014					200	
7380	1014	1013	1019	1015					201	
7440	1015	1014	1020	1016					202	

Note: Entries at and after 6300 s are limited in number because they were recorded by hand. See sec. B.

TABLE IV.2. Observations, Test TJ1-1.

The following observations were made during and after the test:

Time	
0:15:00	No change in the appearance of the unexposed surface.
0:20:00	Some outgassing along the east edge of the aluminum foil.
0:30:00	No change in appearance. Still some outgassing.
0:40:00	No change. Still some outgassing along north edge.
approx. 0:52	Thump in furnace?
0:56:30	Another thump?
1:00:00	No additional changes on unexposed surface. Some outgassing along north and west edges.
1:20:00	No change. No crystals.
1:30:00	Data acquisition system shutdown automatically.
1:55:00	No change.
2:04:00	Furnace shutdown.
2:11	Lift and prop west edge of test assembly. The center of layer D (silicone-impregnated glass-fiber cloth) is missing. Some flaming in northwest corner under torn edge of layer D. Nothing fell during lift and prop. Glass-fiber layer C appears intact.

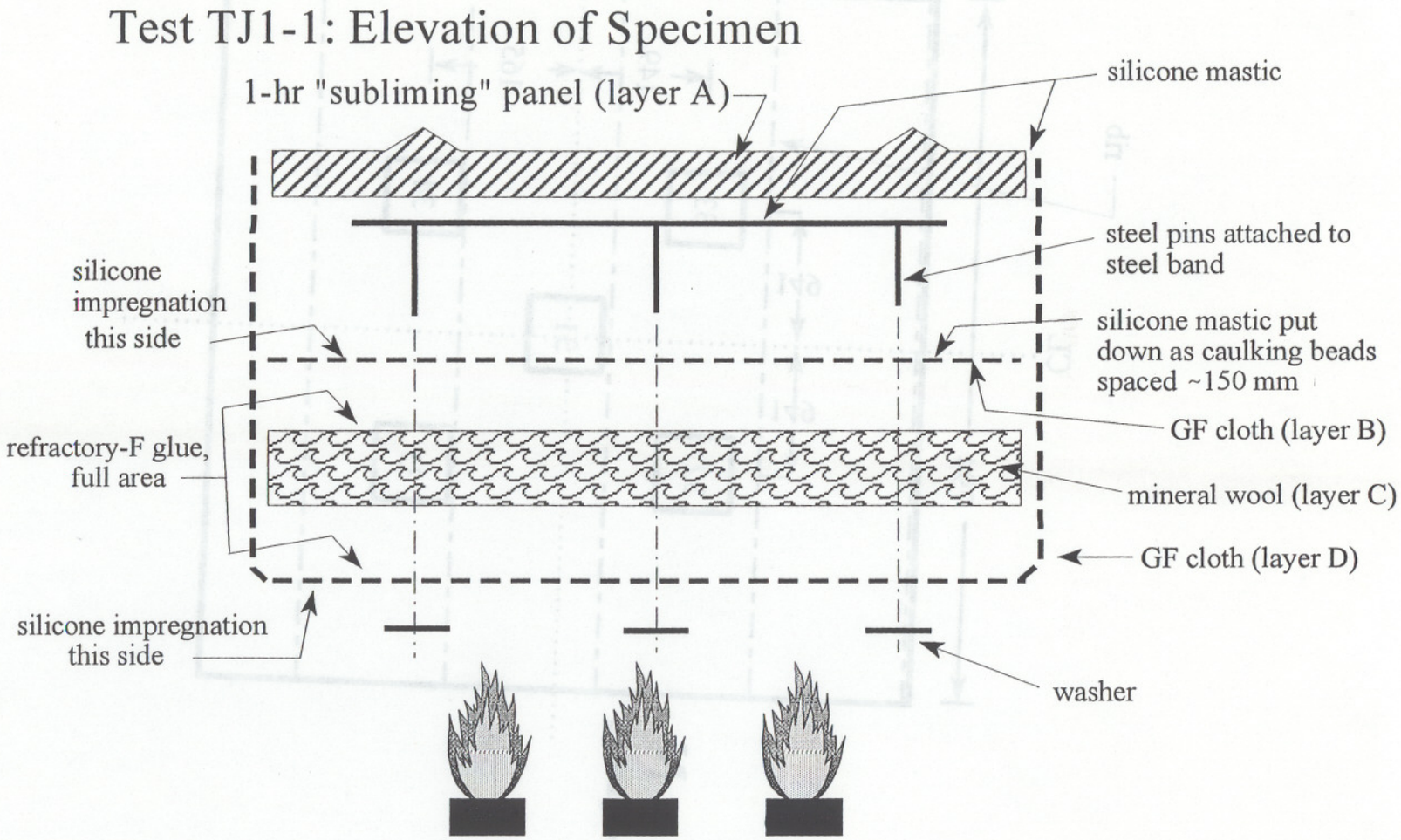


Fig. IV.1. Schematic of elevation of test assembly, Test TJ1-1.

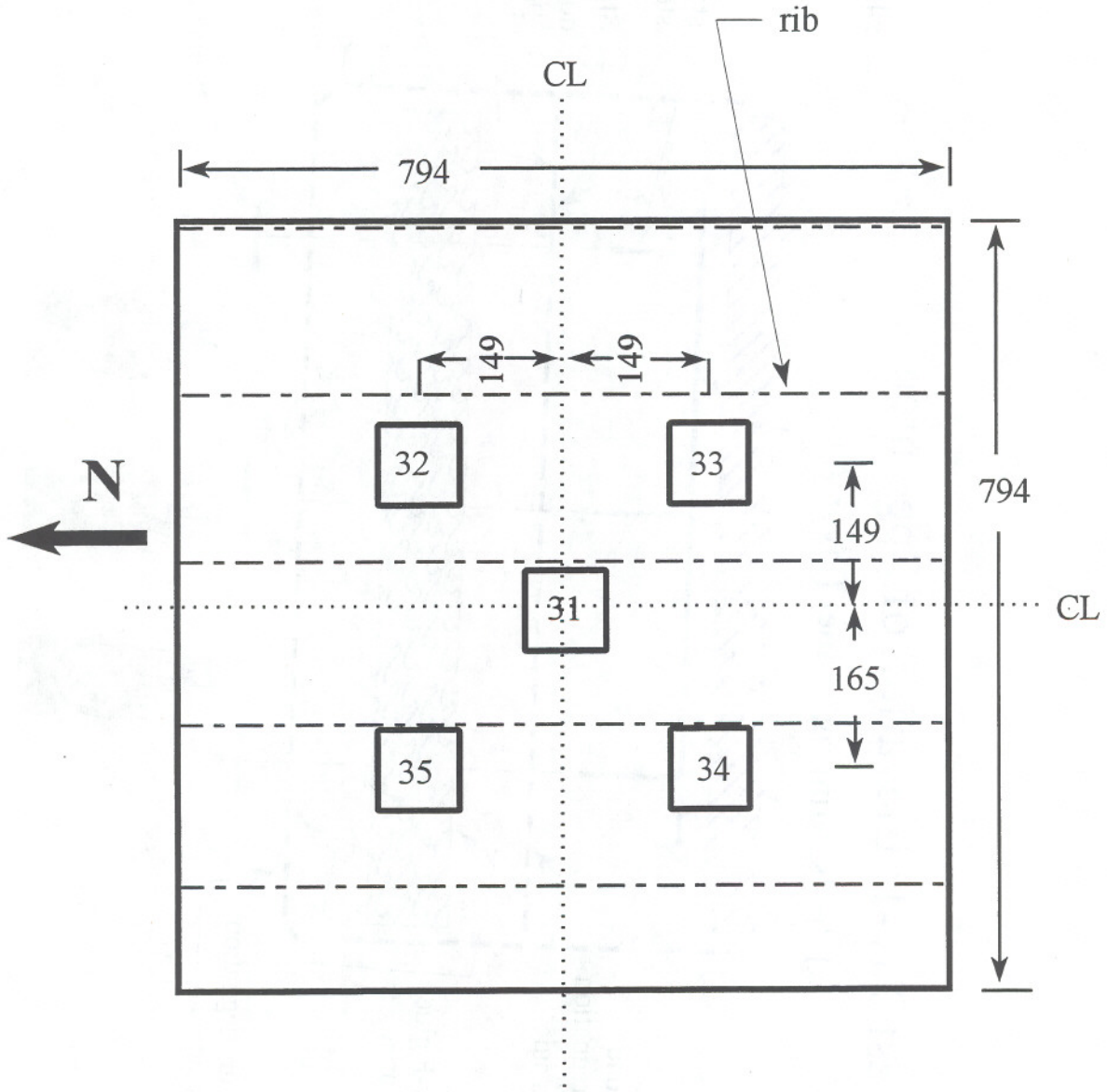
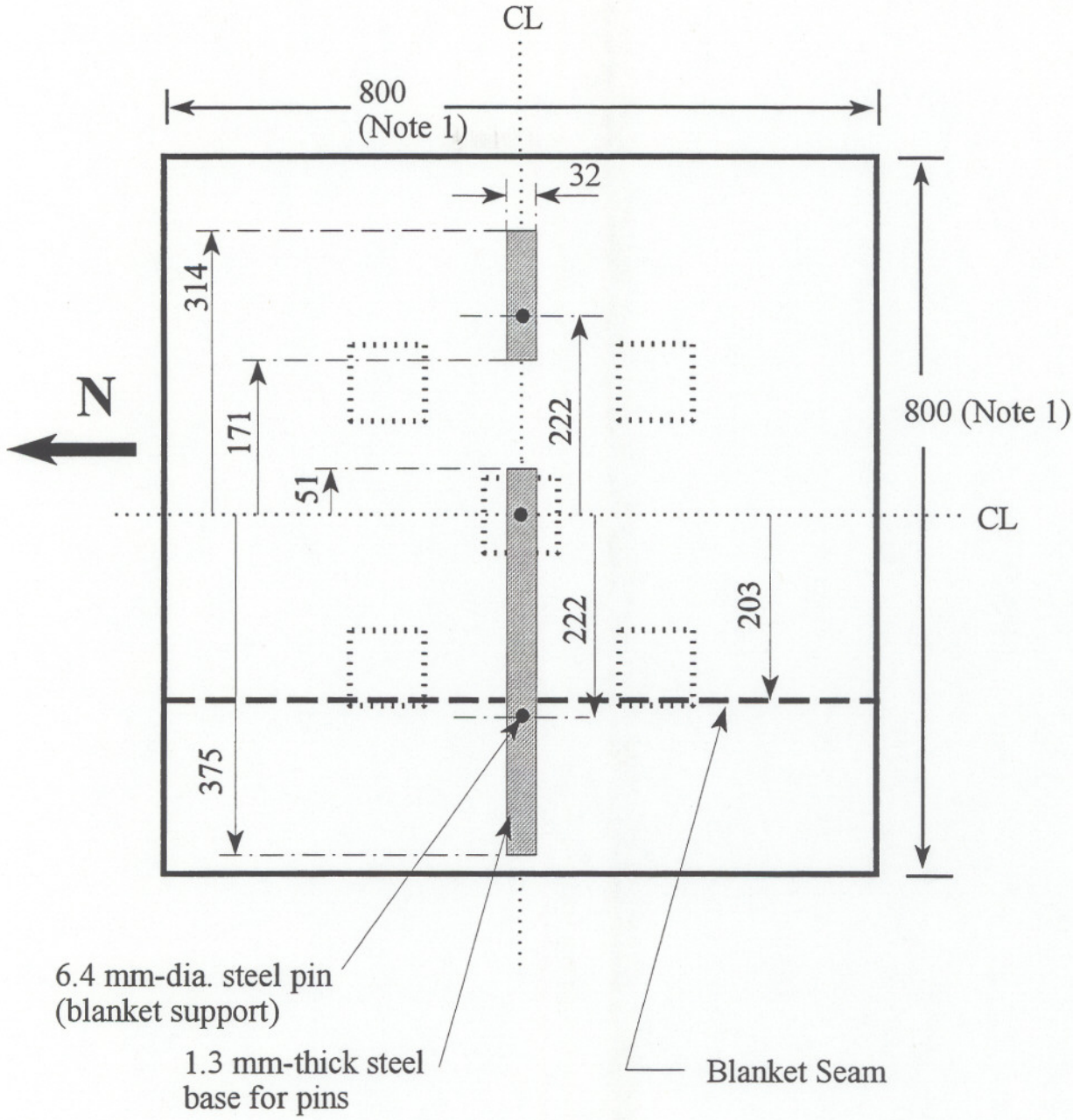


Fig. IV.2. Layer dimensions, Test TJ1-1. View from above unexposed surface of layer A. All dimensions in millimeters (1 in = 25.4 mm). Numbered squares denote unexposed-surface thermocouple pads.

Note 1: Upgrade layers were approx. 6 mm longer than the "subliming" panels in both length and width.



tj1-1.wpg

Fig. IV.3 In-depth view showing locations of supporting pins and blanket seam as viewed through the unexposed surface of the test assembly, Test TJ1-1.

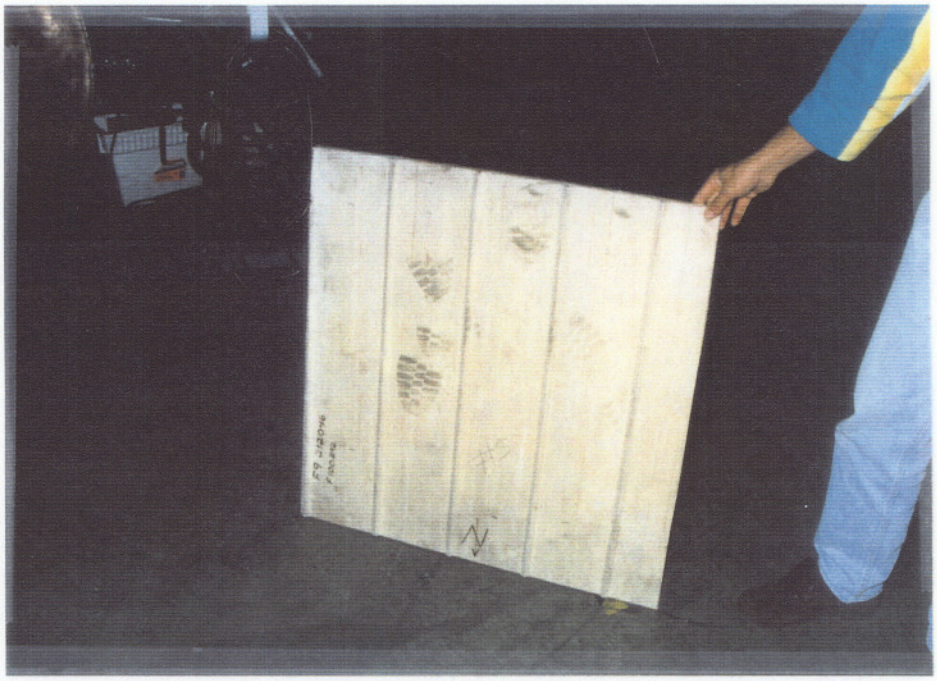


Fig. IV.4. Pre-test photograph of unexposed surface, layer A, Test TJ1-1.

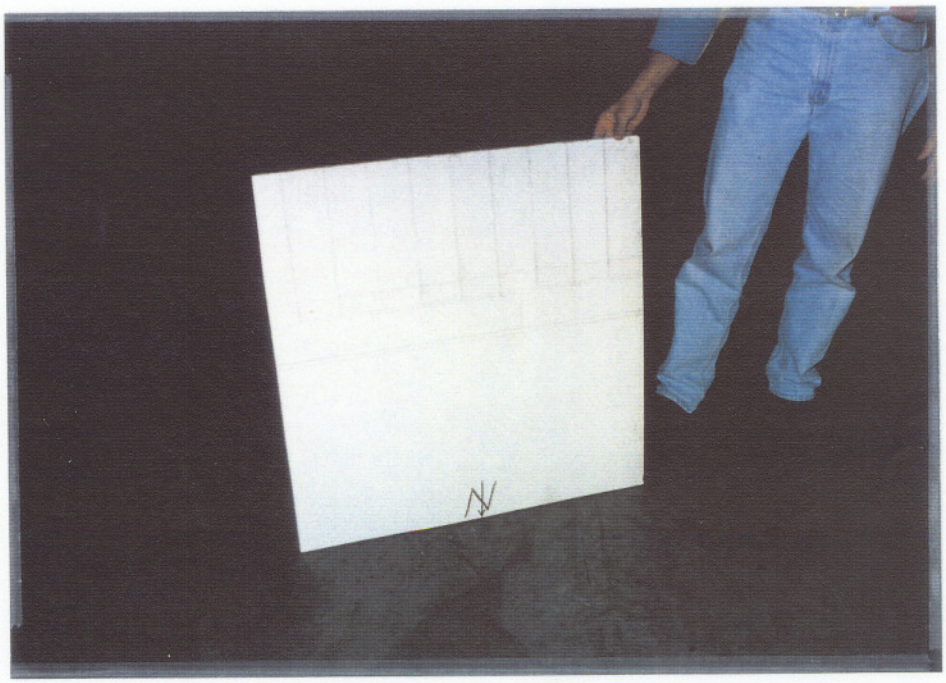


Fig. IV.5. Pre-test photograph of exposed surface, layer A, Test TJ1-1.

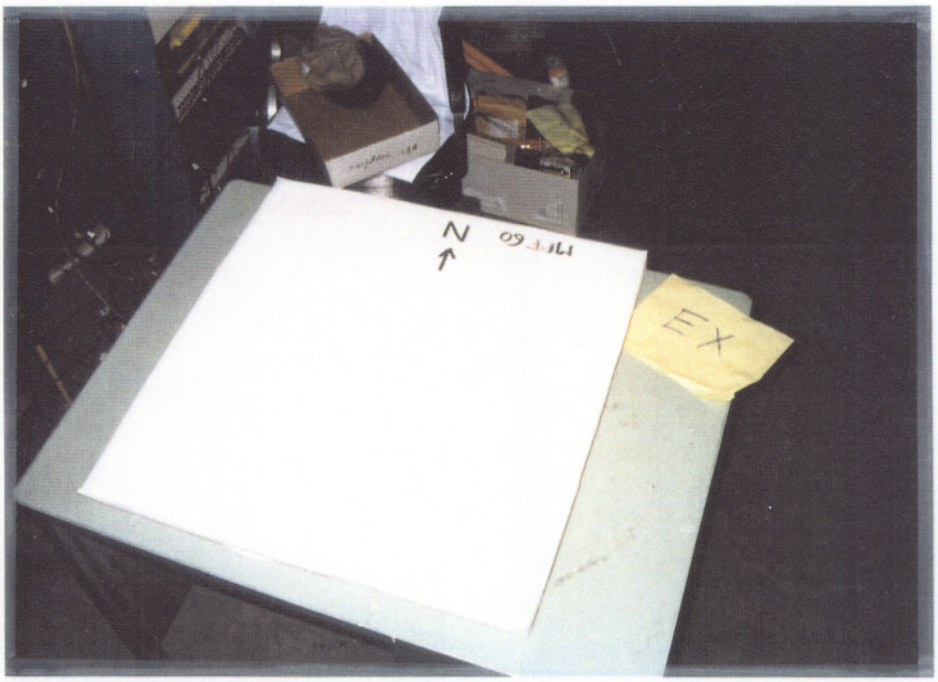


Fig. IV.6 Pre-test photograph of exposed surface, layer D, Test TJ1-1.

