

NATIONAL FIRE DOOR FIRE TEST PROJECT
POSITIVE PRESSURE ROOM BURN TESTS

Technical Report

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Foreword

This report documents the positive pressure room fire tests conducted for the Research Foundation's National Fire Door Fire Test Project. Four fire door types were tested according to parameters specified by the project's technical advisory committee using positive pressure with neutral planes of 40" and 20" above the sill. A separate report, *National Fire Door Fire Test Project: Positive Pressure Furnace Fire Tests*, documents a prior furnace fire test series also conducted for the project.

The Building Code writers, manufacturers and public interests had sought independent test documentation of positive pressure parameters prior to moving forward with potential new provisions in the Codes. These interests were represented on the project's technical advisory committee in order to communicate questions to the project and information from it to code enforcers and industry at the earliest possible time.

The Research Foundation expresses gratitude to authors Dr. Pravinray Gandhi and David Sheppard for their thorough testing and report. The Foundation and the authors thank the project's Technical Advisory Committee for their contribution in all respects: technical expertise, review, as well as financial resources to conduct this landmark initiative. Of course, participation does not necessarily constitute a participant's endorsement of every statement in the report.

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**NATIONAL FIRE DOOR FIRE TEST PROJECT
ROOM BURN TESTS**

**FINAL REPORT
(95NK03144/NC987)
FOR**

NATIONAL FIRE PROTECTION RESEARCH FOUNDATION

**BY
UNDERWRITERS LABORATORIES INC.
MARCH 3, 1995**

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EXECUTIVE SUMMARY

The current fire door test methods, NFPA 252, "Standard Tests of Door Assemblies"; ANSI/UL10B; "Standard for Fire Tests of Door Assemblies"; and ASTM E152, "Standard Methods of Fire Tests of Door Assemblies", are conducted with the neutral pressure plane located at the top of the door assembly. This method results in negative pressure being applied to the entire door assembly during the test. The Uniform Building Code Standard 43-2, "Fire Tests of Door Assemblies" is under consideration to propose that the neutral pressure plane be located 40 inches above the sill. Thus positive pressure would be applied to the upper portion of the door assembly.

In this project, the fire tests were planned in a 16 feet x 14 feet x 8 feet high test facility. The fire doors were exposed to the NFPA 252 standard time-temperature curve, and the performance of the fire doors was monitored with the neutral pressure plane located 40 inches above the door sill. The tests were conducted on single swing wood doors, and single swing and pairs of steel covered composite and steel stiffened doors.

Initially, fire test simulations were conducted using HAZARD I computer fire model to estimate the fire load and the ventilation parameters required for attaining the desired fire exposure on the test samples. These estimates were then further refined by calibration tests.

The general observations and measurements for the three tests conducted with ventilation control post flashover fires were:

1. None of the samples ignited the cotton pad during the first 10 minutes of their test.
2. None of the samples moved from the stop of the frame in which they were installed an amount greater than permitted in NFPA 252 during a 20 minute or 90 minute fire exposure.
3. None of the samples separated at their meeting edges an amount greater than permitted in NFPA 252.
4. None of the test assemblies had visible flames on a unexposed faces during a 20 minute or 90 minute fire exposure.

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ROOM BURN TESTS

INTRODUCTION:

The current fire door test methods, NFPA 252, "Standard Tests of Door Assemblies", ANSI/UL10B, "Standard for Fire Tests of Door Assemblies", and ASTM E152, "Standard Methods of Fire Tests of Door Assemblies", are conducted with the neutral pressure plane located at the top of the door assembly. This method results in negative pressure being applied to the entire door assembly during the test. The Uniform Building Code Standard 43-2, "Fire Tests of Door Assemblies" is under consideration to propose that the neutral pressure plane be located 40 inches above the sill. Thus positive pressure would be applied to the upper portion of the door assembly.

In this project, four fire tests were conducted in a 16 feet x 14 feet x 8 feet high test facility. The fire doors for the first test were exposed to a fire with the average ceiling temperature corresponding to the time-temperature curve specified in NFPA 252 and the performance of the fire doors was monitored. The fire doors for the remaining three tests were exposed to a post-flashover ventilation controlled fire while the average ceiling temperature corresponding to the standard time-temperature curve specified in NFPA 252 was maintained, and the performance of the fire doors were monitored.

PURPOSE:

The purpose of the test project was to conduct room burn tests on fire door assemblies, which had previously been tested in a panel furnace under positive pressure.

FIRE EXPOSURE:

The condition for testing, defined in the original proposal, was to expose the fire door assemblies to the NFPA 252 time-temperature exposure and maintain the neutral pressure plane 40 inches above the sill. These conditions were then revised to include the establishment of post-flashover ventilation conditions within 6 minutes as evidenced by the flaming of hot gases outside the window opening. Under the revised condition, the requirement for the neutral pressure plane location was to be not greater than 40 inches above the door sill.