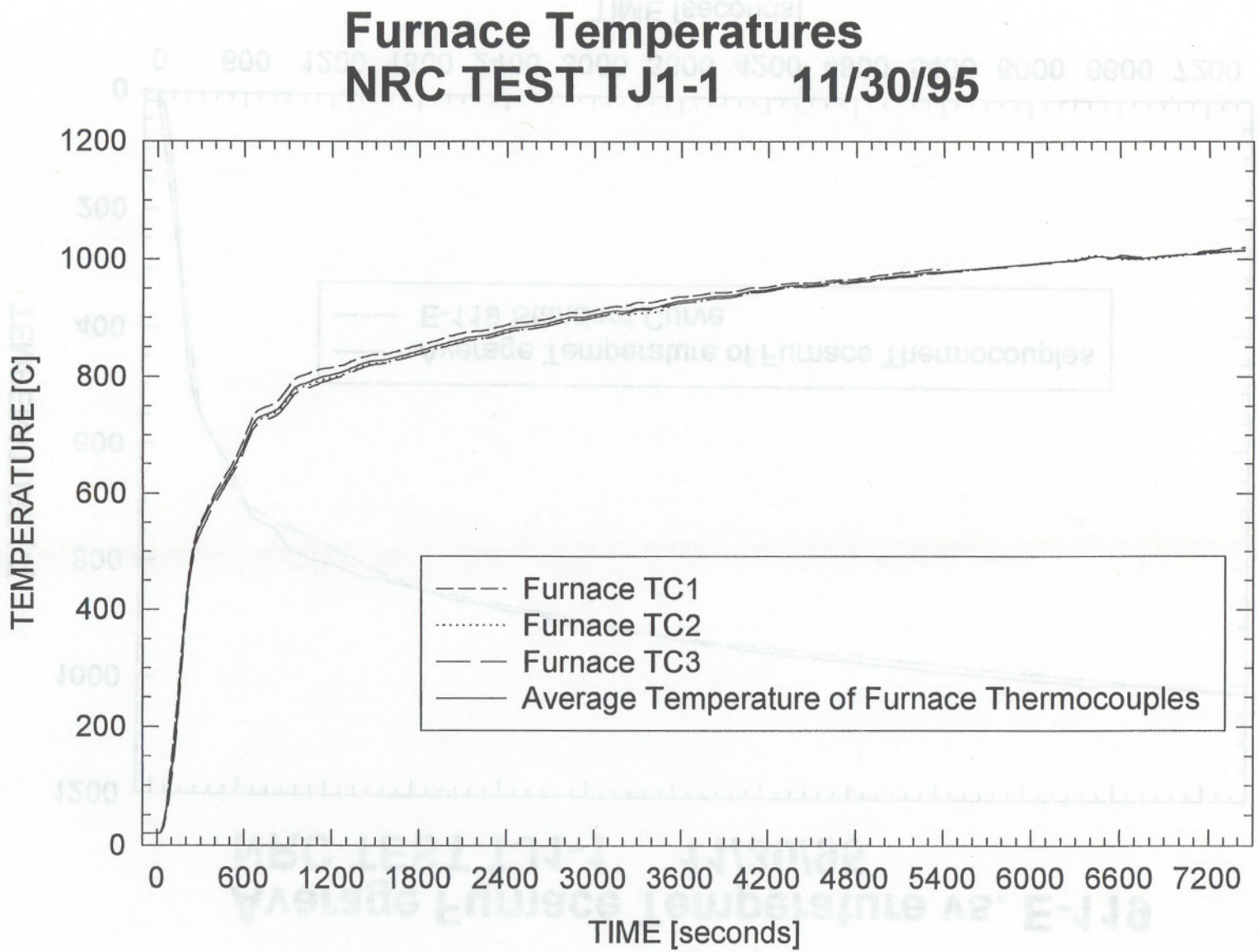


Fig. IV.7 Furnace temperature, Test TJ1-1.

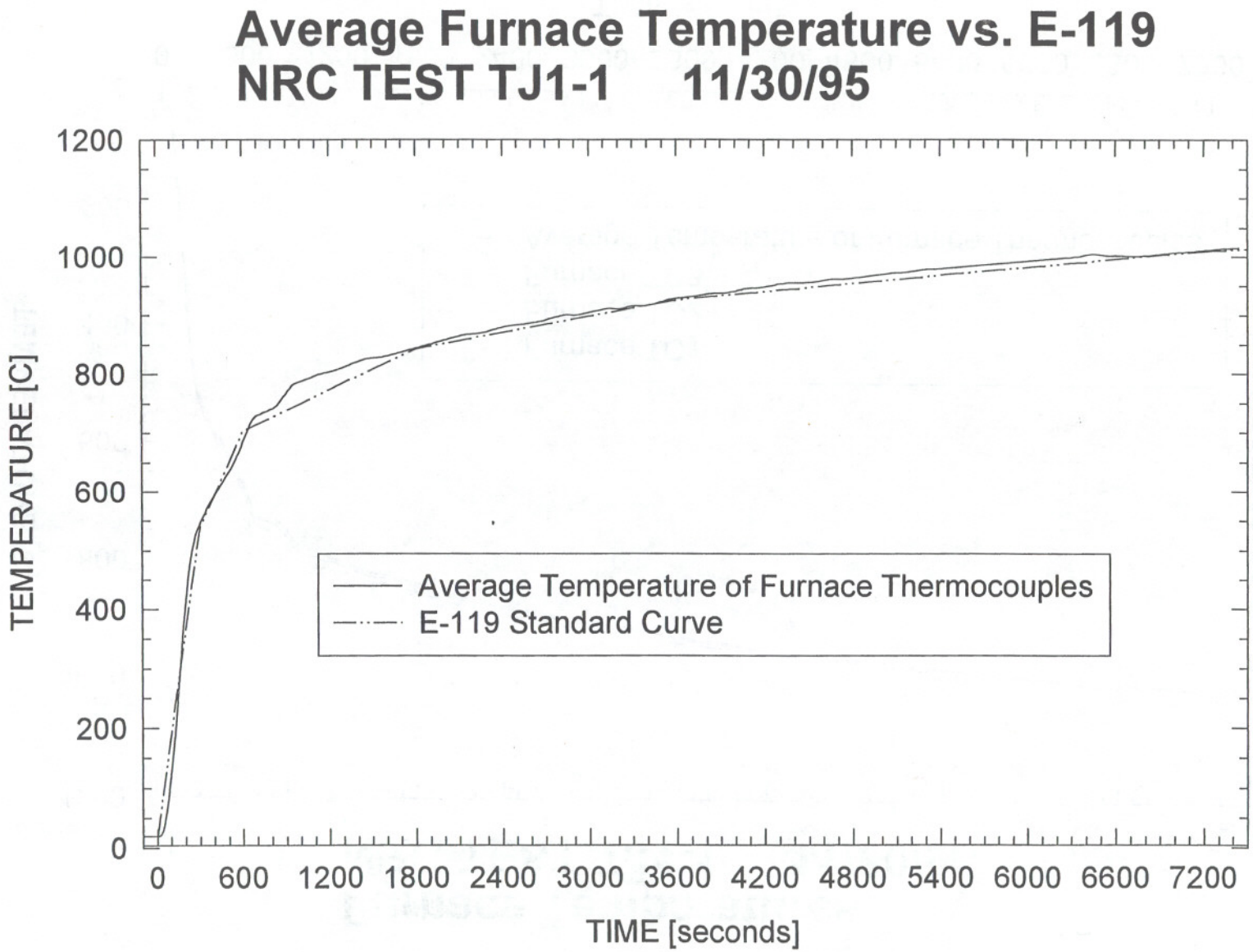


Fig. IV.8. Furnace temperature, Test IV.8.

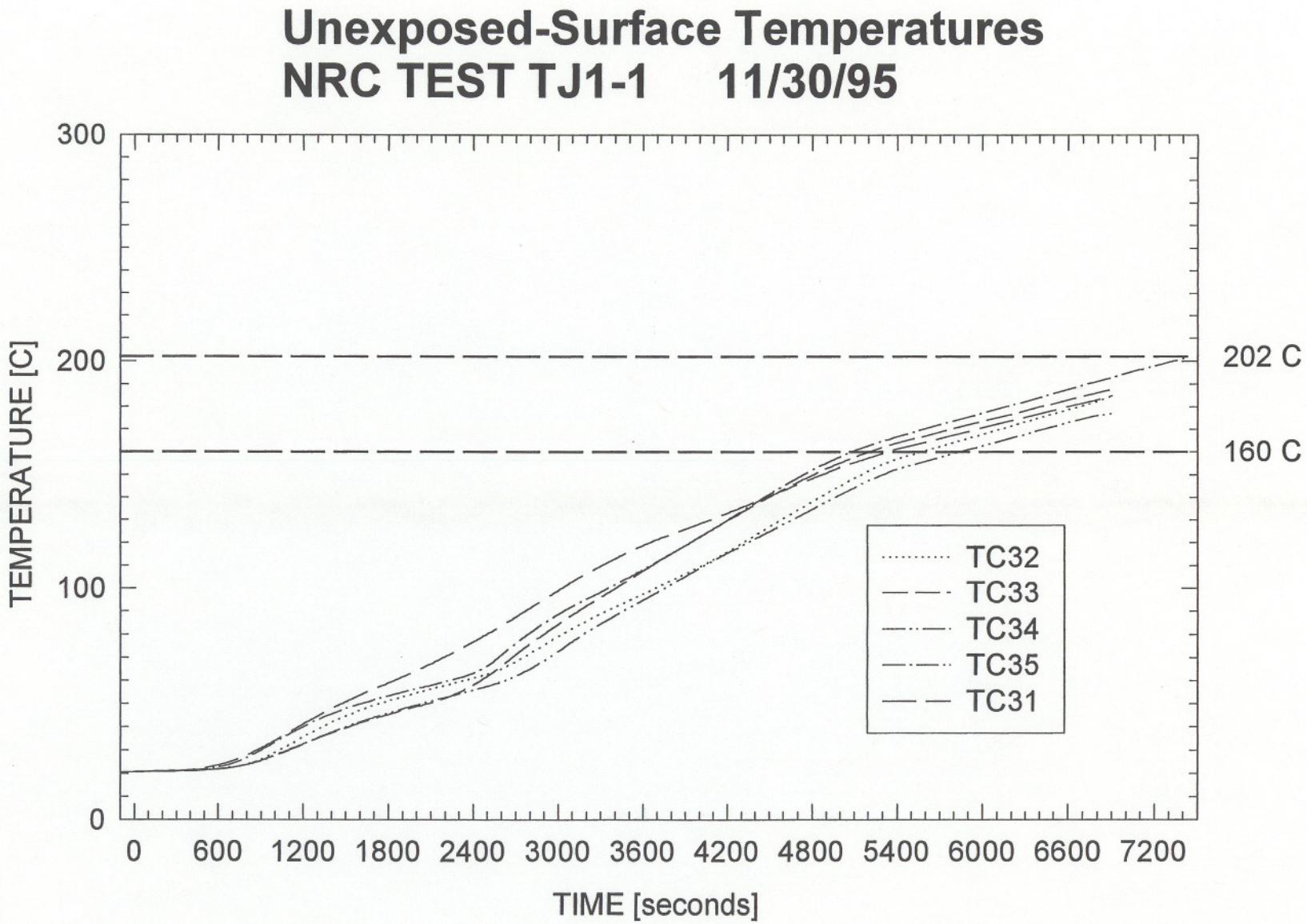


Fig. IV.9. Unexposed-surface temperatures, Test TJ1-1.

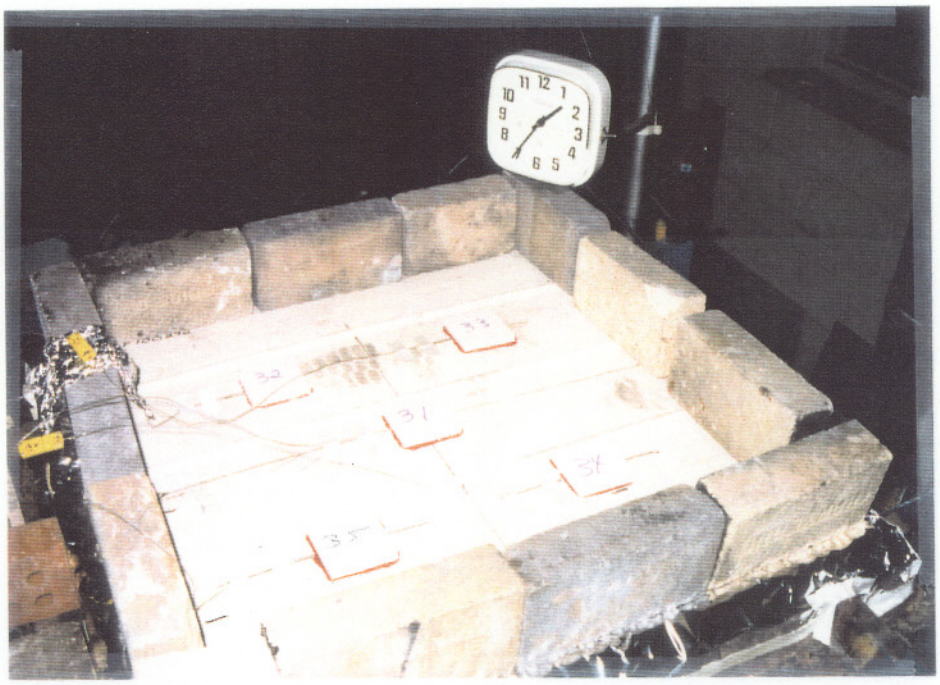


Fig. IV.10. Photograph of unexposed surface during Test IV.10.

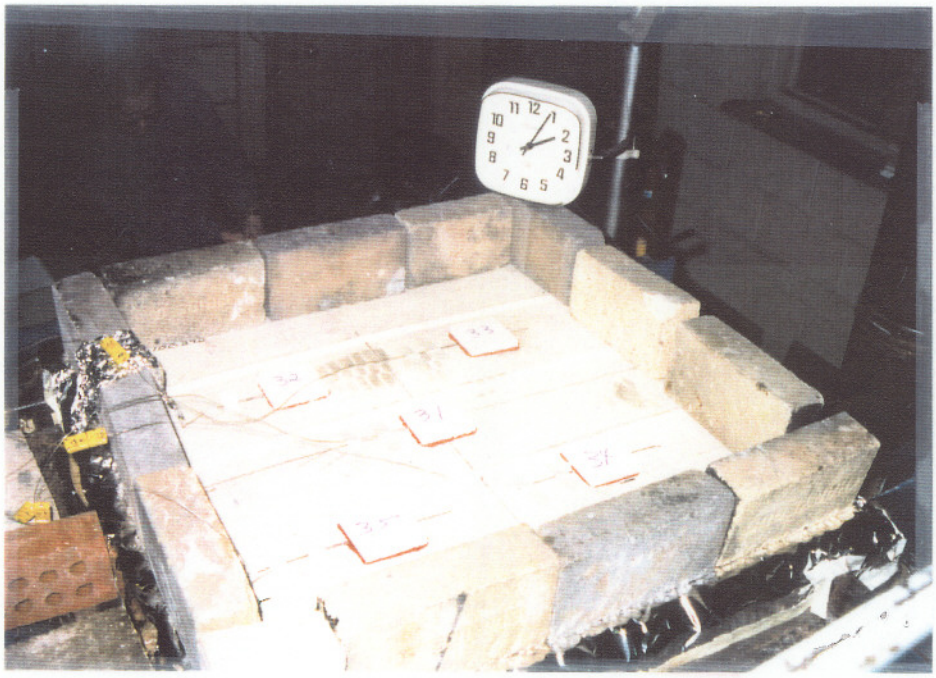


Fig. IV.11. Photograph of unexposed surface during Test TJ1-1.

Fig. IV.12. Post-test photograph of exposed surface of test assembly, Test TJ1-1.

Fig. IV.13. Post-test photograph of exposed surface, layer C, Test TJ1-1.

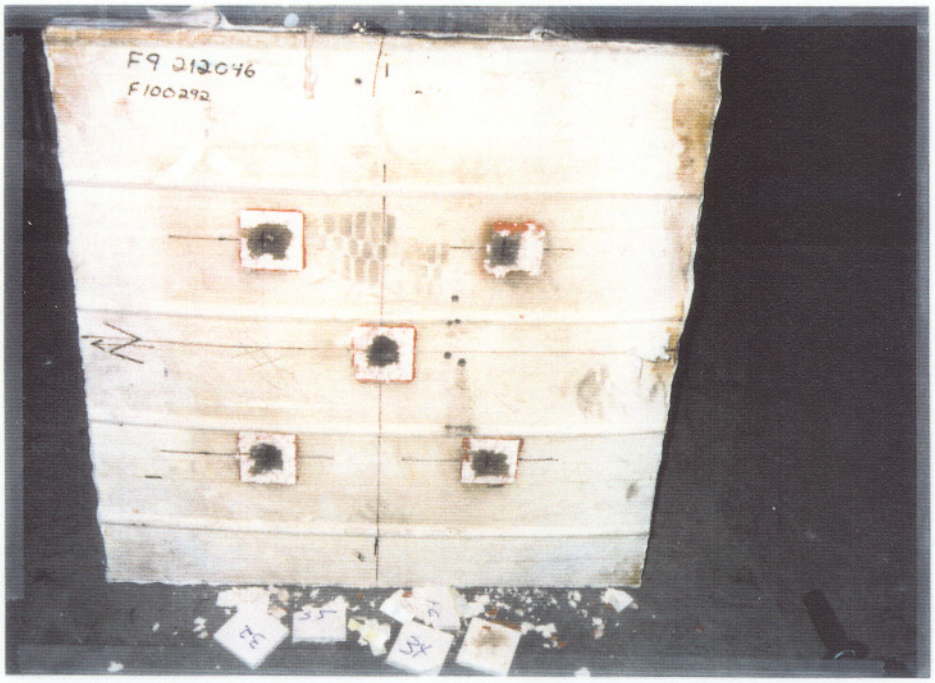


Fig. IV.14. Post-test photograph of unexposed surface, layer A, Test TJ1-1.

Fig. IV.15. Post-test photograph of exposed surface of small specimen cut from layer C, Test TJ1-1.

V. Test TJ3-1

A. Description of Test Assembly

The test assembly, which is shown schematically in Fig. V.1, consisted of one layer of 3-hr "subliming" fire-barrier panel over two layers of mineral-wool fire-barrier blanket. The blanket-pair was sandwiched between two layers of silicon-impregnated glass-fiber cloth. The adhesives used at layer interfaces are identified in Fig. V.1 The "subliming" panel is manufactured with a "flat" face, a ribbed face, and wire mesh covering both faces. The ribbed face became the unexposed surface of the test assembly. A galvanized-steel band with steel pins was glued to the flat side of the panel. Fender washers on the pins helped to support the mineral-wool and glass-fiber-cloth layers.

Plan views of the test assembly are shown in Figs. V.2 and V.3. The 3-hr "subliming" layer was cut at NIST from a panel labeled by the manufacturer as F9-86013 F05286_[8]. The upgrade materials (steel pins, mineral-wool blanket, and glass-fiber cloth) were installed by trained employees of the supplier of the upgrade system.

The arrangement, designations, thicknesses, and masses of the layers were as follows:

Test TJ3-1: Test Assembly			
Arrangement	Thickness in mm [in]	Pre-test Mass in kg ± 0.01 [lb ± 0.02]	Post-test Mass in kg ± 0.01 [lb ± 0.02]
layer A, 3-hr "subliming" panel	off-rib avg.= 28.8 [1.13] std. dev. = 2.17 [0.085] (40 measurements) rib avg.= 39.1 [1.54] std. dev. = 1.13 [0.044] (8 measurements)	21.56 [47.49]	30.28 [66.70] (mass of identified layers plus steel band, pins, and washers; mastic; and glue)
layer B, silicon-impregnated glass-fiber cloth	0.41 (nominal) [0.016]	15.68 [34.54] (mass of identified layers plus steel band, pins, and washers; mastic; and glue)	
layer C, mineral-wool blanket	32 - 38 (nominal) [1.3 - 1.5]		
layer D, mineral-wool blanket	32 - 38 (nominal) [1.3 - 1.5]		
layer E, silicon-impregnated glass-fiber cloth	0.41 (nominal) [0.016]		

[8] It is unclear whether there was or was not a digit missing at the end of this code.

Layer E was closest to the furnace and layer A was farthest away.

Pre-test photographs of the unexposed and exposed surfaces of layer A are shown in Figs. V.4 and V.5, respectively. The exposed surface of layer E is shown in Fig. V.6.

The stainless-steel supports described in section I.A were not in place for this test. After positioning the assembly on the furnace, two layers of nominal 25.4 mm (1 in) thick ceramic-fiber insulation were wrapped around its edges and the exterior of this insulation was covered with aluminum foil. The lower edge of the foil was taped to the furnace and the upper edge was taped to the unexposed surface of layer A with glass-cloth tape. Then the upper edges of the foil were loaded with bricks as described section I.A.

B. Fire Test Procedures and Results

The test was conducted on December 1, 1995 with no official observers present.

The test assembly was subjected to a 5.5-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.7 and tabulated in Table V.1. The average furnace temperatures and the standard temperature-time curve are shown in Fig. V.8.

Unexposed-surface thermocouples measured surface temperatures beneath insulation pads at 5 locations designated 31 to 35 in Fig. V.2. The thermocouples at these locations are designated TC31 to TC35, respectively, and their outputs are plotted in Fig. V.9 and tabulated in Table V.1. Included in the table are the averages of the unexposed-surface temperatures as a function of time. Note that during the first 3780 s, data are missing for TC32 due to a short circuit.

Figures V.10 to V.12 show the unexposed surface during the test. During the first 3.6 hours there was no change in the appearance of the unexposed surface. At about 3:40 there was a hint of very slight browning north of TC34. At 5:21 small crystals were scattered across the unexposed surface of layer A (the "subliming" panel). Neither flame passage nor glowing were observed during the test period.

A log of observations is presented in Table V.2.

Following termination of the test, flames rolled across the exposed face when west edge of the test assembly was lifted and propped (Fig. V.13), but the flames self-extinguished in a few seconds. The seam between blanket pieces on the exposed face was glowing. Essentially all of the exposed area of Layer E was missing, but layer D was intact. The assembly was allowed to cool overnight in the propped position and was removed from the furnace the following day, December 2, 1995.

The exposed surface of layer D and the unexposed surface of layer A are shown in Figs. V.14 and V.15, respectively. Layer D was darkened on its exposed surface, but white throughout its depth. The wire mesh was still in place on the exposed surface of layer A. Layer A did not appear to intumesce. At a near-central location between ribs and away from thermocouple pads, the total thickness of layer A was about 35 mm (1.4 in), comprised of about 19 mm (0.75 in) char and about 16 mm of cream-colored near-virgin material.

The thermocouple pads remained attached and had to be pried off to complete inspection of the unexposed surface. Beneath the pads, the unexposed-surface colors varied from moderate brown to black. There was no burnthrough beneath the pads or elsewhere.

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, 21°C [70°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 during the test neither flame nor hot gases capable of igniting cotton waste held against the unexposed surface pass through the assembly. In addition to these criteria, NRC requests monitoring the time at which any of the unexposed-surface thermocouples exceeds 139°C (250°F) above the initial temperature.

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

Test TJ3-1: 3-hour Test Assembly			
Condition	Location	Time	
		(sec)	[hr:min:sec]
E 119 avg. unexposed surf. temp. criterion (160°C) [320°F]		16094	[4:28:14]
E 119 peak unexposed surf. temp. criterion (202°C) [396°F]	TC31	20381	[5:39:41]
NRC unexposed surf. temp., 1st occurrence (160°C) [320°F]	TC31	15369	[4:16:09]

Concerning E 119 criteria, the average temperature was the controlling factor and the E 119 fire-endurance period was 16094 seconds (4 hours and 28.2 minutes). 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 +60 s and **the corrected fire-endurance period was 16154 s (4 hours and 29.2 minutes)**. The attendant maximum uncertainty was +571/-557 s (+9.5/-9.3 minutes) (see Appendix).

Neither flame nor hot gas passage through the unexposed face of the assembly were observed during the test. No glowing was observed at any time during the test. The post-test inspection revealed no burnthrough at the unexposed surface of the assembly.

TABLE V.1. Temperatures (°C), Test TJ3-1.

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
-120	22	22	22	22	21	--	21	21	21	21
-60	22	22	22	22	21	--	21	21	21	21
0	22	22	22	22	21	--	21	21	22	21
60	49	48	41	46	21	--	21	21	22	21
120	198	169	164	177	22	--	21	22	22	22
180	385	364	363	371	22	--	21	22	22	22
240	511	501	493	502	22	--	21	22	22	22
300	571	565	556	564	22	--	21	22	22	22
360	604	598	590	597	22	--	21	22	22	22
420	625	620	613	619	22	--	21	22	22	22
480	644	638	633	638	22	--	22	22	22	22
540	667	661	655	661	22	--	22	22	22	22
600	695	689	684	689	22	--	22	22	22	22
660	728	720	715	721	22	--	22	22	22	22
720	745	733	727	735	22	--	22	22	22	22
780	757	742	737	745	22	--	22	22	22	22
840	766	752	746	755	22	--	22	22	22	22
900	776	761	756	764	22	--	22	22	22	22
960	786	771	766	774	22		22	22	22	22
1020	795	779	774	783	23		22	22	22	22
1080	800	784	780	788	23		22	22	23	22
1140	803	788	784	792	23		22	22	23	22
1200	807	792	789	796	23		22	22	23	22
1260	812	797	795	801	23		22	22	23	23
1320	818	803	801	807	23		22	22	23	23
1380	824	809	807	813	23		22	23	23	23
1440	830	815	813	819	24	--	22	23	23	23
1500	834	819	818	824	24	--	22	23	23	23
1560	834	820	819	824	24	--	22	23	23	23
1620	839	825	823	829	24	--	22	23	23	23
1680	844	830	829	835	24	--	23	23	23	23
1740	850	836	835	840	25	--	23	23	23	23
1800	855	841	840	845	25	--	23	23	24	24
1860	858	844	843	848	25	--	23	23	24	24
1920	860	847	846	851	25	--	23	23	24	24
1980	862	850	850	854	25	--	23	24	24	24
2040	868	855	855	859	26	--	23	24	24	24
2100	870	858	857	862	26	--	23	24	24	24
2160	873	860	860	864	26	--	23	24	24	24
2220	877	864	863	868	27	--	23	24	24	25
2280	880	867	867	872	27	--	24	24	25	25
2340	883	871	870	875	27	--	24	24	25	25
2400	887	874	874	878	28	--	24	25	25	25
2460	890	878	878	882	28	--	24	25	25	25
2520	893	881	881	885	28	--	24	25	25	26
2580	896	885	884	888	29	--	24	25	26	26
2640	899	888	887	891	29	--	24	25	26	26

TC32 shorted

TABLE V.1. Temperatures (°C), Test TJ3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
2700	900	890	889	893	29	–	24	26	26	26
2760	902	892	891	895	30	–	25	26	26	27
2820	904	894	893	897	30	–	25	26	26	27
2880	906	896	895	899	31	–	25	26	26	27
2940	909	899	898	902	31	–	25	26	27	27
3000	911	901	901	904	31		25	27	27	28
3060	914	904	904	907	32		25	27	27	28
3120	917	906	905	909	32		26	27	27	28
3180	916	906	907	909	33		26	27	28	28
3240	918	908	909	912	34		26	28	28	29
3300	924	913	913	917	34		26	28	28	29
3360	926	917	915	919	35		27	28	28	29
3420	928	919	917	921	35		27	28	29	30
3480	929	921	919	923	36		27	29	29	30
3540	931	923	921	925	37	–	27	29	29	31
3600	934	925	924	928	37	–	28	30	30	31
3660	937	927	926	930	38	–	28	30	30	31
3720	940	929	928	932	39	–	29	30	31	32
3780	942	932	931	935	39	34	29	31	31	33
3840	944	934	934	937	40	34	29	31	32	33
3900	946	935	935	939	41	35	30	32	32	34
3960	946	936	936	939	41	36	30	32	33	34
4020	948	937	937	941	42	36	31	33	33	35
4080	949	939	939	942	43	37	31	34	34	36
4140	951	941	940	944	44	37	32	34	35	36
4200	952	942	942	946	44	38	32	35	35	37
4260	954	944	944	947	45	38	33	35	36	38
4320	956	946	946	949	46	39	33	36	37	38
4380	958	948	948	952	47	40	34	37	37	39
4440	961	950	950	954	47	40	34	37	38	39
4500	963	953	953	956	48	41	35	38	39	40
4560	965	955	955	958	49	41	35	39	39	41
4620	967	957	957	960	49	42	36	39	40	41
4680	967	957	957	961	50	43	36	40	41	42
4740	968	958	958	961	51	43	37	41	42	43
4800	970	960	960	963	51	44	37	41	42	43
4860	973	962	962	966	52	44	38	42	43	44
4920	974	964	964	967	53	45	38	42	43	44
4980	976	965	965	969	53	45	39	43	44	45
5040	977	967	967	970	54	46	39	44	45	46
5100	978	968	969	972	54	46	40	44	45	46
5160	980	970	970	973	55	47	40	45	46	47
5220	981	971	972	975	56	47	41	45	47	47
5280	983	973	973	976	56	48	41	46	47	48
5340	984	974	975	978	57	48	42	46	48	48
5400	986	976	976	979	57	49	42	47	48	49
5460	987	977	977	981	58	49	43	48	49	49

TC32 shorted

TABLE V.1. Temperatures (°C), Test TJ3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
5520	988	978	979	982	58	50	43	48	49	50
5580	990	980	981	984	59	50	44	49	50	50
5640	991	981	982	985	59	51	44	49	50	51
5700	993	983	983	986	60	51	45	50	51	51
5760	994	984	984	988	61	51	45	50	51	52
5820	995	985	986	989	61	52	45	50	52	52
5880	997	987	987	990	62	52	46	51	52	52
5940	998	988	988	992	62	53	46	51	53	53
6000	999	989	990	993	63	53	47	52	53	53
6060	1000	991	991	994	63	53	47	52	53	54
6120	1001	992	993	995	64	54	47	53	54	54
6180	1002	993	993	996	64	54	48	53	54	55
6240	1002	993	993	996	65	54	48	53	55	55
6300	1002	993	993	996	65	55	48	54	55	55
6360	1003	993	994	997	65	55	49	54	56	56
6420	1004	994	995	998	66	55	49	54	56	56
6480	1004	996	995	998	66	56	49	55	56	56
6540	1005	997	997	999	67	56	50	55	57	57
6600	1006	997	998	1000	67	56	50	55	57	57
6660	1007	998	998	1001	68	56	50	56	57	58
6720	1009	1000	1000	1003	68	57	51	56	58	58
6780	1011	1002	1002	1005	69	57	51	56	58	58
6840	1013	1003	1004	1007	69	57	51	57	58	58
6900	1014	1005	1005	1008	70	57	52	57	59	59
6960	1015	1006	1006	1009	70	58	52	57	59	59
7020	1016	1007	1007	1010	71	58	52	57	59	60
7080	1015	1006	1006	1009	71	58	52	58	59	60
7140	1014	1005	1006	1008	72	59	53	58	60	60
7200	1014	1006	1006	1009	73	59	53	58	60	61
7260	1017	1008	1008	1011	73	59	53	58	60	61
7320	1020	1011	1011	1014	74	60	53	59	60	61
7380	1019	1010	1011	1013	74	60	54	59	61	61
7440	1019	1010	1010	1013	75	61	54	59	61	62
7500	1019	1011	1011	1014	75	61	54	59	61	62
7560	1021	1012	1013	1015	76	62	55	60	61	63
7620	1022	1013	1013	1016	77	62	55	60	62	63
7680	1023	1014	1015	1017	77	63	55	60	62	63
7740	1024	1015	1016	1018	78	63	55	61	62	64
7800	1025	1016	1016	1019	79	64	56	61	62	64
7860	1025	1017	1017	1020	79	64	56	61	62	65
7920	1026	1018	1018	1021	80	65	56	62	62	65
7980	1027	1019	1019	1021	81	66	57	62	63	66
8040	1028	1019	1020	1022	81	66	57	63	63	66
8100	1028	1020	1020	1023	82	67	58	64	63	67
8160	1029	1021	1021	1024	83	67	58	64	63	67
8220	1029	1020	1020	1023	84	68	59	65	63	68
8280	1028	1020	1020	1023	84	69	59	65	64	68

TABLE V.1. Temperatures (°C), Test TJ3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
8340	1028	1020	1020	1022	85	70	60	66	64	69
8400	1029	1021	1021	1024	86	70	60	67	64	70
8460	1030	1022	1022	1025	87	71	61	68	65	70
8520	1031	1023	1023	1025	87	72	61	69	65	71
8580	1032	1024	1023	1026	88	73	62	69	66	72
8640	1032	1024	1024	1027	89	73	63	70	66	72
8700	1033	1025	1025	1028	90	74	63	71	67	73
8760	1034	1026	1025	1028	90	75	64	72	68	74
8820	1034	1027	1026	1029	91	76	65	73	68	75
8880	1035	1027	1027	1030	92	76	65	74	69	75
8940	1036	1028	1028	1031	93	77	66	75	70	76
9000	1037	1029	1029	1031	94	78	67	76	70	77
9060	1037	1030	1029	1032	94	79	67	77	71	78
9120	1038	1030	1030	1033	95	79	68	78	72	79
9180	1039	1031	1031	1033	96	80	69	79	73	79
9240	1039	1032	1031	1034	97	81	70	80	74	80
9300	1040	1032	1032	1035	97	82	71	81	74	81
9360	1041	1033	1033	1036	98	83	71	81	75	82
9420	1041	1034	1034	1036	99	83	72	82	76	82
9480	1042	1035	1035	1037	100	84	73	83	77	83
9540	1043	1035	1035	1038	100	85	74	84	78	84
9600	1043	1036	1036	1038	101	86	74	85	78	85
9660	1044	1037	1037	1039	102	87	75	86	79	86
9720	1045	1038	1037	1040	102	88	76	87	80	87
9780	1046	1039	1038	1041	103	89	77	88	81	87
9840	1047	1039	1039	1042	104	90	78	88	82	88
9900	1048	1040	1040	1042	105	90	79	89	83	89
9960	1048	1041	1041	1043	105	91	79	90	83	90
10020	1049	1042	1042	1044	106	92	80	91	84	91
10080	1050	1043	1042	1045	107	93	81	92	85	92
10140	1051	1044	1043	1046	108	93	82	93	86	92
10200	1052	1045	1044	1047	108	94	83	93	87	93
10260	1053	1046	1045	1048	109	95	83	94	88	94
10320	1054	1047	1046	1049	110	96	84	95	89	95
10380	1055	1048	1047	1050	111	97	85	96	90	96
10440	1055	1048	1048	1050	111	97	86	97	91	96
10500	1054	1048	1048	1050	112	98	87	98	91	97
10560	1055	1049	1048	1051	113	99	88	98	92	98
10620	1055	1049	1049	1051	113	99	88	99	93	99
10680	1056	1050	1050	1052	114	100	89	100	94	99
10740	1057	1051	1051	1053	115	101	90	101	95	100
10800	1057	1052	1051	1054	116	102	91	102	96	101
10860	1058	1053	1052	1054	116	103	92	102	96	102
10920	1058	1053	1052	1054	117	103	92	103	97	103
10980	1058	1053	1053	1055	118	104	93	104	98	103
11040	1059	1054	1053	1055	119	105	94	105	99	104
11100	1059	1054	1054	1056	119	105	95	105	100	105

TABLE V.1. Temperatures (°C), Test TJ3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
11160	1060	1055	1055	1057	120	106	96	106	101	106
11220	1061	1056	1056	1058	121	107	97	107	102	106
11280	1062	1057	1057	1059	121	107	97	108	102	107
11340	1064	1059	1059	1060	122	108	98	108	103	108
11400	1065	1060	1060	1061	123	109	99	109	104	109
11460	1066	1061	1061	1063	124	110	100	110	105	110
11520	1067	1062	1062	1064	124	110	101	111	106	110
11580	1066	1062	1061	1063	125	111	101	112	107	111
11640	1065	1060	1060	1062	126	112	102	112	108	112
11700	1065	1061	1060	1062	127	113	103	113	109	113
11760	1066	1062	1061	1063	127	113	104	114	110	114
11820	1068	1063	1063	1065	128	114	104	115	111	115
11880	1069	1065	1064	1066	129	115	105	116	112	115
11940	1070	1066	1065	1067	130	116	106	117	112	116
12000	1071	1067	1066	1068	130	116	107	117	113	117
12060	1071	1067	1066	1068	131	117	107	118	114	118
12120	1070	1066	1065	1067	132	118	108	119	115	118
12180	1070	1066	1065	1067	133	119	109	120	116	119
12240	1070	1067	1066	1068	133	120	109	121	117	120
12300	1071	1068	1067	1069	134	120	110	122	117	121
12360	1073	1068	1067	1070	135	121	111	122	118	121
12420	1073	1069	1068	1070	136	122	111	123	119	122
12480	1074	1070	1069	1071	136	123	112	124	120	123
12540	1075	1071	1070	1072	137	124	113	125	121	124
12600	1075	1071	1070	1072	138	124	114	126	122	125
12660	1076	1072	1071	1073	138	125	114	127	122	125
12720	1077	1073	1072	1074	139	126	115	128	123	126
12780	1077	1074	1072	1074	140	127	116	129	124	127
12840	1078	1074	1073	1075	140	127	116	129	125	128
12900	1079	1075	1074	1076	141	128	117	130	126	128
12960	1080	1076	1074	1077	142	129	118	131	127	129
13020	1080	1076	1075	1077	142	129	118	132	127	130
13080	1081	1077	1076	1078	143	130	119	133	128	131
13140	1081	1078	1076	1078	143	131	120	134	129	131
13200	1082	1078	1077	1079	144	131	121	134	130	132
13260	1083	1079	1077	1080	144	132	121	135	131	133
13320	1083	1079	1078	1080	145	133	122	136	132	134
13380	1084	1080	1078	1081	146	134	123	137	132	134
13440	1084	1080	1079	1081	146	134	124	138	133	135
13500	1085	1081	1080	1082	147	135	125	139	134	136
13560	1086	1083	1081	1083	147	136	125	140	135	137
13620	1088	1084	1082	1085	148	137	126	140	136	137
13680	1089	1085	1083	1086	148	137	127	141	137	138
13740	1090	1086	1084	1087	149	138	128	142	138	139
13800	1091	1087	1085	1087	149	139	129	143	138	140
13860	1091	1088	1086	1088	150	140	129	143	139	140
13920	1092	1088	1086	1089	150	140	130	144	140	141

TABLE V.1. Temperatures (°C), Test TJ3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
13980	1092	1089	1087	1089	151	141	131	145	141	142
14040	1093	1089	1088	1090	151	142	132	145	142	142
14100	1094	1090	1088	1091	152	142	133	146	143	143
14160	1095	1091	1089	1092	152	143	133	147	143	144
14220	1095	1091	1089	1092	153	143	134	147	144	144
14280	1095	1092	1090	1092	153	144	135	148	145	145
14340	1096	1093	1090	1093	154	145	136	148	145	145
14400	1097	1093	1091	1094	154	145	136	149	146	146
14460	1097	1094	1092	1094	154	146	137	150	147	147
14520	1098	1094	1092	1095	155	146	138	150	147	147
14580	1099	1095	1093	1095	155	147	138	151	148	148
14640	1099	1095	1093	1096	156	147	139	151	148	148
14700	1099	1096	1094	1096	156	148	140	152	149	149
14760	1100	1096	1094	1097	156	148	140	152	150	149
14820	1100	1097	1095	1097	157	149	141	153	150	150
14880	1101	1098	1096	1098	157	149	142	153	151	150
14940	1103	1099	1098	1100	158	150	143	154	151	151
15000	1104	1100	1098	1101	158	150	143	154	152	151
15060	1105	1101	1099	1102	158	151	144	155	152	152
15120	1106	1102	1100	1103	159	151	144	155	153	152
15180	1106	1103	1101	1103	159	151	145	156	153	153
15240	1107	1104	1101	1104	160	152	146	156	154	153
15300	1108	1104	1102	1105	160	152	146	156	155	154
15360	1109	1105	1103	1105	160	153	147	157	155	154
15420	1109	1106	1103	1106	161	153	147	157	156	155
15480	1110	1106	1104	1107	161	154	148	158	156	155
15540	1110	1107	1105	1107	162	154	148	158	157	156
15600	1111	1107	1105	1108	162	155	149	158	157	156
15660	1111	1108	1105	1108	163	155	149	159	157	157
15720	1112	1108	1106	1109	164	155	150	159	158	157
15780	1112	1109	1106	1109	165	156	150	160	158	158
15840	1113	1109	1107	1110	166	156	151	160	159	158
15900	1113	1110	1108	1110	167	156	151	160	159	159
15960	1114	1111	1109	1111	167	157	152	161	160	159
16020	1115	1112	1110	1112	168	157	152	161	160	160
16080	1116	1113	1111	1113	169	158	153	162	160	160
16140	1117	1114	1112	1114	170	158	153	162	161	161
16200	1118	1115	1112	1115	171	158	154	162	161	161
16260	1118	1115	1113	1115	171	159	154	163	162	162
16320	1119	1116	1114	1116	172	159	155	163	162	162
16380	1120	1116	1114	1117	172	159	155	164	162	163
16440	1120	1117	1115	1117	173	160	156	164	163	163
16500	1120	1117	1115	1118	174	160	156	165	163	163
16560	1121	1118	1116	1118	174	160	156	165	164	164
16620	1121	1118	1116	1119	175	160	157	166	164	164
16680	1122	1119	1116	1119	175	161	157	166	164	165
16740	1122	1119	1117	1119	176	161	158	167	165	165

TEST: NRC TJ3-1 12/1/95

TABLE V.1. Temperatures (°C), Test TJ3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
16800	1123	1120	1117	1120	176	162	158	168	165	166
16860	1123	1120	1118	1120	177	162	158	168	166	166
16920	1124	1121	1119	1121	177	162	159	169	166	167
16980	1124	1121	1119	1122	178	163	159	170	167	167
17040	1124	1122	1119	1122	176	163	160	170	168	167
17100	1126	1123	1121	1123	178	163	160	171	169	168
17160	1127	1124	1122	1124	178	164	160	171	170	169
17220	1128	1125	1123	1125	179	164	161	172	170	169
17280	1129	1126	1124	1126	179	165	161	172	171	170
17340	1129	1126	1124	1127	178	165	162	173	171	170
17400	1130	1127	1125	1128	178	165	162	173	172	170
17460	1131	1128	1126	1128	180	166	163	173	173	171
17520	1131	1129	1127	1129	181	166	163	173	173	171
17580	1132	1129	1127	1129	181	167	164	174	174	172
17640	1132	1130	1128	1130	182	167	164	174	174	172
17700	1134	1132	1129	1132	181	168	164	174	175	172
17760	1136	1133	1131	1133	181	168	165	175	175	173
17820	1137	1134	1132	1134	182	169	166	175	176	173
17880	1138	1136	1133	1136	182	169	167	176	176	174
17940	1139	1137	1135	1137	182	169	169	176	177	175
18000	1140	1138	1135	1138	183	170	170	177	177	175
18060	1141	1138	1136	1138	183	170	170	177	178	176
18120	1141	1138	1136	1139	183	171	171	177	178	176
18180	1141	1138	1136	1138	184	171	171	178	179	177
18240	1141	1139	1136	1139	185	171	172	178	179	177
18300	1141	1139	1136	1139	185	172	172	179	179	177
18360	1141	1139	1137	1139	185	172	172	179	180	178
18420	1141	1139	1137	1139	186	173	173	180	180	178
18480	1142	1140	1137	1140	186	173	173	180	181	179
18540	1142	1140	1138	1140	186	173	174	181	181	179
18600	1143	1141	1138	1141	187	174	174	181	182	180
18660	1143	1141	1139	1141	187	174	175	182	182	180
18720	1143	1141	1139	1141	188	175	175	182	183	180
18780	1144	1142	1139	1142	188	175	175	182	183	181
18840	1144	1142	1140	1142	188	175	175	183	183	181
18900	1145	1143	1141	1143	189	176	175	183	184	181
18960	1147	1145	1143	1145	189	176	176	184	184	182
19145	1151	1148	1146	1148	191	177	177	185	186	183
19205	1151	1148	1147	1149	191	178	177	186	186	184
19265	1152	1150	1148	1150	192	178	178	186	187	184
19325	1153	1151	1149	1151	192	179	178	186	187	184
19385	1154	1152	1150	1152	193	179	178	187	187	185
19445	1154	1151	1150	1152	193	180	179	187	188	185
19505	1155	1152	1151	1153	194	180	179	188	188	186
19565	1155	1153	1151	1153	194	180	180	188	189	186
19625	1156	1153	1152	1154	194	181	180	189	189	187
19685	1157	1154	1153	1155	195	181	181	189	190	187

TABLE V.1. Temperatures (°C), Test TJ3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
19745	1157	1155	1153	1155	196	182	182	190	190	188
19805	1158	1155	1154	1156	196	182	182	190	191	188
19865	1158	1156	1154	1156	197	183	183	191	191	189
19925	1159	1156	1155	1156	198	183	183	191	192	189
19985	1159	1156	1155	1157	198	183	184	192	192	190
20045	1160	1157	1156	1158	199	184	184	192	192	190
20105	1161	1158	1158	1159	200	184	185	193	193	191
20165	1163	1160	1160	1161	200	184	185	193	193	191
20225	1164	1161	1161	1162	201	185	185	194	194	192
20285	1165	1162	1162	1163	201	185	186	194	194	192
20345	1166	1162	1162	1164	202	185	186	195	195	193
20405	1167	1164	1163	1165	203	186	187	195	195	193

TABLE V.2. Observations, Test TJ3-1.