TECHNICAL PLAN:

The project consisted of five tasks and the final report. The tasks were as follows:

- TASK 1 - Construction of Fire Test Room
- TASK 2 - Instrumentation
- TASK 3 - Data Collection, Measurements and Observations
- TASK 4 - Calibration Tests
- TASK 5 - Room Burn Tests

TASK 1 - CONSTRUCTION FIRE TEST ROOM

Fire Test Facility

The fire test room was constructed in a 66 feet by 36 feet by 21 feet high fire test facility. The test facility is of masonry block construction, and has a capacity to exhaust combustion products at a rate of 30,000 CFM.

Fire Test Room

A fire room facility with internal dimensions of 14 ft. by 16 ft. by 8 ft. high was constructed. Three walls of the fire test room were constructed using 16 in. x 8 in. by 8 in. high concrete blocks. The fourth wall containing one single door, and one pair of doors was moveable, and was also constructed using concrete blocks. One wall, opposite the moveable wall had a window opening 3 ft. 6 in. wide. The opening had a 2 ft. 7 in. high window sill constructed from an inorganic board. A sliding steel plate, supported by an electric hoist, was assembled at the top of the window opening to adjust the neutral pressure plane location during the test. A steel deck assembly was used as the ceiling. The ceiling was further supported by an external steel joist assembly. The fire test room floor was constructed from 4 inches of vermiculite concrete.

The ceiling and walls of the fire test room were lined with 3 inches ceramic fiber insulation. The insulation was mounted on the ceiling and walls using steel pins embedded in the steel ceiling and the concrete walls. There was an overlap of the insulation around the corners, and the edges of the room to prevent leakage of combustion products during the test.

The density of the ceramic fiber insulation was 8 lb/ft³. The thermal conductivity data, obtained from the manufacturer, are presented in Table 1.

Table 1 - Thermal Conductivity of the Ceramic Fiber Insulation

Temperature (°F)	Thermal Conductivity (BTU-in/ft ² -hr-°F)
400	0.25
800	0.6
1000	0.8
1200	1.0
1600	1.4
1800	1.6

A natural gas diffusion fire burner was designed to provide the heat input to the fire test facility. The burner consisted of three separate 3 inch elbows, approximately 4 ft. apart, providing equal rates of gas during the fire test. The burner was located in the center of the room along the 16 ft. axis. Flame igniters were provided at each gas port to ignite the gas.

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The schematic of the fire test room plan is shown in Figure 1, and the front elevation is shown in Figure 2. The moveable door assemblies are depicted in Figure 3. The schematic of the rear elevation with the sliding steel plate is shown in Figure 4.