The following observations were made during and after the test:

Time	
0:34:00	No change in the appearance of the unexposed surface. Some light outgassing along edge.
approx. 1:03	Repaired TC32: it was shorted up to this time.
2:00:00	No change in the appearance of the unexposed surface.
3:00:00	No change.
3:30:00	No change.
3:40:00	Maybe some darkening of unexposed surface north of TC34.
4:00:00	No change (might be darkening as described above).
4:40:00	No change. No crystals.
5:16:45	Shut down computer to avoid automatic shutdown.
5:18:45	Computer restarted.
5:21:30	Some crystals scattered across unexposed surface.
5:30:00	Number of crystals increasing.
5:41:00	Furnace Shutdown. No additional change. Final appearance includes crystals scattered across face and some darkening around TC34.
5:46	Lifted and propped west edge of test assembly. Flames rolling across exposed surface; seam on exposed face between pieces of blanket that make up layer D is glowing. Only some ragged edges of silicone-impregnated glass-fiber cloth (layer E) remain in place: essentially all of exposed area of this layer is gone. Layer D was intact at the time the assembly was lifted.

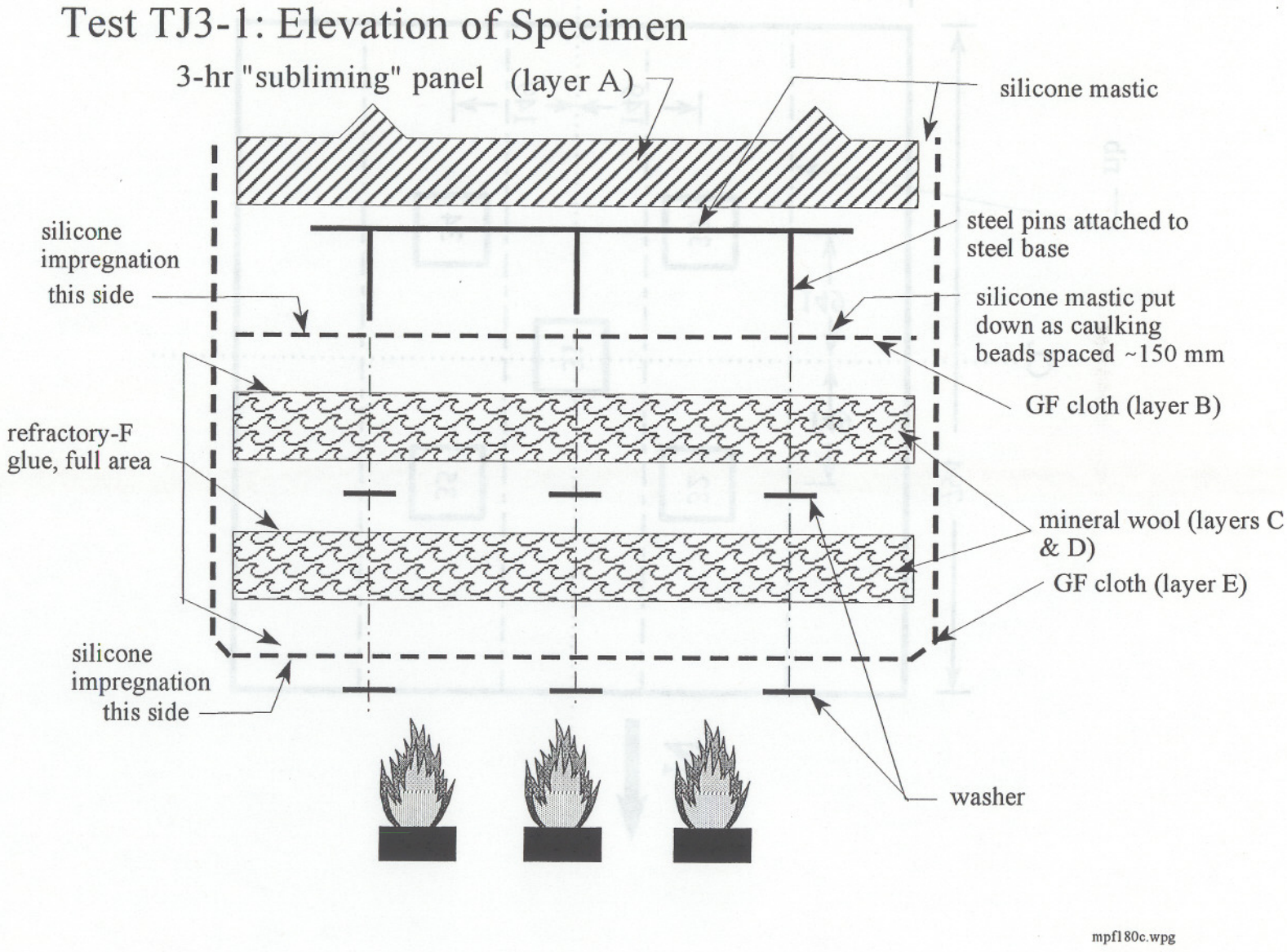


Fig. V.1. Schematic of elevation of test assembly, Test TJ3-1.

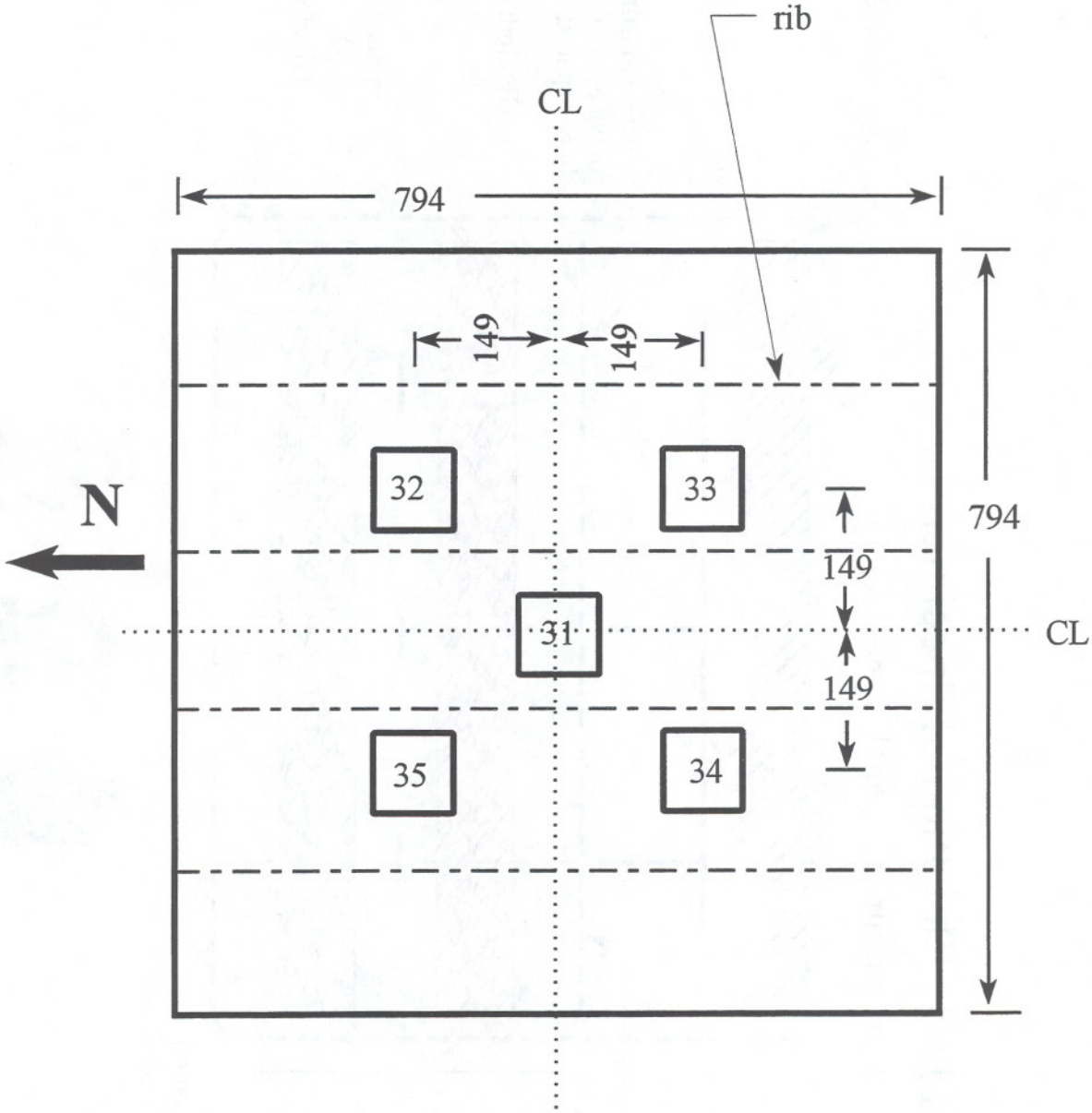
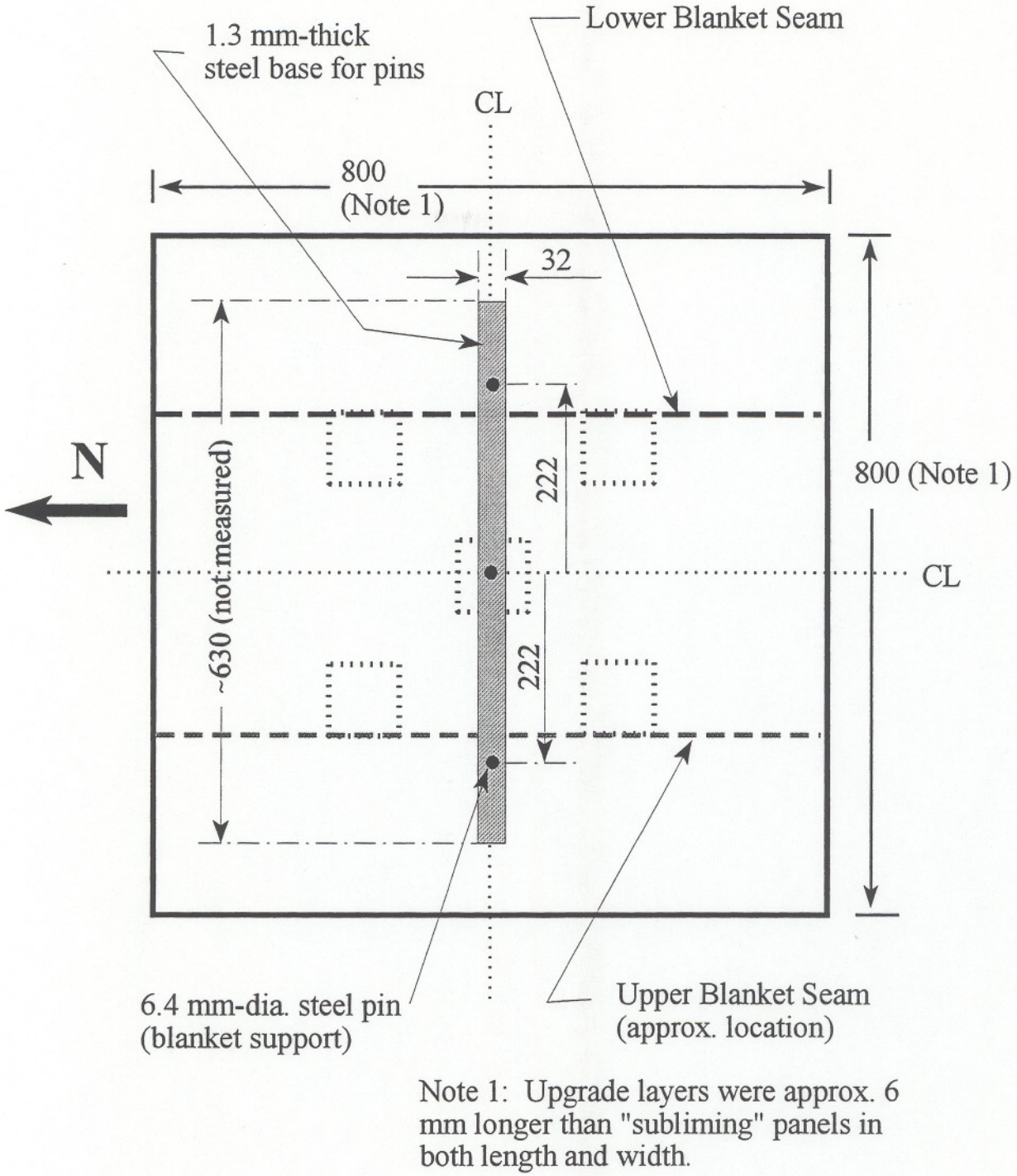


Fig. V.2. Layer dimensions, Test TJ3-1. View from above unexposed surface of layer A. All dimensions in millimeters (1 in = 25.4 mm). Numbered squares denote unexposed-surface thermocouple pads.



tj3-1.wpg

Fig. V.3 In-depth view showing locations of supporting pins and blanket seam as viewed through the unexposed surface of the test assembly, Test TJ3-1.

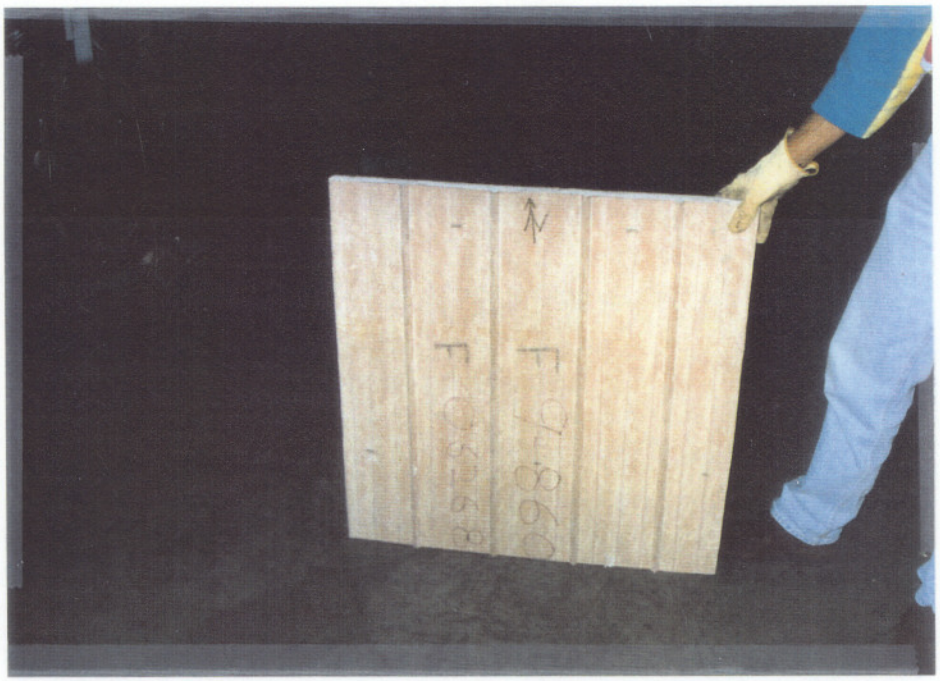


Fig. V.4. Pre-test photograph of unexposed surface, layer A, Test TJ3-1.

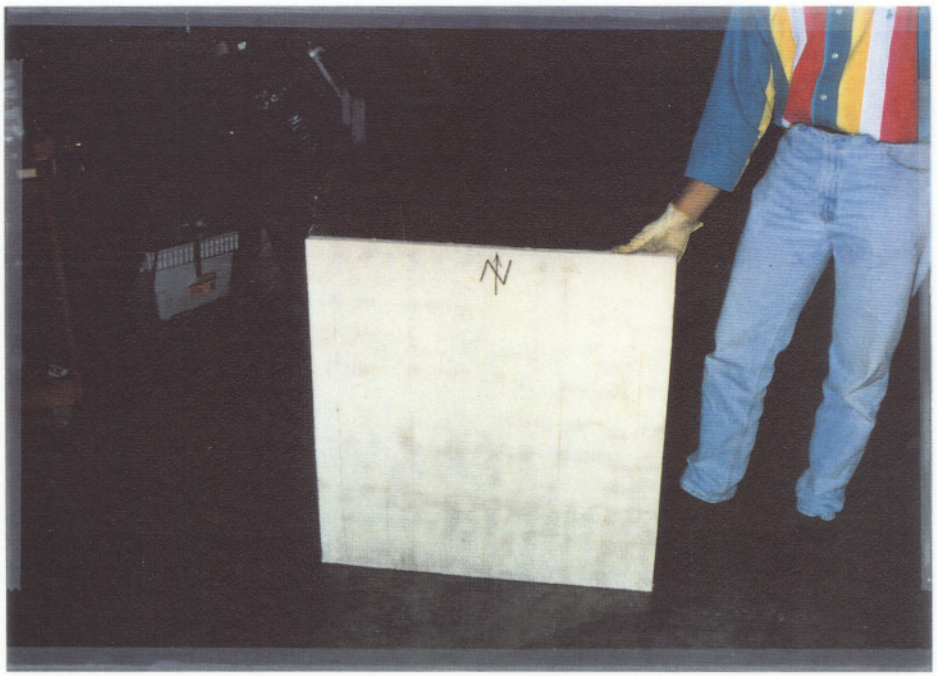


Fig. V.5. Pre-test photograph of exposed surface, layer A, Test TJ3-1.

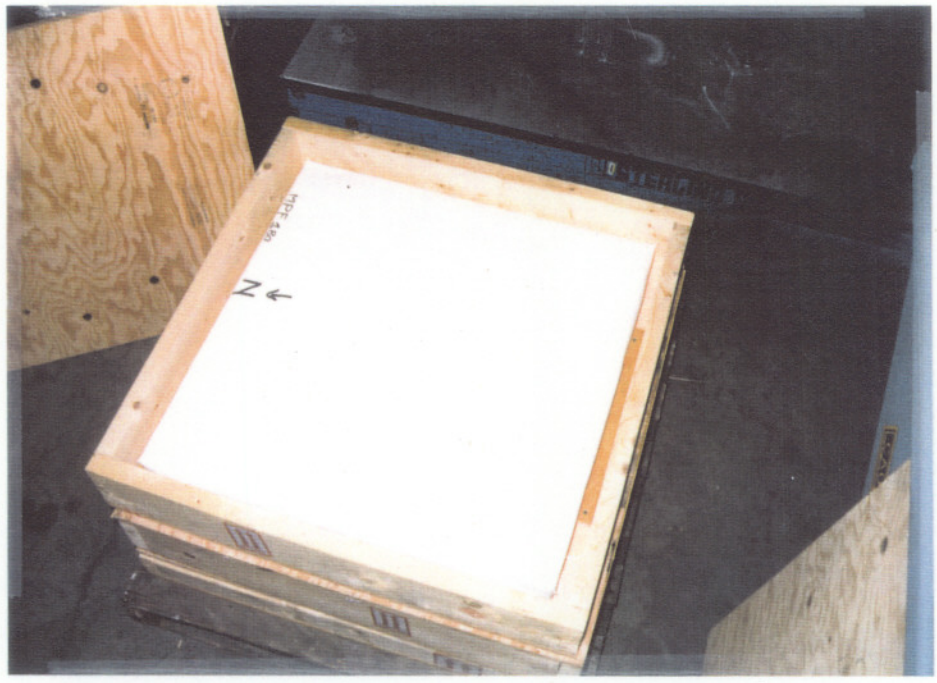


Fig. V.6. Pre-test photograph of exposed surface, layer E, Test TJ3-1.