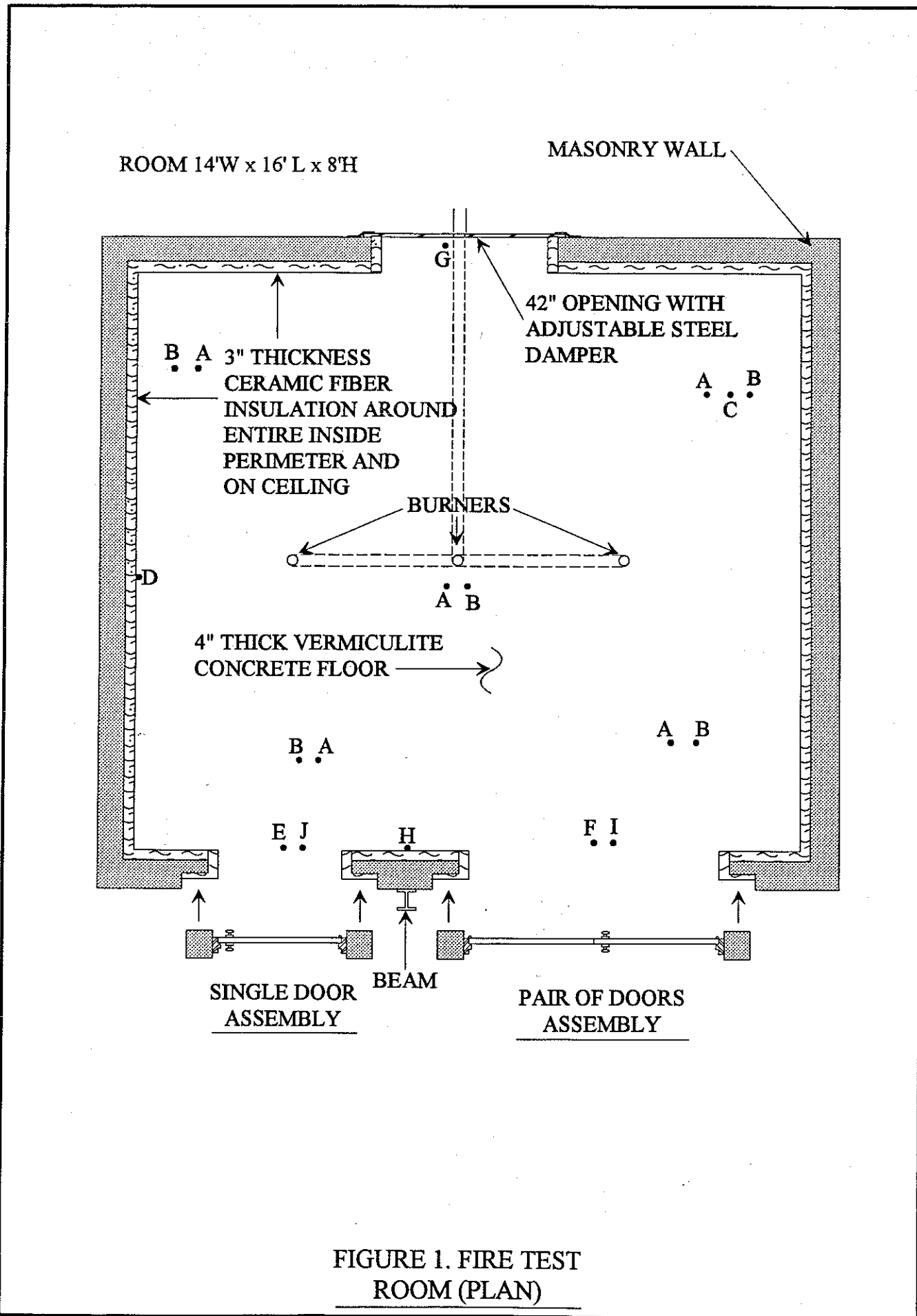


FIGURE 1. FIRE TEST ROOM (PLAN)