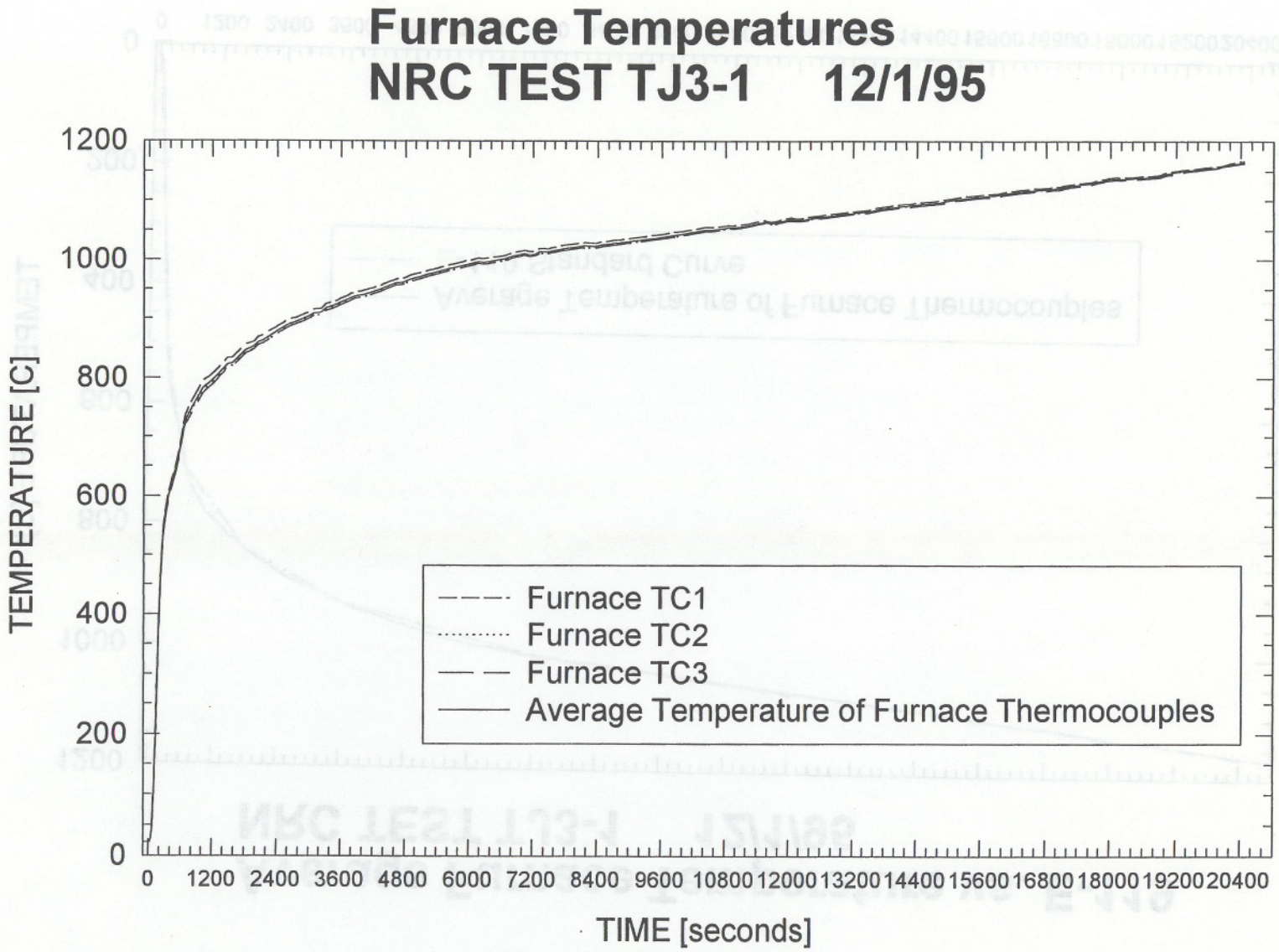


Fig. V.7 Furnace temperature, Test TJ3-1.

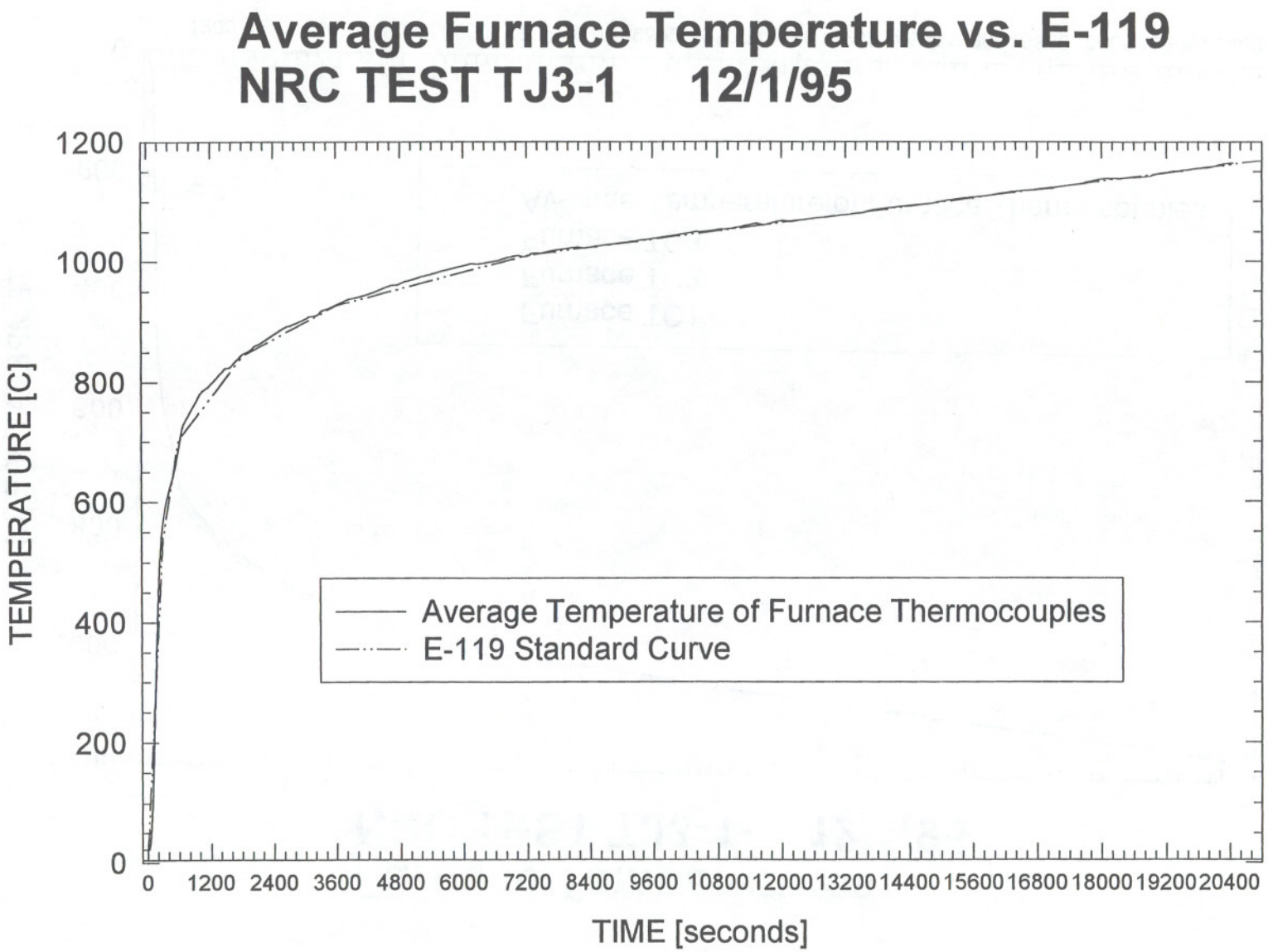


Fig. V.8. Furnace temperature, Test TJ3-1.

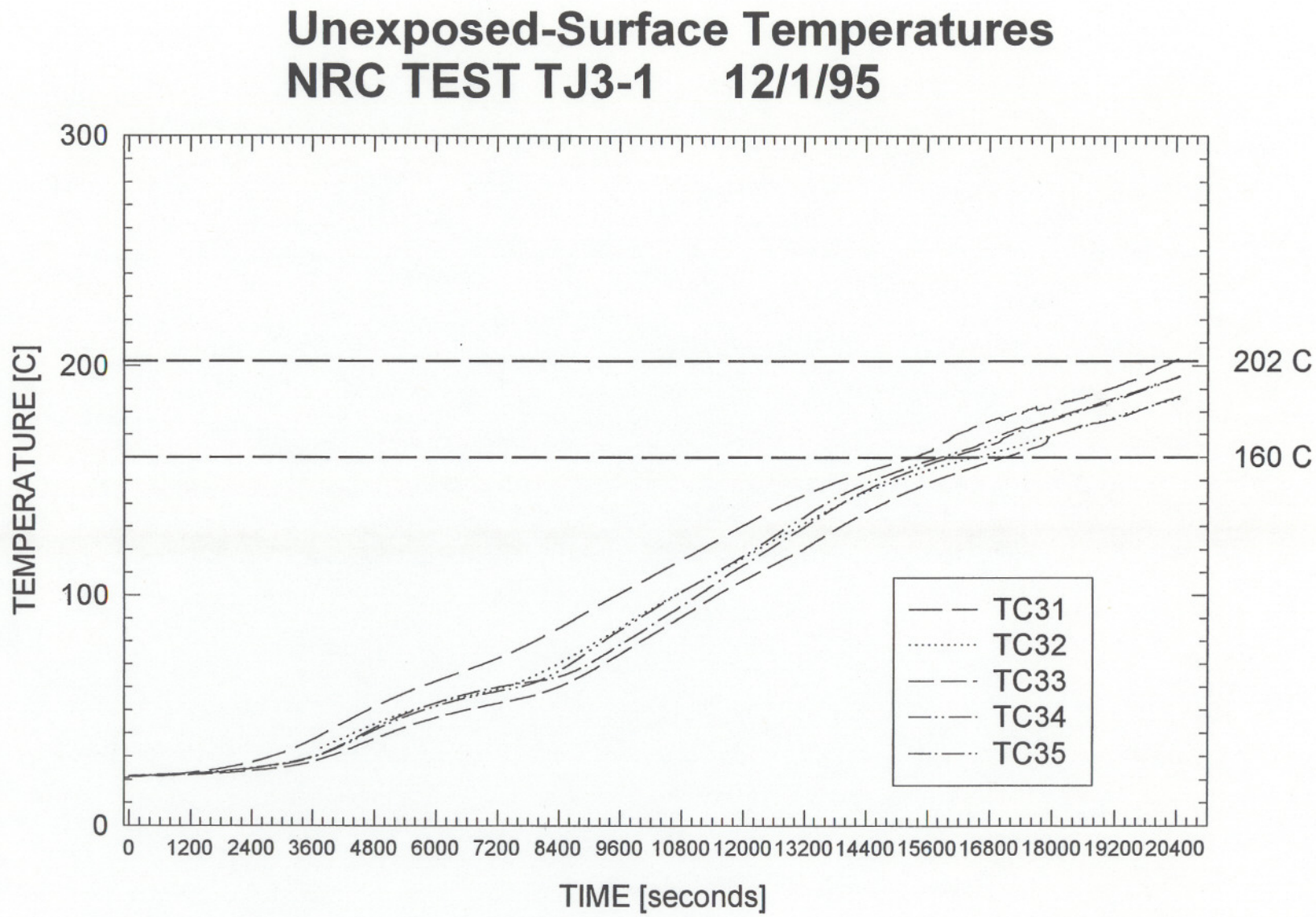


Fig. V.9. Unexposed-surface temperatures, Test TJ3-1.

Fig. V.10. Photograph of unexposed surface during Test TJ3-1.

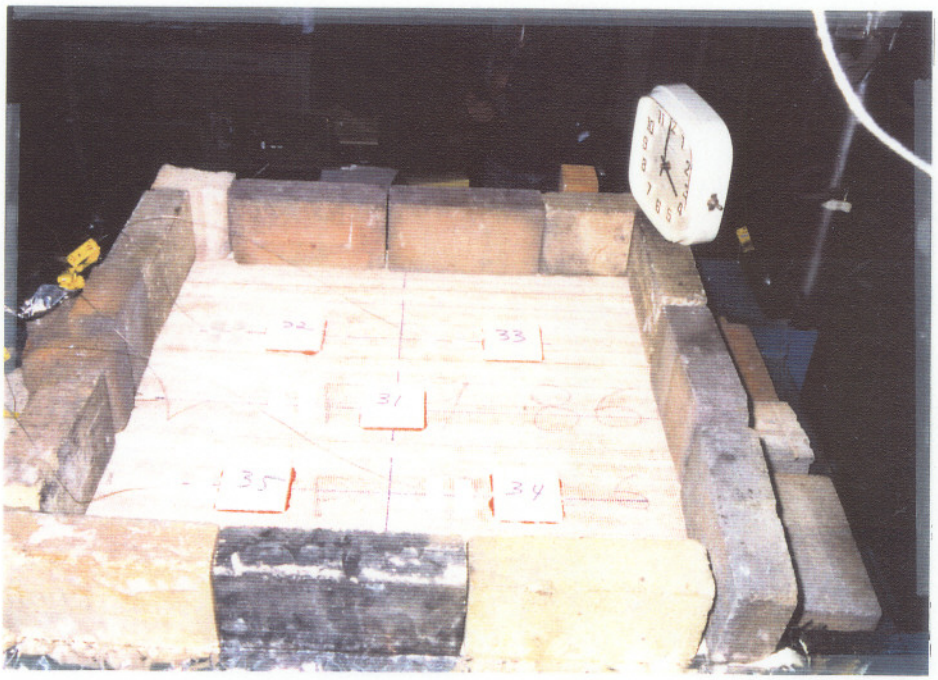


Fig. V.11. Photograph of unexposed surface during Test TJ3-1.

Fig. V.12. Photograph of unexposed surface during Test TJ3-1.

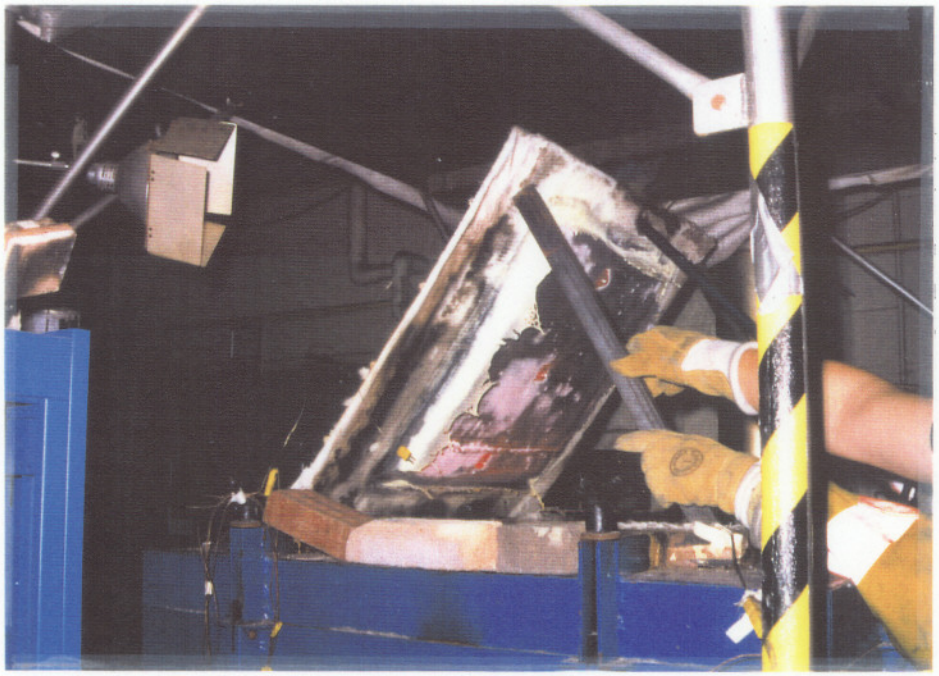


Fig. V.13. Post-test photograph of exposed surface of test assembly, Test TJ3-1.

Fig. V.14. Post-test photograph of exposed surface, layer D, Test TJ3-1.

Fig. V.15. Post-test photograph of unexposed surface, layer A, Test TJ3-1.

VI. Test TU3-1

A. Description of Test Assembly

The test assembly consisted of one layer of 3-hr "subliming" fire-barrier panel over one layer of fire-barrier blanket (flexible mat). The panel is manufactured with a "flat" face, a ribbed face, and wire mesh covering both faces. The ribbed face became the unexposed surface of the test assembly. The blanket consists of an unidentified but fairly dense material with one surface faced with nominal 2.3 cells/cm^2 (15 cell/in^2) carbon-fiber mesh and the other faced with nominal 0.16 cells/cm^2 (1 cell/in^2) carbon-fiber mesh. The surface with the 0.16 cells/cm^2 mesh became the exposed surface of the test assembly.

Both layers were cut to the dimensions shown in Fig. VI.1. The 3-hr "subliming" layer was cut from a panel labeled by the manufacturer as F9-86003 and the blanket layer was cut from a blanket labeled F95-04007.

The arrangement, designations, thicknesses, and masses of the layers were as follows:

Test TU3-1: Test Assembly			
Arrangement	Thickness in mm [in]	Pre-test Mass in kg ± 0.01 [lb ± 0.02]	Post-test Mass in kg ± 0.01 [lb ± 0.02]
layer A, 3-hr "subliming" panel	off-rib avg.= 31 [1.2] std. dev. = 2.3 [0.091] (36 measurements) rib avg.= 38 [1.5] std. dev. = 2.3 [0.091] (10 measurements)	24.16 [53.22]	22.45 [49.5]
layer B, blanket	avg.= 9 [0.4] std. dev. = 1.7 [0.067] (19 measurements)	8.65 [19.1]	

Layer B was closest to the furnace and layer A was farthest away.

Pre-test photographs of the unexposed and exposed surfaces of layers A and B are shown in Figs. VI.2 to VI.5. Layer B was attached to layer A with fourteen sheet metal screws (No. 8 x 49 mm) along the perimeter of the test assembly. Fender washers were installed beneath the heads of the perimeter screws located along the north and south edges (Fig.VI.6). The remaining screws passed through the stainless-steel flats located along the east and west edges of the assembly (Fig. VI.6). The flats served as anchor points for the stainless-steel supports described in section I.A.

After positioning the assembly on the furnace, two layers of nominal 25.4 mm (1 in) thick ceramic-fiber insulation were wrapped around its edges and the exterior of this insulation was covered with aluminum foil. The lower edge of the foil was taped to the furnace and the upper edge was taped to the unexposed surface of layer A with glass-cloth tape. Then the upper edges of the foil were loaded with bricks as

described section I.A.

B. Fire Test Procedures and Results

The test was conducted on September 11, 1995 and was witnessed by the following official observer: Patrick M. Madden (NRC).

The test assembly was subjected to a 5-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. VI.7 and tabulated in Table VI.1. The average furnace temperatures and the standard temperature-time curve are shown in Fig. VI.8.

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

Figures VI.10 to VI.12 show the unexposed surface during the test. During the first 4 hours there was no change in the appearance of the unexposed surface. At about 4:00 a few small crystals and some slight browning began to appear in the area southeast of TC pad 33 on the unexposed surface of layer A (the "subliming" panel). At 4:26 additional browning was observed southwest of TC pad 33. The discolored areas were in the region directly above the southern stainless-steel support. Neither flame passage nor glowing were observed during the test period.

A log of observations is presented in Table VI.2.

Following termination of the test, no exposed-surface flaming was observed when the west edge of the assembly was lifted and propped (Fig. VI.13). The exposed surface of layer B was severely charred, but, except for one small puncture, was intact. No debris was found at the bottom of the furnace. The assembly was allowed to cool overnight in the propped position and was removed from the furnace the following day.

The exposed surface of layer B and the unexposed surface of layer A the day after the test are shown in Figs. VI.14 and VI.15, respectively. The overall thickness of layer B was about 22 mm (0.87 in). The exposed surface of this layer was powdery for the first 10 mm (0.38 in) into the layer. The remaining thickness was composed of rigid char. The carbon-fiber mesh on the unexposed side was intact and there was an air gap of about 14 mm (0.56 in) between it and layer A.

The overall thickness of layer A was about 48 mm (1.87 in) and the wire mesh on the exposed surface was intact. In regions away from thermocouple pads, about 16 mm (0.63 in) of the thickness contained virgin material. The thermocouple pads remained attached and had to be pried off to complete inspection of the unexposed surface. Beneath the pads, the unexposed-surface colors varied from moderate to very dark brown. There was no burnthrough beneath the pads or elsewhere.

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, 22°C [72°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 during the test neither flame nor hot gases capable of igniting cotton waste held against the unexposed surface pass through the assembly. In addition to these criteria, NRC requests monitoring the time at which any of the unexposed-surface thermocouples exceeds 139°C (250°F) above the initial temperature.

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

Test TU3-1: 3-hour Test Assembly			
Condition	Location	Time	
		(sec)	[hr:min:sec]
E 119 avg. unexposed surf. temp. criterion (161°C) [322°F]		14153	[3:55:53]
E 119 peak unexposed surf. temp. criterion (203°C) [397°F]	TC33	18325	[5:05:45]
NRC unexposed surf. temp., 1st occurrence (161°C) [322°F]	TC33	13300	[3:41:40]

Concerning E 119 criteria, the average temperature was the controlling factor and the E 119 fire-endurance period was 14153 seconds (3 hours and 55.9 minutes). 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 +52 s and **the corrected fire-endurance period was 14205 s (3 hours and 56.8 minutes)**. The attendant maximum uncertainty was +457/-444 s (+7.6/-7.4 minutes) (see Appendix).

Neither flame nor hot gas passage through the unexposed face of the assembly were observed during the test. No glowing was observed at any time during the test. The post-test inspection revealed no burnthrough at the unexposed surface of the assembly.

TABLE VI.1. Temperatures (°C), Test TU3-1.

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
-120	21	21	21	21	21	21	21	21	21	21
-60	21	21	21	21	21	21	21	21	21	21
0	21	21	21	21	22	21	21	22	22	22
60	62	52	46	53	22	22	21	22	22	22
120	213	159	146	173	22	22	22	22	22	22
180	375	312	301	329	22	22	22	22	22	22
240	500	453	445	466	22	22	22	22	22	22
300	582	548	541	557	22	22	22	22	22	22
360	626	602	597	608	22	22	22	22	22	22
420	656	638	634	643	22	22	22	22	22	22
480	671	659	656	662	22	22	22	22	23	22
540	682	675	673	677	22	22	22	22	23	22
600	704	693	692	696	22	22	22	22	23	22
660	728	711	711	717	22	22	22	22	23	22
720	744	726	728	733	22	22	22	22	23	22
780	756	741	742	746	23	22	22	23	23	23
840	765	753	753	757	23	22	23	23	23	23
900	773	763	763	766	23	22	23	23	23	23
960	782	773	774	776	23	23	23	23	24	23
1020	785	779	778	781	24	23	24	24	24	24
1080	784	782	780	782	24	23	24	24	24	24
1140	787	787	785	786	25	23	25	25	24	24
1200	791	793	790	791	25	24	25	25	25	25
1260	797	798	796	797	26	24	26	26	25	25
1320	803	804	802	803	26	24	26	26	26	26
1380	808	810	809	809	27	25	27	27	26	26
1440	815	816	814	815	28	25	28	28	27	27
1500	825	821	819	822	28	26	29	28	27	28
1560	833	826	826	828	29	26	30	29	28	28
1620	833	832	831	832	30	27	31	30	29	29
1680	836	835	834	835	31	28	32	31	29	30
1740	838	840	838	839	32	28	33	32	30	31
1800	843	844	841	843	33	29	34	33	31	32
1860	847	849	847	847	34	30	35	34	32	33
1920	850	854	851	852	34	30	36	36	32	34
1980	855	857	853	855	36	31	37	37	33	35
2040	859	861	856	858	36	32	39	38	34	36
2100	862	865	860	862	37	33	40	39	35	37
2160	864	868	863	865	39	33	41	41	36	38
2220	868	869	866	868	40	34	42	42	37	39
2280	872	872	867	870	41	35	44	43	38	40
2340	874	875	870	873	42	36	45	44	38	41
2400	877	878	874	876	43	37	46	46	39	42
2460	877	880	877	878	44	38	47	47	40	43
2520	877	882	879	879	45	39	49	48	41	44
2580	881	885	884	883	46	40	50	49	42	46
2640	885	889	888	888	47	42	51	51	43	47

TEST: NRC TU3-1 9/11/95

TABLE VI.1. Temperatures (°C), Test TU3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
2700	889	893	891	891	48	43	52	52	44	48
2760	892	896	895	894	49	44	53	53	45	49
2820	895	899	898	897	50	45	54	54	46	50
2880	898	902	900	900	51	46	56	55	47	51
2940	901	905	903	903	52	47	57	56	48	52
3000	904	908	906	906	53	48	58	57	49	53
3060	906	910	908	908	54	49	59	58	50	54
3120	907	912	909	909	55	50	60	59	51	55
3180	909	913	911	911	56	51	61	60	52	56
3240	911	916	913	914	57	52	62	61	53	57
3300	914	918	916	916	58	53	63	62	54	58
3360	917	920	918	918	59	54	64	63	55	59
3420	921	921	920	921	60	55	65	64	56	60
3480	923	923	922	923	61	56	66	65	56	61
3540	924	926	925	925	62	57	66	66	57	62
3600	927	928	927	927	63	58	67	67	58	63
3660	930	929	927	929	64	59	68	68	59	64
3720	932	931	929	931	65	60	69	69	60	65
3780	934	934	932	933	66	61	70	70	61	66
3840	935	935	933	934	66	62	71	71	62	67
3900	938	937	936	937	67	63	72	72	63	67
3960	940	939	937	939	68	64	73	73	64	68
4020	943	941	939	941	69	65	74	74	65	69
4080	945	943	941	943	70	66	75	74	66	70
4140	947	945	942	944	71	67	76	75	67	71
4200	946	945	944	945	72	67	76	76	68	72
4260	947	946	945	946	73	68	77	77	68	73
4320	947	947	946	946	73	69	78	78	69	73
4380	949	948	946	947	74	70	79	79	70	74
4440	951	950	948	950	75	71	80	79	71	75
4500	952	952	949	951	76	71	81	80	72	76
4560	954	953	950	952	77	72	81	81	73	77
4620	957	956	952	955	77	73	82	82	73	78
4680	960	958	955	958	78	74	83	82	74	78
4740	963	960	957	960	79	75	84	83	75	79
4800	965	962	959	962	80	75	85	84	76	80
4860	967	966	961	965	80	76	85	85	76	81
4920	969	968	963	967	81	77	86	85	77	81
4980	971	969	965	968	82	78	87	86	78	82
5040	972	971	966	970	82	78	88	87	79	83
5100	974	973	968	972	83	79	88	88	79	83
5160	976	976	970	974	84	80	89	88	80	84
5220	978	977	971	975	85	80	90	89	81	85
5280	979	977	973	976	85	81	91	90	81	86
5340	980	980	974	978	86	82	92	90	82	86
5400	982	981	978	980	87	82	92	91	83	87
5460	984	982	978	981	87	83	93	92	83	88

TEST: NRC TU3-1 9/11/95

TABLE VI.1. Temperatures (°C), Test TU3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
5520	984	983	978	982	88	83	94	92	84	88
5580	986	984	980	983	89	84	94	93	85	89
5640	988	985	981	985	89	85	95	94	85	90
5700	989	987	983	986	90	85	95	94	86	90
5760	992	987	985	988	90	86	96	95	87	91
5820	993	989	987	990	91	87	97	96	87	91
5880	995	990	989	991	92	87	97	96	88	92
5940	995	992	989	992	92	88	98	97	88	93
6000	997	992	990	993	93	88	99	98	89	93
6060	997	993	991	994	94	89	99	98	90	94
6120	998	994	992	995	94	89	100	99	90	95
6180	999	995	993	996	95	90	100	99	91	95
6240	1000	996	994	997	95	91	101	100	91	96
6300	1001	997	995	998	96	91	102	101	92	96
6360	1002	998	996	999	97	92	102	101	93	97
6420	1003	998	998	1000	97	92	103	102	93	97
6480	1003	999	998	1000	98	93	103	103	94	98
6540	1002	1000	999	1000	99	93	104	103	94	99
6600	1003	1000	1000	1001	99	94	105	104	95	99
6660	1004	1001	1000	1002	100	94	105	104	95	100
6720	1006	1002	1002	1003	100	95	106	105	96	100
6780	1006	1003	1002	1004	101	95	107	105	96	101
6840	1006	1004	1003	1005	101	96	107	106	97	102
6900	1008	1005	1004	1006	102	96	108	107	97	102
6960	1009	1005	1004	1006	102	97	109	107	98	103
7020	1010	1006	1006	1007	103	97	109	108	98	103
7080	1010	1007	1006	1008	104	98	110	108	99	104
7140	1011	1008	1007	1009	104	98	111	109	99	104
7200	1013	1008	1008	1010	105	99	111	109	100	105
7260	1014	1009	1009	1011	105	99	112	110	100	105
7320	1015	1010	1010	1012	106	100	112	111	101	106
7380	1016	1011	1010	1012	107	100	113	111	101	106
7440	1017	1012	1012	1014	107	101	114	112	102	107
7500	1018	1013	1012	1014	108	101	114	112	103	108
7560	1019	1014	1014	1016	108	102	115	113	103	108
7620	1020	1014	1014	1016	109	102	116	114	104	109
7680	1022	1016	1015	1018	109	103	116	114	104	109
7740	1022	1017	1017	1018	110	103	117	115	104	110
7800	1023	1017	1017	1019	110	104	118	115	105	110
7860	1024	1019	1018	1020	111	104	118	116	106	111
7920	1025	1020	1019	1021	112	105	119	116	106	112
7980	1026	1020	1020	1022	112	105	120	117	107	112
8040	1026	1019	1019	1022	113	106	120	118	107	113
8100	1025	1019	1020	1021	114	106	121	118	108	113
8160	1026	1021	1021	1023	114	107	122	119	108	114
8220	1026	1022	1022	1023	115	107	122	119	109	115
8280	1026	1023	1023	1024	115	108	123	120	109	115

TEST: NRC TU3-1 9/11/95

TABLE VI.1. Temperatures (°C), Test TU3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
8340	1027	1022	1022	1023	116	109	124	121	110	116
8400	1029	1023	1023	1025	117	109	124	121	110	116
8460	1029	1023	1023	1025	117	110	125	122	111	117
8520	1030	1024	1024	1026	118	110	126	122	111	117
8580	1031	1026	1025	1027	118	111	126	123	112	118
8640	1033	1026	1026	1028	119	111	127	124	112	119
8700	1033	1027	1027	1029	120	112	128	124	113	119
8760	1033	1027	1027	1029	120	112	128	125	113	120
8820	1034	1028	1028	1030	121	113	129	126	114	120
8880	1034	1029	1029	1031	121	113	130	126	114	121
8940	1035	1029	1029	1031	122	114	130	127	115	122
9000	1036	1029	1030	1032	123	114	131	127	115	122
9060	1036	1031	1031	1033	123	115	131	128	116	123
9120	1038	1032	1032	1034	124	115	132	129	116	123
9180	1038	1032	1032	1034	124	115	133	129	117	124
9240	1038	1032	1032	1034	125	116	133	130	117	124
9300	1039	1032	1032	1034	126	117	134	131	118	125
9360	1039	1033	1033	1035	126	117	134	131	118	125
9420	1040	1034	1034	1036	127	117	135	132	119	126
9480	1041	1035	1035	1037	128	118	136	132	119	127
9540	1041	1035	1035	1037	128	118	136	133	120	127
9600	1042	1036	1036	1038	129	119	137	134	120	128
9660	1042	1036	1036	1038	129	120	137	134	121	128
9720	1043	1037	1037	1039	130	120	138	135	121	129
9780	1043	1037	1037	1039	131	121	138	135	122	129
9840	1043	1037	1037	1039	131	121	139	136	122	130
9900	1045	1039	1039	1041	132	122	139	137	123	131
9960	1045	1040	1040	1042	133	122	140	137	124	131
10020	1045	1039	1039	1041	133	123	140	138	124	132
10080	1045	1040	1040	1042	134	124	141	138	125	132
10140	1046	1041	1041	1043	134	124	141	139	125	133
10200	1047	1043	1042	1044	135	125	142	140	126	133
10260	1048	1044	1044	1045	136	125	142	140	126	134
10320	1050	1045	1045	1046	136	126	143	141	127	134
10380	1051	1046	1046	1048	137	127	143	141	128	135
10440	1052	1047	1047	1049	137	127	144	142	128	136
10500	1053	1048	1048	1050	138	128	144	142	129	136
10560	1053	1049	1048	1050	138	128	145	143	129	137
10620	1054	1049	1049	1051	139	129	145	143	130	137
10680	1055	1050	1050	1051	139	130	145	144	130	138
10740	1055	1051	1050	1052	140	130	146	144	131	138
10800	1056	1051	1051	1053	140	131	146	145	131	139
10860	1056	1052	1051	1053	141	131	147	145	132	139
10920	1057	1052	1052	1054	141	132	147	146	133	140
10980	1057	1053	1053	1054	142	132	147	146	133	140
11040	1058	1054	1053	1055	143	133	148	147	134	141
11100	1059	1054	1054	1055	143	134	148	147	134	141

TABLE VI.1. Temperatures (°C), Test TU3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
11160	1059	1055	1054	1056	143	134	149	147	135	142
11220	1060	1056	1055	1057	144	135	149	148	135	142
11280	1061	1056	1056	1057	144	135	149	148	136	143
11340	1061	1057	1056	1058	145	136	150	149	136	143
11400	1060	1057	1056	1058	145	136	150	149	137	144
11460	1061	1057	1057	1059	146	137	150	150	137	144
11520	1062	1058	1058	1059	146	137	151	150	138	144
11580	1063	1059	1058	1060	147	138	151	150	138	145
11640	1064	1061	1059	1061	147	138	151	151	139	145
11700	1065	1062	1061	1063	147	139	152	151	139	146
11760	1067	1064	1062	1064	148	140	152	152	140	146
11820	1068	1064	1063	1065	148	140	152	152	140	147
11880	1068	1065	1063	1065	149	140	153	152	141	147
11940	1069	1066	1064	1066	149	141	153	153	141	147
12000	1070	1067	1065	1067	149	141	153	153	142	148
12060	1070	1068	1066	1068	150	142	154	153	142	148
12120	1071	1069	1066	1069	150	142	154	154	143	149
12180	1072	1069	1067	1070	150	143	154	154	143	149
12240	1073	1070	1068	1070	151	143	155	155	144	149
12300	1073	1071	1069	1071	151	144	155	155	144	150
12360	1074	1071	1070	1072	151	144	155	155	144	150
12420	1075	1071	1070	1072	152	145	156	156	145	151
12480	1075	1072	1070	1073	152	145	156	156	145	151
12540	1075	1073	1071	1073	152	145	157	156	146	151
12600	1076	1073	1072	1074	153	146	157	157	146	152
12660	1077	1074	1072	1074	153	146	157	157	147	152
12720	1077	1075	1073	1075	153	147	158	157	147	152
12780	1078	1075	1073	1075	154	147	158	158	147	153
12840	1078	1075	1074	1076	154	147	158	158	148	153
12900	1079	1076	1074	1076	154	148	159	158	148	153
12960	1079	1076	1075	1077	154	148	159	159	148	154
13020	1080	1077	1076	1077	155	148	160	159	149	154
13080	1080	1077	1076	1078	155	149	160	159	149	155
13140	1081	1078	1076	1078	155	149	160	160	149	155
13200	1081	1078	1076	1079	156	150	161	160	150	155
13260	1082	1079	1077	1079	156	150	161	160	150	156
13320	1082	1079	1078	1080	156	150	162	161	151	156
13380	1082	1080	1078	1080	157	151	162	161	151	156
13440	1084	1081	1079	1081	157	151	163	162	151	157
13500	1085	1082	1080	1083	157	152	163	162	152	157
13560	1086	1083	1081	1083	158	152	163	162	152	157
13620	1087	1084	1082	1084	158	152	164	163	152	158
13680	1088	1085	1083	1085	158	153	165	163	153	158
13740	1088	1085	1083	1086	158	153	165	164	153	159
13800	1089	1086	1084	1086	159	153	166	164	153	159
13860	1089	1086	1084	1086	159	154	166	165	154	159
13920	1090	1087	1085	1087	159	154	167	165	154	160

TABLE VI.1. Temperatures (°C), Test TU3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
13980	1090	1087	1085	1088	160	154	167	166	155	160
14040	1091	1088	1086	1088	160	155	168	166	155	161
14100	1091	1088	1087	1089	160	155	168	167	155	161
14160	1092	1089	1087	1089	161	155	169	167	155	162
14220	1092	1089	1087	1089	161	156	170	168	156	162
14280	1093	1090	1088	1090	161	156	170	168	156	163
14340	1093	1090	1088	1091	162	157	172	169	157	163
14400	1094	1091	1089	1091	162	157	173	169	157	164
14460	1095	1092	1090	1092	162	157	173	170	157	164
14520	1095	1092	1090	1093	163	158	174	171	158	164
14580	1096	1093	1091	1093	163	158	174	171	158	165
14640	1097	1093	1091	1094	164	158	175	171	158	165
14700	1098	1094	1092	1095	164	159	175	172	159	166
14760	1098	1094	1093	1095	164	159	176	172	159	166
14820	1099	1096	1094	1097	165	159	176	173	159	166
14880	1101	1098	1096	1098	165	160	177	173	160	167
14940	1102	1099	1097	1099	166	160	177	174	160	167
15000	1103	1099	1097	1100	166	160	177	174	160	168
15060	1104	1100	1098	1101	167	161	178	175	161	168
15120	1104	1101	1099	1102	167	161	178	175	161	168
15180	1105	1101	1100	1102	168	162	178	175	161	169
15240	1105	1102	1100	1103	168	162	179	176	162	169
15300	1106	1103	1101	1103	169	163	179	175	162	170
15360	1107	1103	1101	1104	169	163	180	175	162	170
15420	1108	1104	1102	1105	170	164	180	176	163	170
15480	1109	1106	1104	1106	170	165	181	176	163	171
15540	1110	1107	1105	1107	171	165	181	177	164	171
15600	1111	1107	1106	1108	171	166	181	177	164	172
15660	1112	1108	1107	1109	171	166	181	177	165	172
15720	1113	1109	1107	1110	172	167	182	178	165	173
15780	1114	1110	1108	1111	172	167	182	178	166	173
15840	1114	1111	1109	1111	173	168	183	179	166	174
15900	1115	1111	1109	1112	173	168	183	179	167	174
15960	1115	1112	1110	1112	173	169	183	179	167	174
16020	1116	1112	1110	1113	174	170	184	180	168	175
16080	1116	1112	1111	1113	174	170	184	180	168	175
16140	1117	1113	1111	1114	175	171	185	181	169	176
16200	1118	1114	1112	1115	175	171	185	181	169	176
16260	1118	1114	1112	1115	175	171	186	182	169	177
16320	1118	1115	1113	1115	176	172	186	182	170	177
16380	1119	1115	1113	1116	176	172	187	182	170	178
16440	1119	1115	1114	1116	177	173	187	183	171	178
16500	1119	1116	1114	1116	177	173	187	183	171	178
16560	1120	1116	1115	1117	177	173	188	184	171	179
16620	1122	1119	1117	1119	177	174	188	184	172	179
16680	1124	1120	1119	1121	177	174	189	185	172	179
16740	1125	1121	1119	1122	177	174	189	185	172	180

TEST: NRC TU3-1 9/11/95

TABLE VI.1. Temperatures (°C), Test TU3-1 (cont.).

TIME [s]	TC1	TC2	TC3	AVG [C]	TC31	TC32	TC33	TC34	TC35	AVG [C]
16800	1125	1122	1120	1122	178	175	190	185	173	180
16860	1125	1122	1120	1122	178	175	190	186	173	181
16920	1126	1122	1120	1123	178	175	191	186	173	181
16980	1126	1123	1121	1123	179	176	191	187	174	181
17040	1127	1123	1122	1124	179	176	192	187	174	182
17100	1128	1124	1122	1125	180	176	193	188	174	182
17160	1128	1125	1123	1125	180	177	193	188	175	183
17220	1128	1125	1123	1125	181	177	193	189	175	183
17280	1129	1125	1124	1126	181	177	194	189	175	183
17340	1130	1126	1124	1127	182	178	194	190	176	184
17400	1130	1126	1124	1127	182	178	195	190	176	184
17460	1131	1128	1126	1129	182	179	195	190	176	185
17520	1133	1129	1128	1130	183	179	196	191	177	185
17580	1134	1131	1129	1131	183	179	197	191	177	185
17640	1135	1131	1130	1132	183	180	197	191	177	186
17700	1137	1133	1132	1134	184	180	198	192	178	186
17760	1137	1133	1133	1134	184	181	198	192	178	187
17820	1138	1134	1133	1135	185	181	198	193	178	187
17880	–	–	–	–	–	–	–	–	–	–
17940	1139	1135	1134	1136	185	182	200	194	179	188
18000	1140	1136	1136	1137	186	182	201	194	179	188
18060	1141	1137	1136	1138	186	183	201	195	180	189
18120	1141	1137	1136	1138	187	183	202	195	180	189
18180	1141	1138	1137	1139	187	183	202	196	181	190
18240	1141	1137	1136	1138	188	184	203	196	181	190
18300	1141	1138	1136	1139	188	184	203	197	181	191
18360	1143	1139	1138	1140	189	185	204	197	182	191
18420	1144	1140	1139	1141	189	185	204	198	182	192
18480	1145	1141	1140	1142	190	185	205	198	182	192
18540	1145	1142	1141	1143	190	186	205	199	183	192
18600	1146	1142	1141	1143	190	186	206	199	183	193

TABLE VI.2. Observations, Test TU3-1.