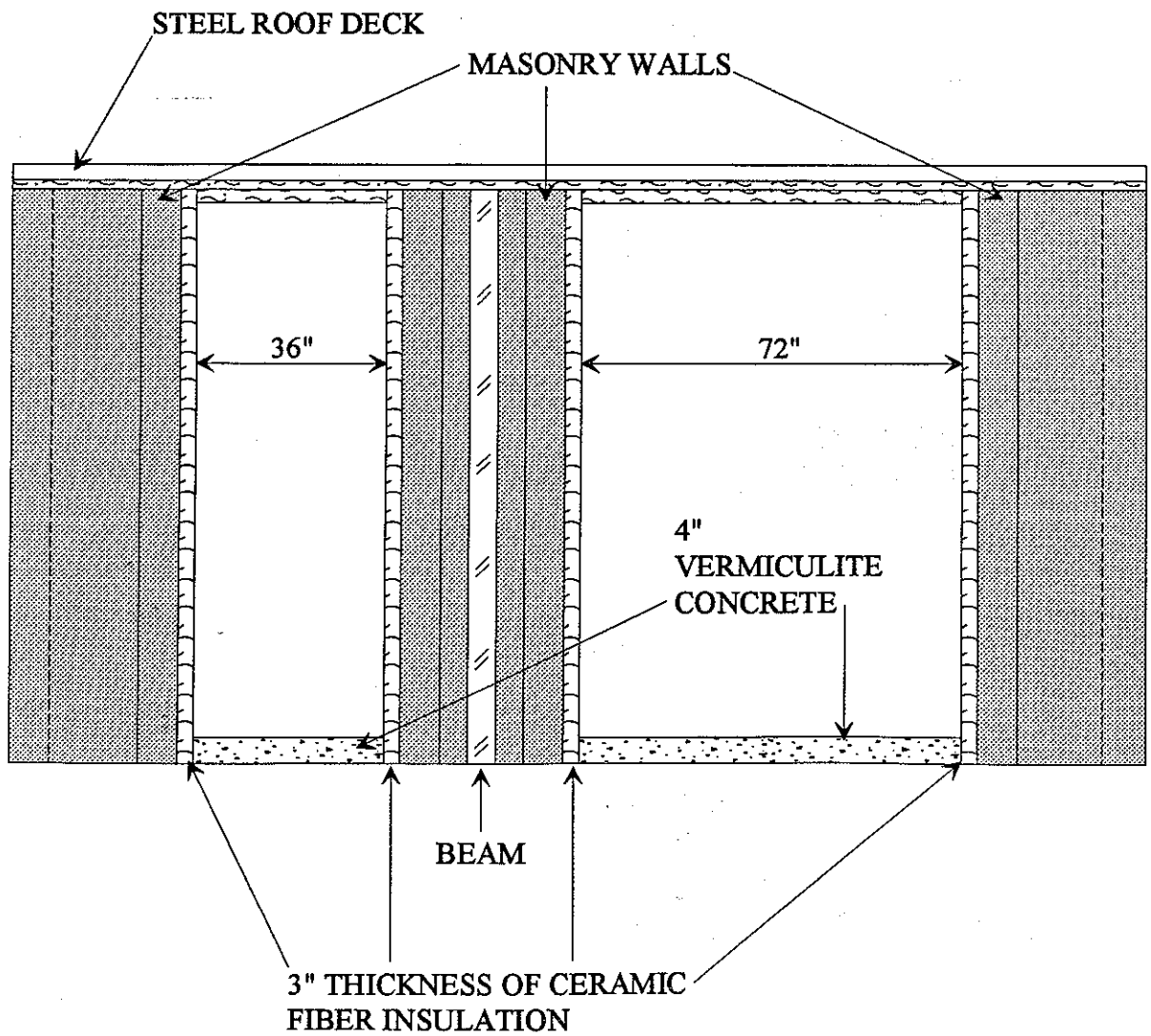
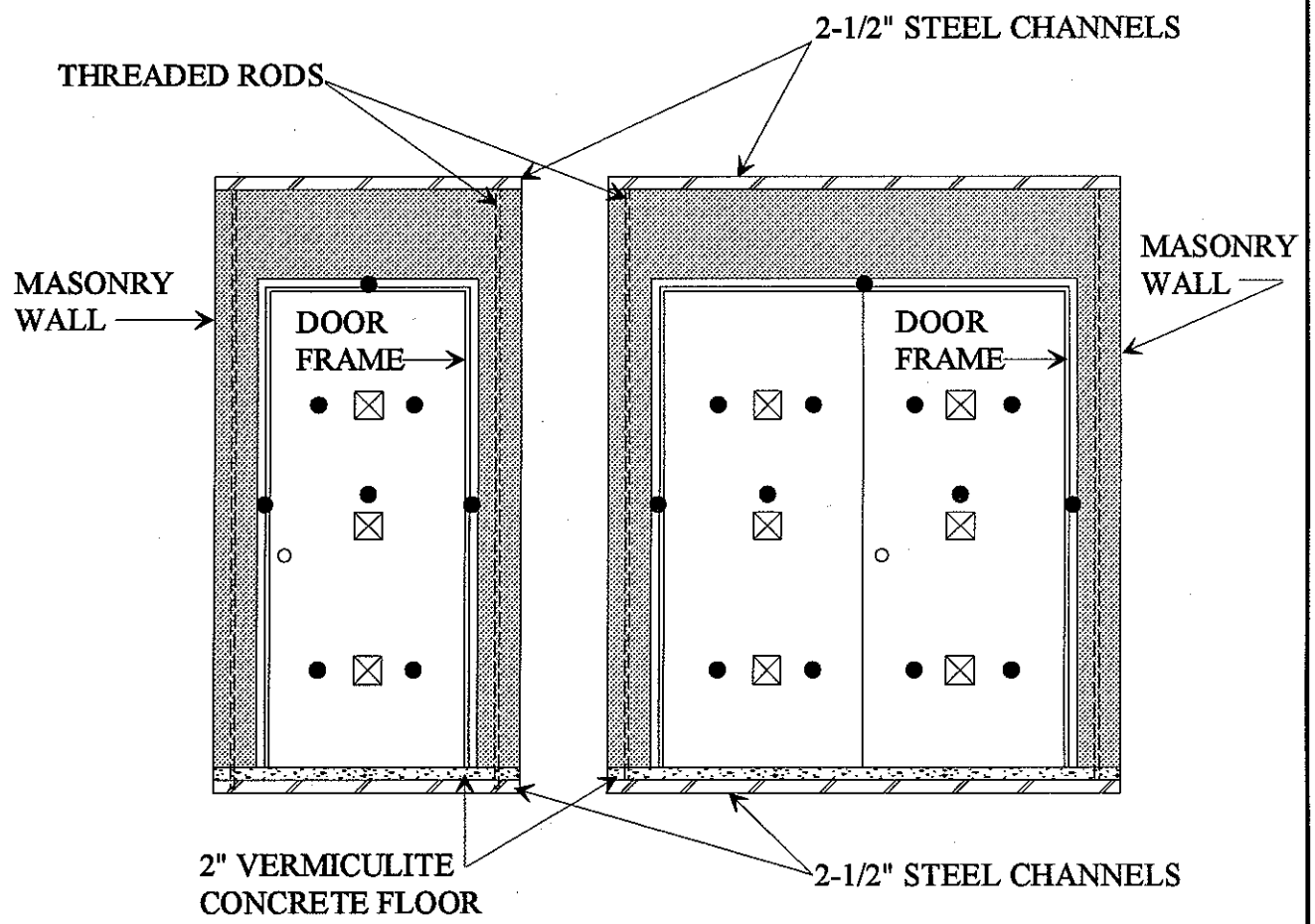


FIGURE 2. FIRE TEST ROOM (FRONT ELEVATION)



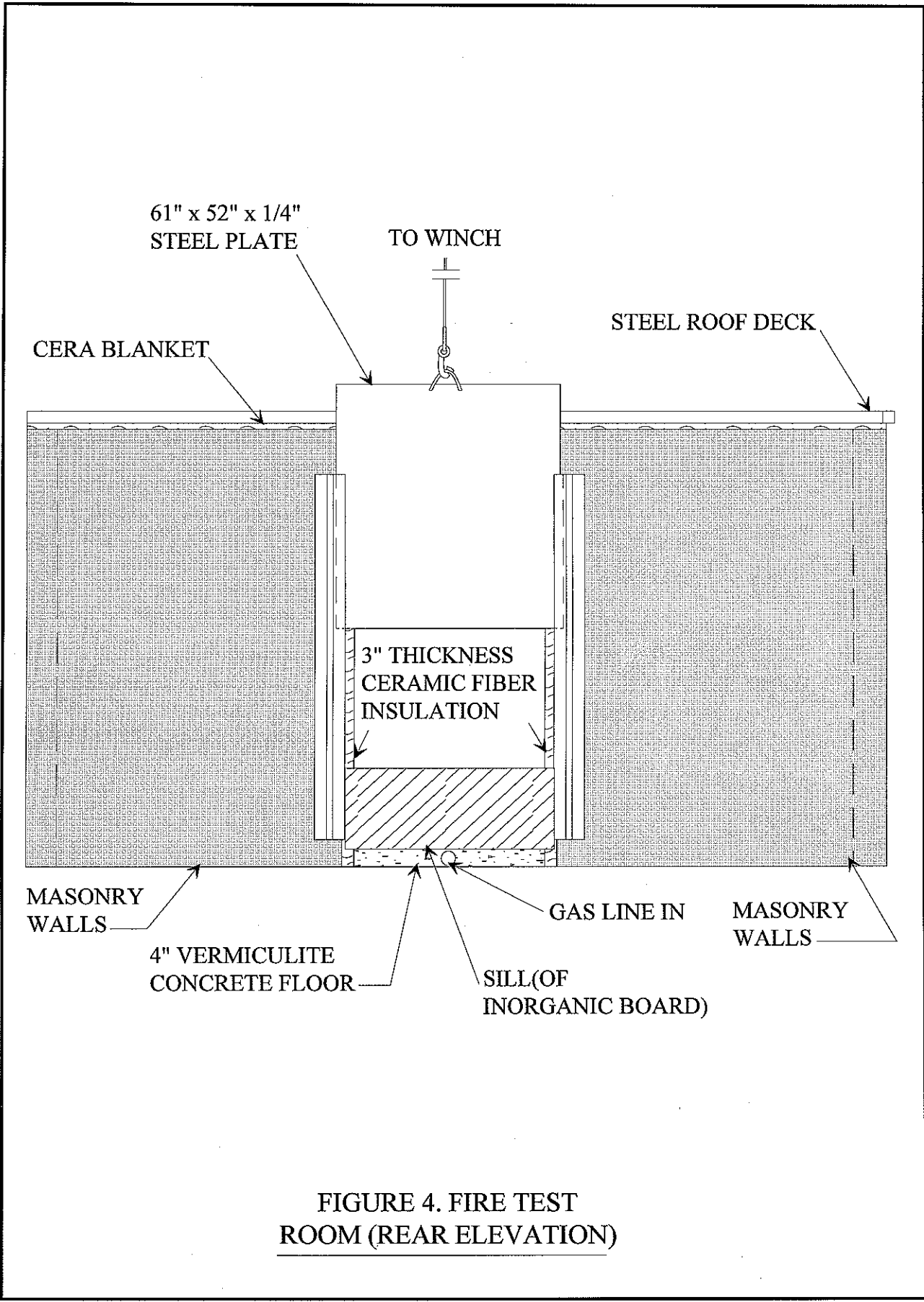
SINGLE DOOR ASSEMBLY

PAIR OF DOORS ASSEMBLY

THERMOCOUPLES

- BS 476
- ⊠ NFPA 252

FIGURE 3. MOVABLE DOOR ASSEMBLIES



TASK 2 - INSTRUMENTATION

The instrumentation consisted of thermocouples, radiometers, pressure probes and transducers, and a total hydrocarbon analyzer.

Internal Temperature Measurements

The temperatures in the fire test room were measured by bare bead, 19 gauge wire diameter, Type K thermocouples (in accordance with ISO 3008). The thermocouples were encased in a 0.188 inch diameter stainless steel sheath. In addition, five thermocouples of the type specified in NFPA 252 were located at the ceiling to monitor the room temperature. These thermocouples were 12 gauge, Type K encased in 1/2 inch steel pipes with welded closed ends. The thermocouple wire was separated using ceramic insulators.