The following observations were made during and after the test:

Time	
0:30:00	No change in the appearance of the unexposed surface.
0:53:00	Some outgassing along the east edge of the aluminum foil.
2:00:00	No change in the appearance of the unexposed surface.
2:30:00	No change.
3:00:00	No change.
3:30:00	Increased outgassing along edges.
4:00:00	A few crystals visible and slight browning in the area S.E. of TC pad 33.
4:26:00	Browning occurring S.W. of TC pad 33.
4:57:00	Computer (data acquisition system) shut down to avoid automatic shutdown at 5:00:00.
4:59:00	Computer restarted.
5:10:00	Furnace shutdown. Brown spots at the two locations mentioned earlier.
approx 5:20	Lifted and propped west edge of assembly. West edge ignited but no flaming on exposed surface.

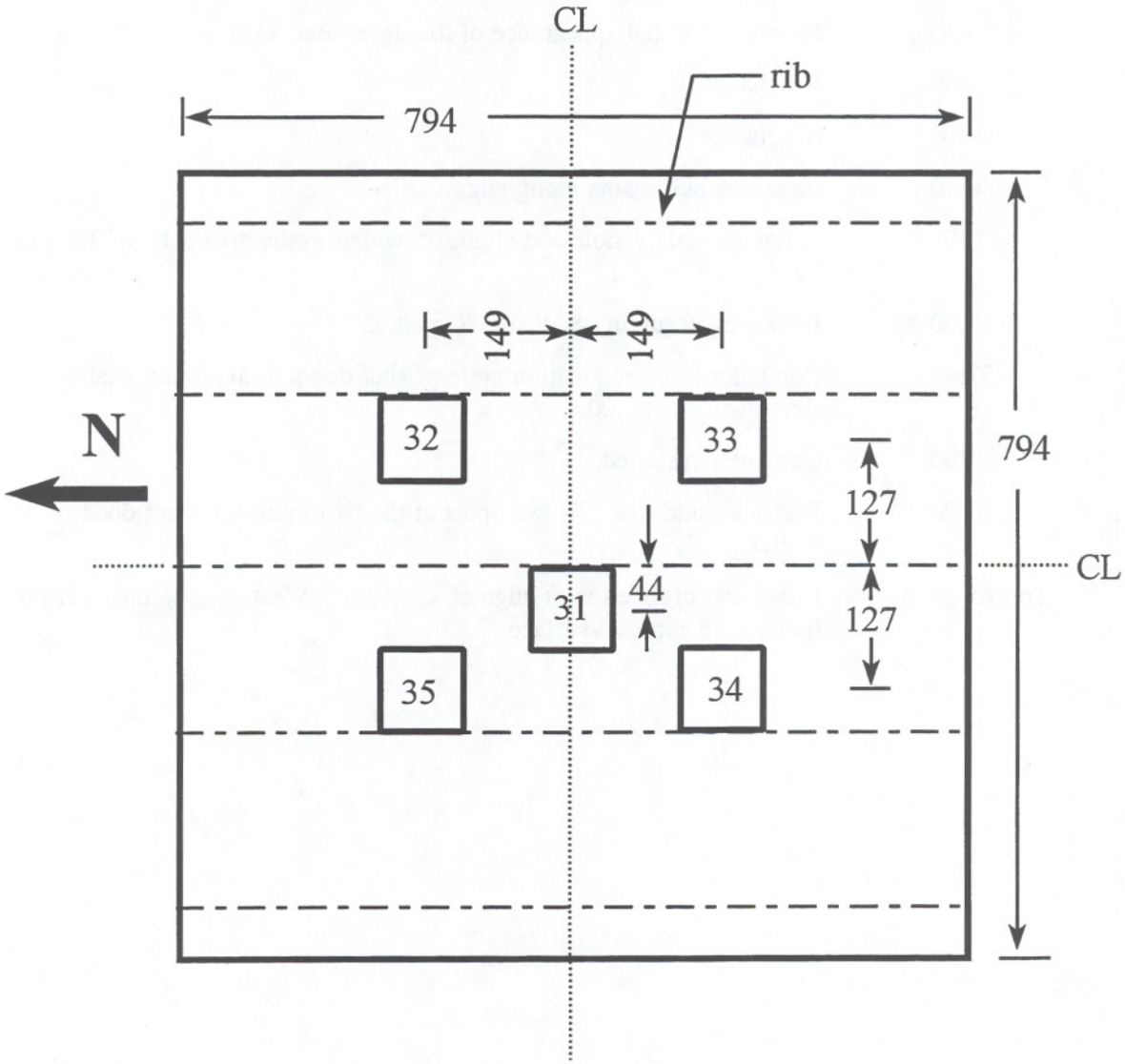


Fig. VI.1. Layer dimensions, Test TU3-1. All dimensions in millimeters (1 in = 25.4 mm). Numbered squares denote unexposed-surface thermocouple pads.

Fig. VI.2. Pre-test photograph of unexposed surface, layer A, Test TU3-1.

Fig. VI.3 Pre-test photograph of exposed surface, layer A, Test TU3-1.

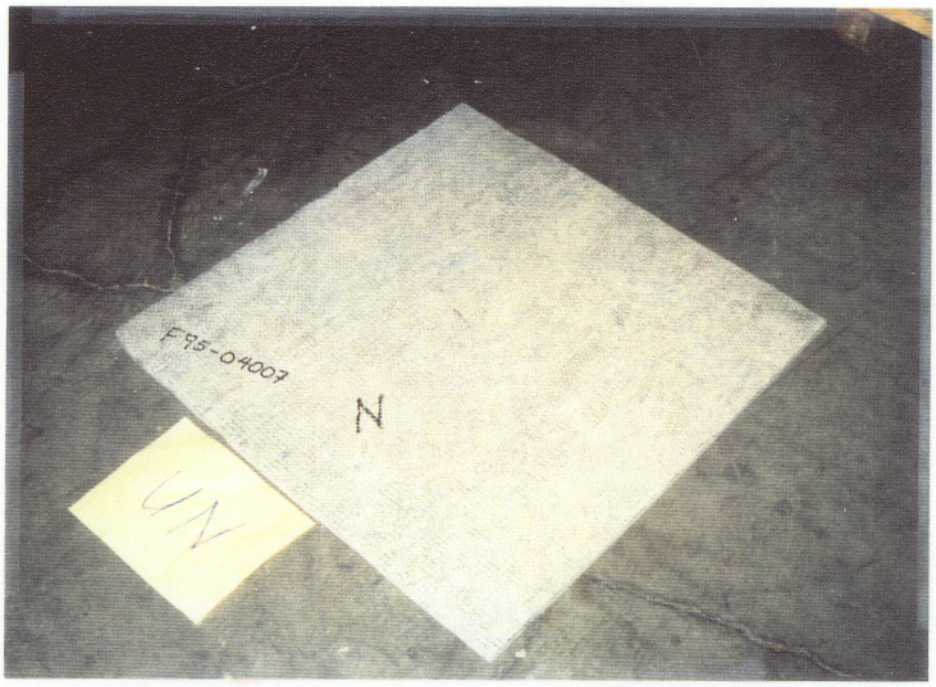


Fig. VI.4. Pre-test photograph of unexposed surface, layer B, Test TU3-1.

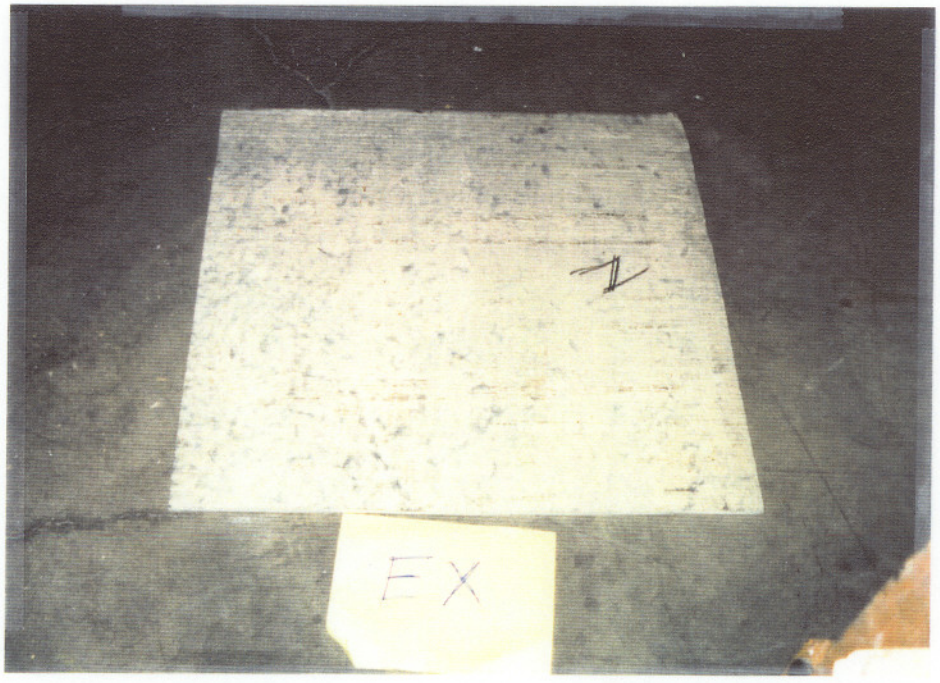


Fig. VI.5 Pre-test photograph of exposed surface, layer B, Test TU3-1.

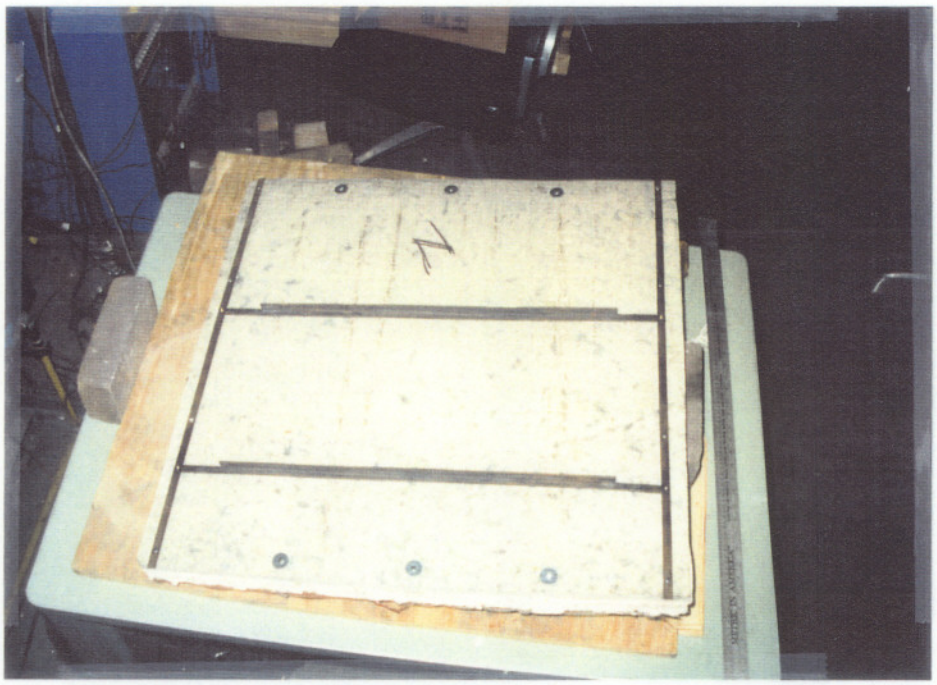


Fig. VI.6. Pre-test photograph of exposed surface, layer B, showing perimeter screws with fender washers on north and south edges and with stainless steel flats on east and west edges; Test TU3-1.

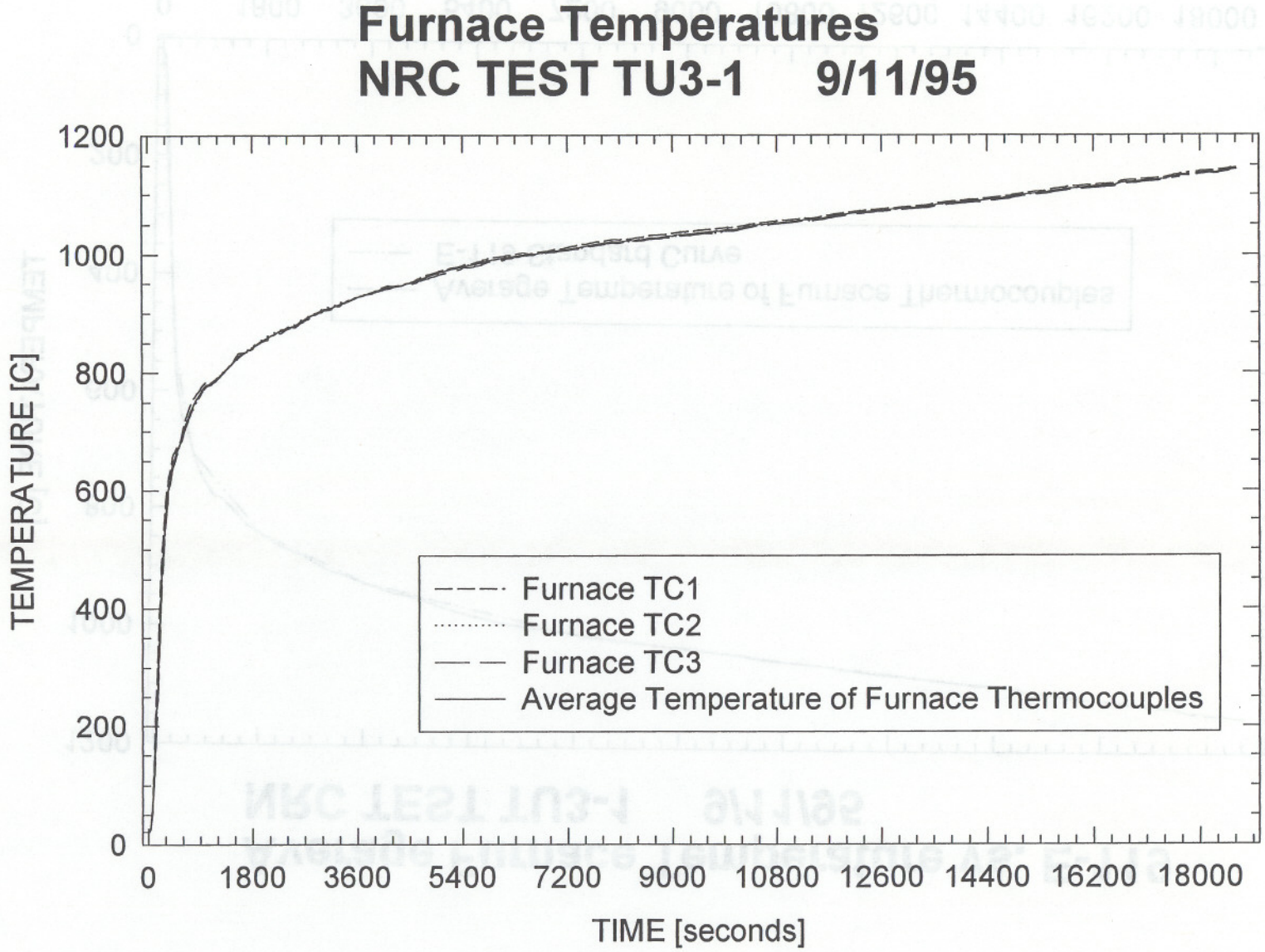


Fig. VI.7. Furnace temperature, Test TU3-1.

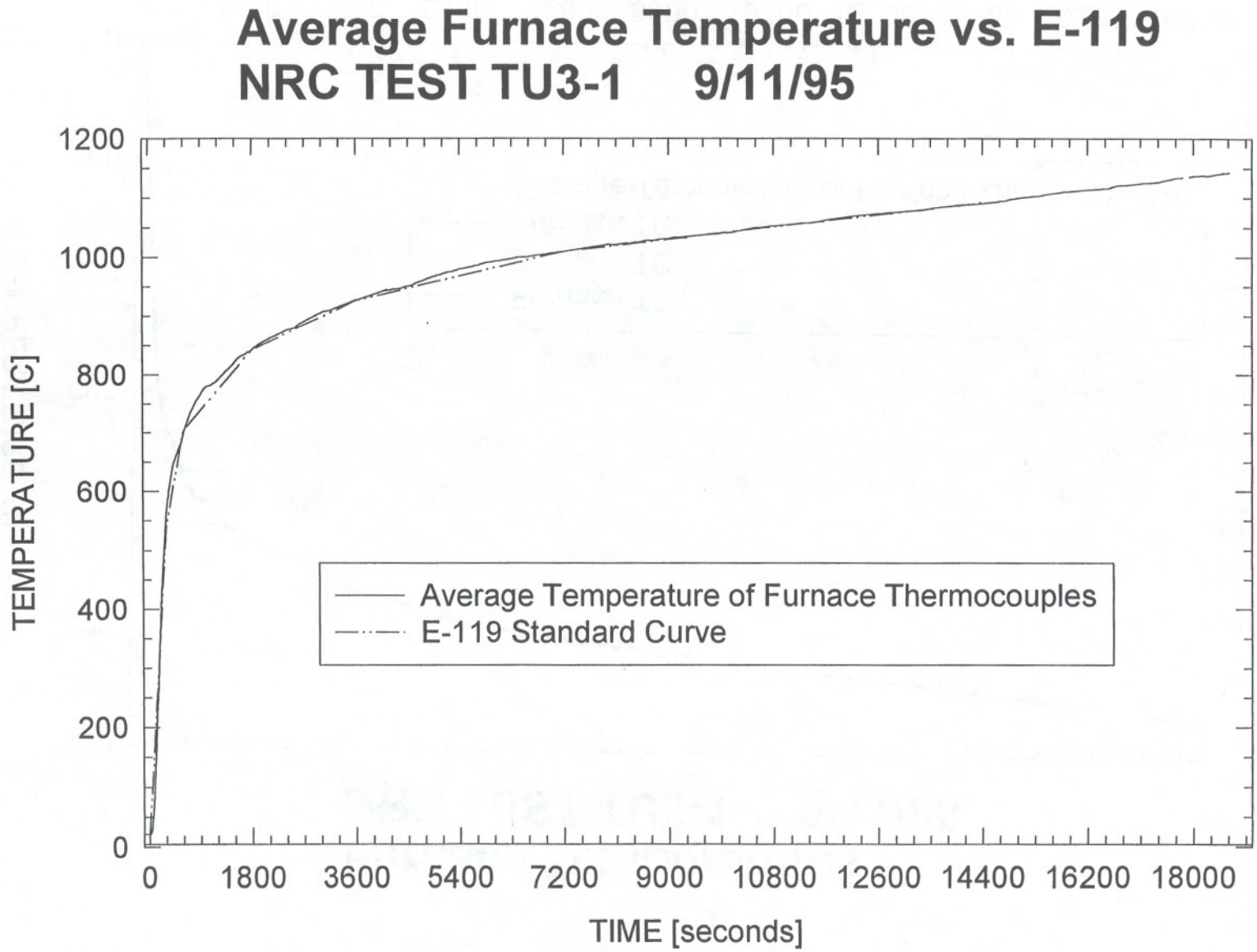


Fig. VI.8. Furnace temperature, Test TU3-1.