The thermocouples were mounted as follows:

Thermocouple tree at window - The thermocouples were located at the centerline of the window and flush with the outside of the frame. They were positioned with 6 inch spacing from the sill to the soffit. The window thermocouples are shown as location "G" in Figure 1.

Thermocouple tree at doors - The thermocouples were located at the centerline of the single doors and in the centerline of the gap of the pair of doors. They were positioned from floor to ceiling with a 12 inch spacing and 6 inches away from the door surface. The door thermocouples are shown as locations "E" and "F" in Figure 1.

Thermocouples at side wall - The thermocouples were located at the centerline of the wall and flush with the wall at 0", 20", 40", 72" and 96" above the sill. The side wall thermocouples are shown as location "D" in Figure 1.

Ceiling Thermocouples - The bare beaded (ISO 3008) and control thermocouples (NFPA 252) were located at five positions in the ceiling. At four locations a single thermocouple was located 4 inch below the ceiling. The ceiling thermocouples are shown as location "A" for control thermocouples, and "B" for bare bead thermocouples in Figure 1. At the fifth position, nine (9) thermocouples were placed at 1 inch increments starting at the ceiling. These thermocouples are shown as location "C" in Figure 1.

External Temperature Measurements

The thermocouples on the unexposed side of the door, door frame, and lock set at the spindle, were of the type and located in accordance with BS 476, "Fire test on building materials and structures," without pads covering the thermocouple junction. The thermocouples required by NFPA 252 (UBC Standard 43-2) were located on the door only. The thermocouples mounted on the door and frame are depicted in Figure 3.

Pressure Measurements

Room pressure measurements were in accordance with the August 9, 1993 ICBO Evaluation Services, Inc. protocol with the exception that only the probe shown in Figure 3 of the ICBO protocol was used.

There were two pressure probes located at (i) 40 inches above the top of the door sill; and (ii) at the top of the doors under test. The probe locations are shown as locations "H" in Figure 1.

The pressure probes were constructed from 1/2 inch diameter stainless steel tube. The probes were located so that the centerline of the sensing holes was positioned 6 ± 1 inch from the surface of the exposed face of the test assembly in no case closer than 18 in. from the edges of the room. The probes were run horizontally through the wall into the room without a change in vertical elevation of the probes or tubing within the test room.

Data recording provided monitoring of the output of an electronic pressure transducer in the range of ± 0.25 w.c. with an accuracy of $\pm 1\%$. The pressure transducers were located within 3 ft. vertically and 10 ft. horizontally from the static probes outside the room.

Radiant Heat Flux From Unexposed Face

The radiant heat flux from the unexposed surface of each of the door assembly was measured by means of a radiometer (Circular-foil-Gardon type radiometer without window, Medtherm Model Number 64-5-20/AP-1-60), mounted along an axis normal to the center of the door and at a distance of 79 ± 0.79 in. ($2000 \text{ mm} \pm 20 \text{ mm}$) away, geometrically opposite to the center of the door. The radiometers had a range of 0-5 W/cm². To prevent the radiometers from receiving thermal radiation from heated surfaces other than the door assembly, a water cooled aluminum plate containing an aperture were placed between the radiometer and the specimen. The maximum plate temperature was maintained below 100°F (38°C). A thermocouple was welded on the plate surface facing the fire doors to monitor its temperature. A schematic of the water cooled plates is shown in Figure 5. The apertures were sized and were geometrically similar to the door assembly. The plates were large enough to shield the radiometers from thermal radiation from heated surfaces other than the door assembly.

Total Hydrocarbons

The measurement of total unburned hydrocarbons in the fire test room was measured using a flame ionization type hydrocarbon gas analyzer, from Foxboro Company, Model Number OVA108. The analyzer had a range of 1% by volume. One stainless steel sampling probe was positioned approximately 100 mm from the surface of the exposed face of each door assembly in the test, at the centerline of the top edge of each door/door pair. The probes were then connected by a single line through a cold trap, filters and dryers to the measuring chamber in which was mounted the hydrocarbon analyzer. The combustion products were diluted with a metered quantity of bottled air in order to

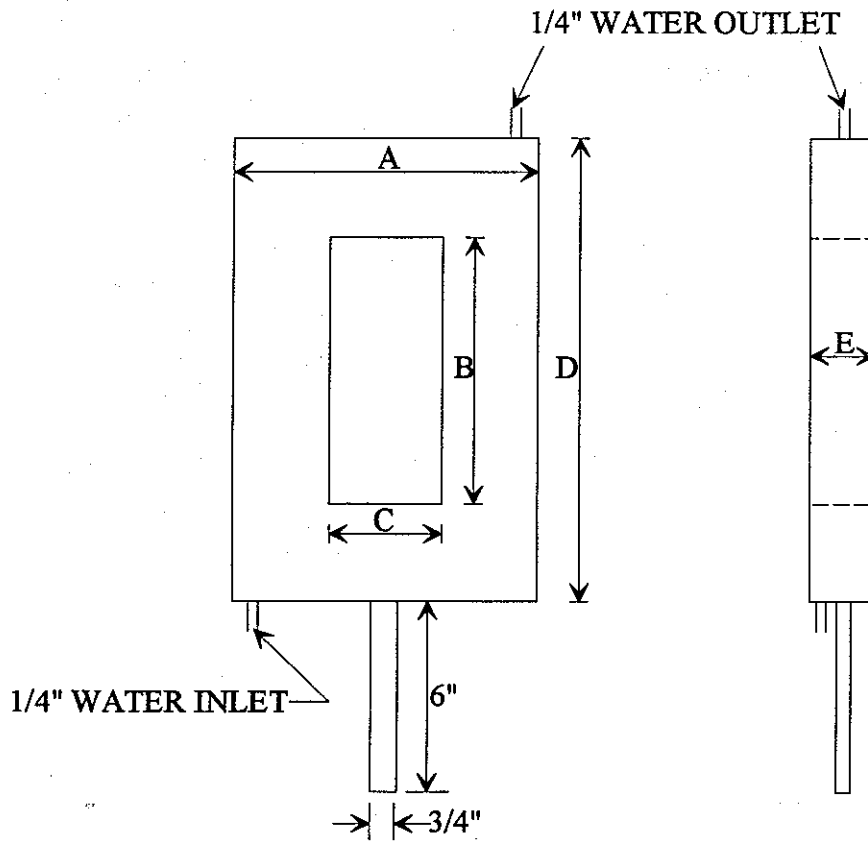
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measure hydrocarbons excess of 1%. The flow rate of the combustion products and the dilution air were monitored during the test. A schematic of the sampling arrangement is shown in Figure 6 and the sampling locations are shown as "I" and "J" in Figure 1.

Cotton Pad Test

The cotton pad test specified in British Standards Institute Standard BS 476, "Fire test on building materials and structures," parts 20-22 was conducted during each room burn test.



	DIMENSIONS (IN.)				
	A	B	C	D	E
PLATE FOR SINGLE DOOR	9.5	14.5	3.5	8.25	2
PLATE FOR DOUBLE DOOR	13.5	14.5	7	8.25	2

FIGURE 5. WATER COOLED ALUMINUM PLATES

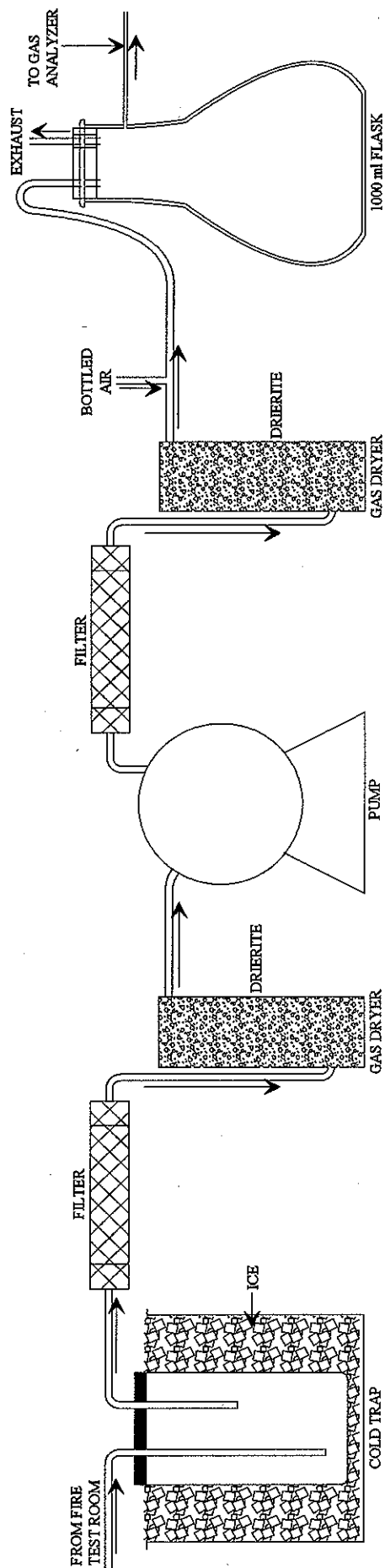


FIGURE 6. GAS SAMPLING FOR THE HYDROCARBON ANALYZER

TASK 3 - DATA COLLECTION, MEASUREMENTS AND OBSERVATIONS

The test data were acquired using two digital data acquisition systems (Fluke Helios System). The temperature, pressure, heat flux, and hydrocarbon data were scanned at intervals of at least 5 seconds throughout the test.

The channel numbers used on the data acquisition system are shown in Table 2, and are used in the graphical and tabulated data provided in the report.