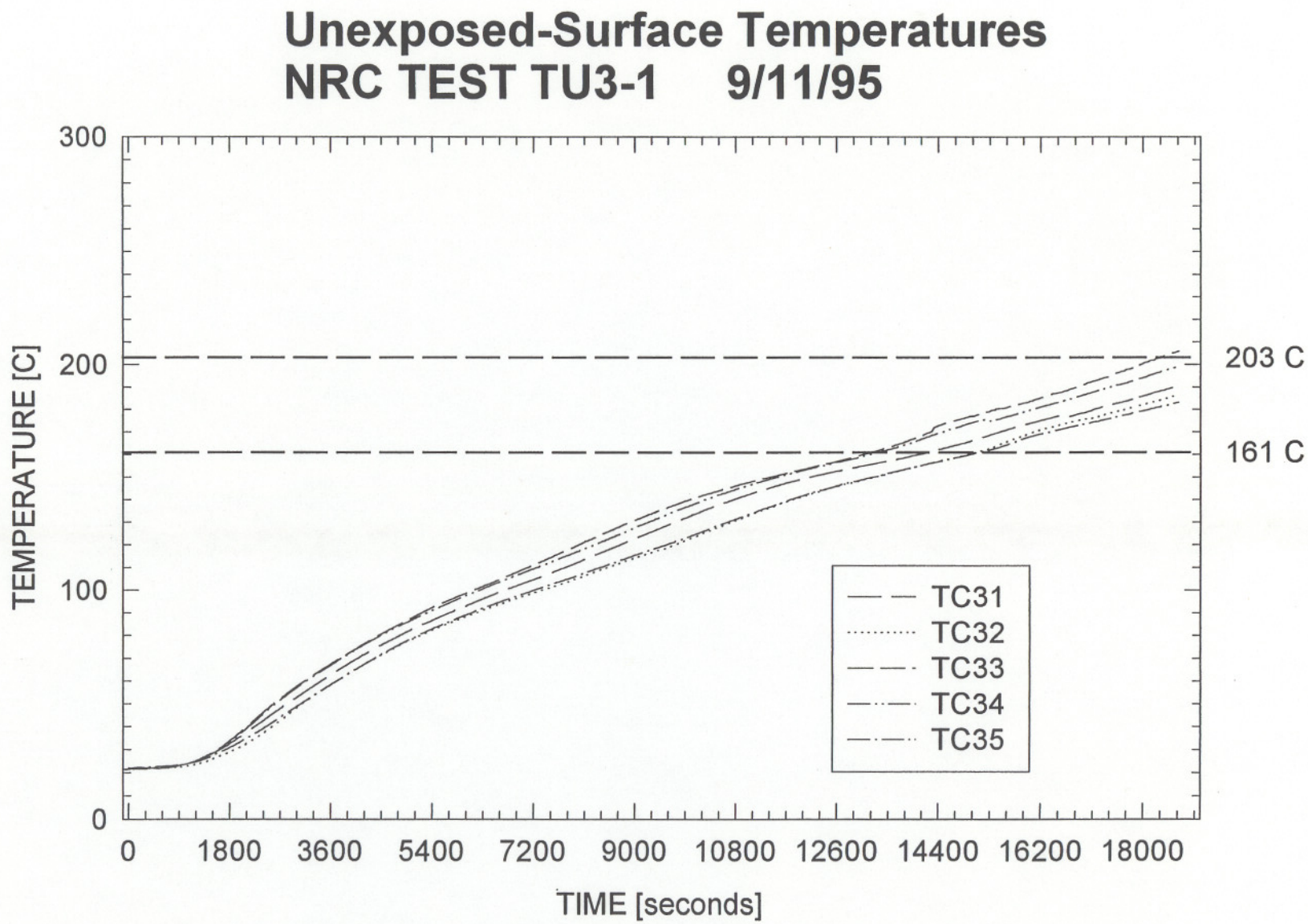


Fig. VI.9. Unexposed-surface temperatures, Test TU3-1.

Fig. VI.10. Photograph of unexposed surface during Test TU3-1.

Fig. VI.11. Photograph of unexposed surface during Test TU3-1.

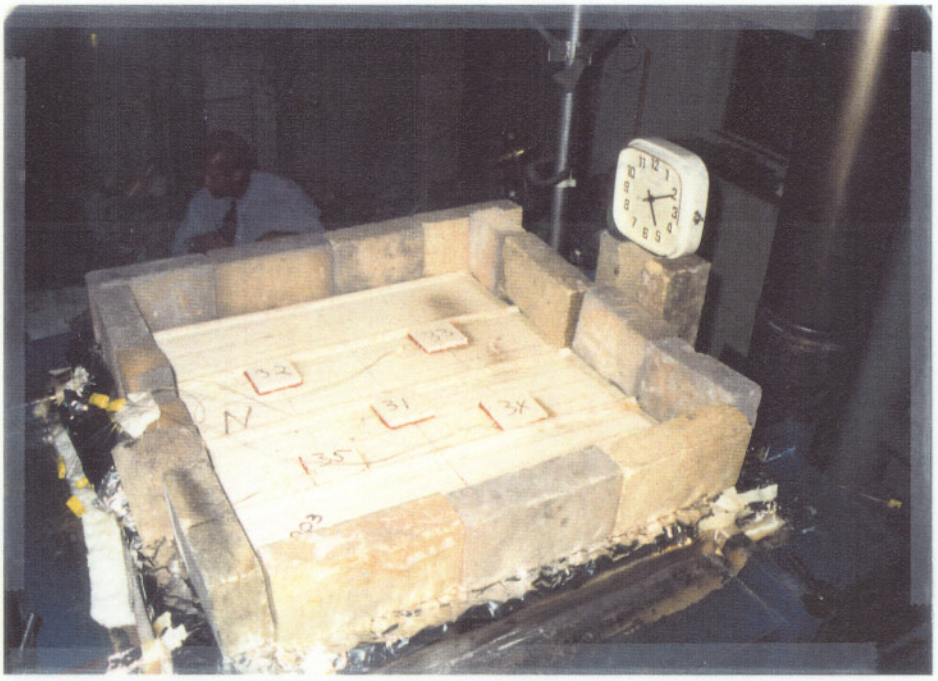


Fig. VI.12. Photograph of unexposed surface during Test TU3-1.

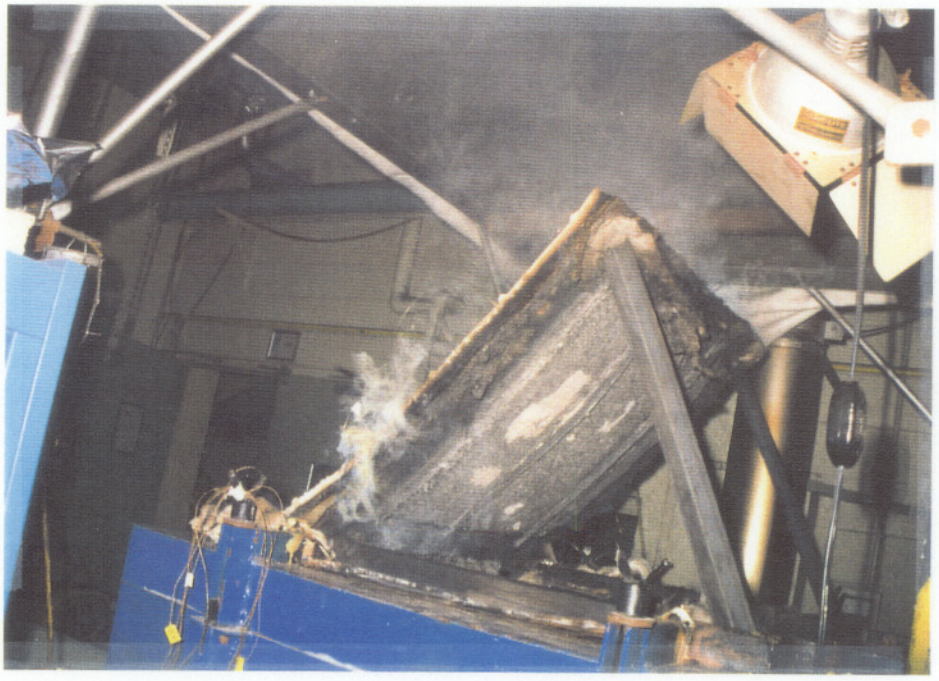


Fig. VI.13. Post-test photograph of exposed surface, layer B, Test TU3-1.

Fig. VI.14. Post-test photograph of exposed surface, layer B, Test TU3-1.

Fig. VI.15. Post-test photograph of un exposed surface, layer A, Test TU3-1.

References

1. ASTM E 119-88, Standard Test Methods for Fire Tests of Building Construction Materials, 1992 Annual Book of ASTM Standards, Vol 4.07, American Society for Testing and Materials, Philadelphia, PA.

2. ASTM E 176-93a, Standard Terminology of Fire Standards, Annual Book of ASTM Standards, Sec. 4, Construction, Vol. 4.07, American Society for Testing and Materials, Philadelphia, PA, 1995.

3. Babrauskas, V., "Fire Endurance in Buildings", Report No. UCB FRG 76-16, Ph.D. dissertation, University of California, Berkeley, November 1976, pp. 241-242.

Prepared by:

8/20/96

Kenneth D. Steckler
Physicist, Materials Fire Research

APPROVED

Richard G. Gann
Chief, Fire Science Division

APPENDIX. Uncertainty Analysis

The following assesses **uncertainties associated with instruments** which were used to determine the fire-endurance period of a fire-barrier system. **As only one test assembly (sample) of each system was tested, no statement can be made regarding the repeatability (within-laboratory variability) of a fire-endurance result.** Furthermore, no other data exist to indicate repeatability of results obtained from the NIST reduced-scale furnace.

Two measurements were involved in the determination of fire-endurance period, time and temperature.

Time

Time was kept by a computer-based clock with an accuracy of better than 1 second over a test period (1 to 5.5 hours). A more significant uncertainty was associated with the scanning of the various thermocouple channels by the computer-controlled data acquisition system, which scanned 15 channels in about 4 seconds every 10 seconds. Since the computer clock was read at the beginning of the scan, a given temperature measurement was made and recorded up to 4 seconds after the time was recorded. Consequently, the maximum combined uncertainty in the time measurement, C1 (Table App.1), due to the accuracy of the clock and the uncertainty associated with the scanning process was judged to be +5/-1 seconds.

Temperature

Uncertainties associated with the measurements of the unexposed-surface temperatures and the furnace temperatures contribute to the total uncertainty attached to the fire-endurance period.

a. Unexposed-surface temperatures

We considered the following sources of error for unexposed surface temperatures in the range actually encountered, 75°C to 166°C:

* inherent accuracy of the thermocouple materials [1]; (±2.2°C).
* accuracy of the voltage-to-temperature conversion polynomial [2] (+0.30/-0.64°C), and
* accuracy of the digital voltmeter[9] (DVM) used to measure the thermocouple voltages (+0.68/-0.64°C[10]).

Uncertainties associated with the attachment of the thermocouples to the test assembly were judged to be small since insulation pads were used as described in sections I.B and I.C.

---

[9]Accuracy was determined with a precision voltage source of known accuracy.

[10]This temperature uncertainty is the ratio of the voltage uncertainty to the thermoelectric power (mV/°C) of the thermocouple materials.

Adding the above uncertainties produced a maximum uncertainty of +3.2/-3.0, which we simplified conservatively to ±3.2°C. Dividing ±3.2°C by the average rate of change of unexposed-surface temperature at the indicated fire-endurance time yielded the attendant uncertainty in the fire-endurance period, C2 (Table App.1).

b. Furnace temperatures

We considered the same sources of error for furnace temperatures in the range actually encountered, 20°C to 1100°C, as follows:

* inherent accuracy of the thermocouple materials; (±2.2°C or 0.75% (C scale), whichever is greater [1]).
* accuracy of the voltage-to-temperature conversion polynomial [2] (±0.7°C), and
* accuracy of the DVM used to measure the thermocouple voltages (expressed as third-order polynomials relating temperature uncertainty to temperature. See Fig. App.1).

These uncertainties were added to the experimental temperature-time curve to obtain maximum and minimum furnace temperature-time curves. These bounding curves were integrated with respect to time and the results processed per ASTM E 119, Par. 7.4 [3] to determine corrections to the indicated fire-endurance period to account for variations in furnace temperature. These corrections or uncertainties are listed as C3 in Table App.1.

Combined uncertainty

The total maximum uncertainty was calculated as the sum of C1, C2, and C3 and is reported in Table App.1. The percent maximum uncertainty, shown in the last column of the table, falls in the range 2.2 to 3.5 percent.

References

1. Manual on the Use of Thermocouples in Temperature Measurement, ASTM Special Technical Publication 470, American Society for Testing and Materials, Philadelphia, PA, 1970, p. 151.

2. Omega Complete Temperature Measurement Handbook and Encyclopedia, vol. 26, Omega Engineering Inc., Stamford, CT, 1988, p. T-12.

3. ASTM E 119-88, Standard Test Methods for Fire Tests of Building Construction Materials, 1992 Annual Book of ASTM Standards, Vol 4.07, American Society for Testing and Materials, Philadelphia, PA.

Table App.1. MAXIMUM UNCERTAINTY OF FIRE-ENDURANCE PERIOD

Test	Due to uncertain. in time measure	Due to uncertain. in unexp. surf. temperature measurement			Due to uncertain. in furn. temp. measure	Total max. uncert.	Fire-endur. period (or time at shutdown) including E 119 par.7.4 correction	Percent max. uncert.
	C1			C2	C3	C1+C2+C3		
		Uncertainty in average unexposed surface temp.	Unexposed surface temp. heat. rate, dT_s/dt	±3.2°C / (dT_s/dt)				
	s	°C	°C/s	s	s	s	s (hr:min.)	%
H1-1	+5/-1	±3.2	0.050	±64	+22 -21	+91 -86	3320 (0:55.3)	2.7
H3-1	+5/-1	±3.2	0.017	±188	+86 -79	+279 -268	12748 (3:32.5)	2.2
TJ1-1	+5/-1	±3.2	0.023	±139	+37 -34	+181 -174	5436 (1:30.6)	3.3
TJ3-1	+5/-1	±3.2	0.007	±457	+109 -99	+571 -557	16154 (4:29.2)	3.5
TU3-1	+5/-1	±3.2	0.009	±356	+96 -87	+457 -444	14205 (3:56.8)	3.2

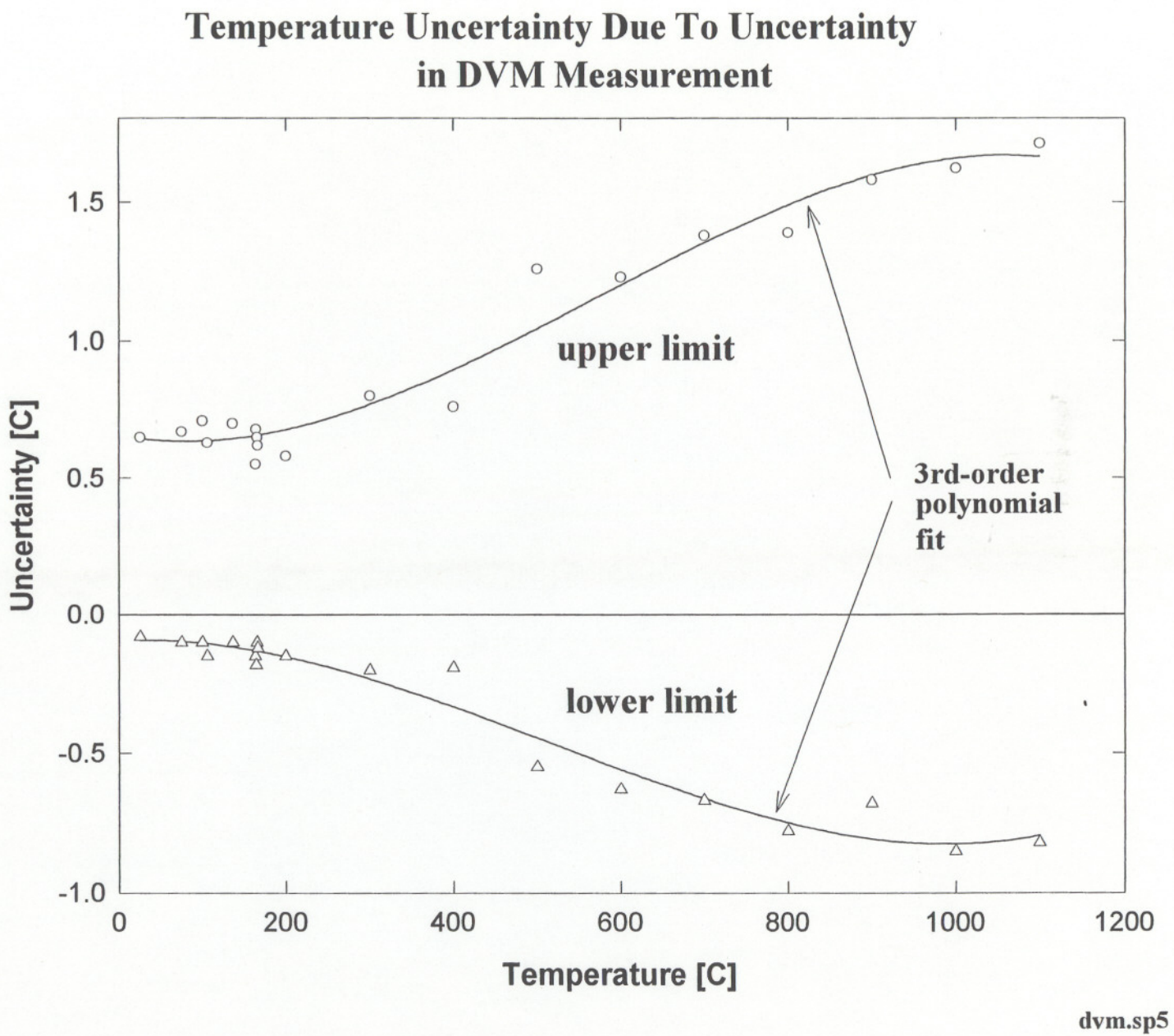


Fig. App.1. Uncertainty in recorded temperature due to uncertainty in voltage indicated by DVM.

IIST-114
REV. 6-93)
ADMAN 4.09

U.S. DEPARTMENT OF COMMERCE
NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

MANUSCRIPT REVIEW AND APPROVAL

(ERB USE ONLY)	
ERB CONTROL NUMBER	DIVISION
PUBLICATION REPORT NUMBER	CATEGORY CODE
PUBLICATION DATE	NUMBER PRINTED PAGES

ISTRUCTIONS: ATTACH ORIGINAL OF THIS FORM TO ONE (1) COPY OF MANUSCRIPT AND SEND TO HE SECRETARY, APPROPRIATE EDITORIAL REVIEW BOARD

ITLE AND SUBTITLE (CITE IN FULL)

.eport of Test FR 4008 on Pilot-Scale Fire Endurance Test of Fire-Barrier Panels and Panel/Blanket Combinations

ONTRACT OR GRANT NUMBER

TYPE OF REPORT AND/OR PERIOD COVERED

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

:eckler, Kenneth D.

PERFORMING ORGANIZATION (CHECK (X) ONE BOX)

- [X] NIST/GAITHERSBURG
- [ ] NIST/BOULDER
- [ ] JILA/BOULDER

ABORATORY AND DIVISION NAMES (FIRST NIST AUTHOR ONLY)

uilding and Fire Research Laboratory, Fire Science Division

PONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (STREET, CITY, STATE, ZIP)

ffice of Nuclear Reactor Regulation
nited States Nuclear Regulatory Commission
'ashington, DC 20555

OPOSED FOR NIST PUBLICATION

- [ ] JOURNAL OF RESEARCH (NIST JRES)
- [ ] J. PHYS. & CHEM. REF. DATA (JPCRD)
- [ ] HANDBOOK (NIST HB)
- [ ] SPECIAL PUBLICATION (NIST SP)
- [ ] TECHNICAL NOTE (NIST TN)
- [ ] MONOGRAPH (NIST MN)
- [ ] NATL. STD. REF. DATA SERIES (NIST NSRDS)
- [ ] FEDERAL INF. PROCESS. STDS. (NIST FIPS)
- [ ] LIST OF PUBLICATIONS (NIST LP)
- [ ] NIST INTERAGENCY/INTERNAL REPORT (NISTIR)
- [ ] LETTER CIRCULAR
- [ ] BUILDING SCIENCE SERIES
- [ ] PRODUCT STANDARDS
- [X] OTHER Report of Test

OPOSED FOR NON-NIST PUBLICATION (CITE FULLY) [ ] U.S. [ ] FOREIGN

PUBLISHING MEDIUM

- [ ] PAPER
- [ ] CD-ROM
- [ ] DISKETTE (SPECIFY)
- [ ] OTHER (SPECIFY)

PPLEMENTARY NOTES

STRACT (A 2000-CHARACTER OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR ERATURE SURVEY, CITE IT HERE. SPELL OUT ACRONYMS ON FIRST REFERENCE.) (CONTINUE ON SEPARATE PAGE, IF NECESSARY.)

series of tests was carried out at the request of the Nuclear Regulatory Commission to obtain information on the fire endurance of veral configurations of fire-barrier panels and panel/blanket combinations when tested in a pilot-scale furnace.

WORDS (MAXIMUM OF 9; 28 CHARACTERS AND SPACES EACH; SEPARATE WITH SEMICOLONS; ALPHABETIC ORDER; CAPITALIZE ONLY PROPER NAMES)

e Barriers; Fire Endurance; Fire Research; Fire Resistance Tests; Small Scale Fire Tests

ILABILITY

- [ ] UNLIMITED
- [X] FOR OFFICIAL DISTRIBUTION - DO NOT RELEASE TO NTIS
- [ ] ORDER FROM SUPERINTENDENT OF DOCUMENTS, U.S. GPO, WASHINGTON, DC 20402
- [ ] ORDER FROM NTIS, SPRINGFIELD, VA 22161

NOTE TO AUTHOR(S): IF YOU DO NOT WISH THIS MANUSCRIPT ANNOUNCED BEFORE PUBLICATION, PLEASE CHECK HERE. [X]

DPERFECT