Table 2 - Channel Number Descriptions

Channel #	Location
0	left front ceiling thermocouple control 4" below ceiling in pipe
1	right front ceiling thermocouple control 4" below ceiling in pipe
2	center ceiling thermocouple control 4" below ceiling in pipe
3	left rear ceiling thermocouple control 4" below ceiling in pipe
4	right rear ceiling thermocouple control 4" below ceiling in pipe
5	left front ceiling thermocouple 4" below ceiling small thermocouple
6	right front ceiling thermocouple 4" below ceiling small thermocouple
7	center ceiling thermocouple 4" below ceiling small thermocouple
8	left rear ceiling thermocouple 4" below ceiling small thermocouple
9	right rear ceiling thermocouple 4" below ceiling small thermocouple
10	right rear ceiling thermocouple 1" below ceiling
11	right rear ceiling thermocouple 2" below ceiling
12	right rear ceiling thermocouple 3" below ceiling
13	right rear ceiling thermocouple 5" below ceiling
14	right rear ceiling thermocouple 6" below ceiling
15	right rear ceiling thermocouple 7" below ceiling
16	right rear ceiling thermocouple 8" below ceiling
17	right rear ceiling thermocouple 9" below ceiling
18	side wall thermocouple 0" above floor flush with wall
19	side wall thermocouple 20" above floor flush with wall
20	side wall thermocouple 40" above floor flush with wall
21	side wall thermocouple 72" above floor flush with wall
22	side wall thermocouple 96" above floor flush with wall
23	left sample door inside furnace 6" from door 0" from floor
24	left sample door inside furnace 6" from door 12" from floor
25	left sample door inside furnace 6" from door 24" from floor
26	left sample door inside furnace 6" from door 36" from floor
27	left sample door inside furnace 6" from door 48" from floor

28	left sample door inside furnace 6" from door 60" from floor
29	left sample door inside furnace 6" from door 72" from floor
30	left sample door inside furnace 6" from door 84" from floor
31	left sample door inside furnace 6" from door 96" from floor
32	right sample door inside furnace 6" from door 0" from floor
33	right sample door inside furnace 6" from door 12" from floor
34	right sample door inside furnace 6" from door 24" from floor
35	right sample door inside furnace 6" from door 36" from floor
36	right sample door inside furnace 6" from door 48" from floor
37	right sample door inside furnace 6" from door 60" from floor
38	right sample door inside furnace 6" from door 72" from floor
39	right sample door inside furnace 6" from door 84" from floor
40	right sample door inside furnace 6" from door 96" from floor
41	exhaust window 0" from floor, flush with outside wall
42	exhaust window 6" from floor, flush with outside wall
43	exhaust window 12" from floor, flush with outside wall
44	exhaust window 18" from floor, flush with outside wall
45	exhaust window 24" from floor, flush with outside wall
46	exhaust window 30" from floor, flush with outside wall
47	exhaust window 36" from floor, flush with outside wall
48	exhaust window 42" from floor, flush with outside wall
49	exhaust window 48" from floor, flush with outside wall
50	exhaust window 54" from floor, flush with outside wall
51	exhaust window 60" from floor, flush with outside wall
52	left door, frame thermocouple left side
53	left door, frame thermocouple top
54	left door, frame thermocouple right side
55	left door, BS-476 type thermocouple top left
56	left door, BS-476 type thermocouple top right
57	left door, BS-476 type thermocouple center left
58	left door, BS-476 type thermocouple bottom left
59	left door, BS-476 type thermocouple bottom right
60	left door, NFPA type top
61	left door, NFPA type center
62	left door, NFPA type bottom
63	right door, frame thermocouple left side
64	right door, frame thermocouple top
65	right door, frame thermocouple right side
66	BS-476 type thermocouple, top left
67	BS-476 type thermocouple, top right

68	BS-476 type thermocouple, center
69	BS-476 type thermocouple, bottom left
70	BS-476 type thermocouple, bottom right
71	NFPA type thermocouple, top
72	NFPA type thermocouple, center
73	NFPA type thermocouple, bottom
74	BS-476 type thermocouple, top left
75	BS-476 type thermocouple, top right
76	BS-476 type thermocouple, center
77	BS-476 type thermocouple, bottom left
78	BS-476 type thermocouple, bottom right
79	NFPA type thermocouple, top
80	NFPA type thermocouple, center
81	NFPA type thermocouple, bottom
82	baratron, furnace pressure top of doors
83	baratron, furnace pressure 40" from floor
84	calorimeter left door
85	calorimeter right door
86	flowmeter SCFM
87	HC meter 0-5 volts

A video camera was located in front of the unexposed face of each of the fire door assemblies to observe their performance during the test, and another video camera was positioned to observe the fire from the window opening. In addition, the fire tests were recorded using still photography.

For each test, the following observations and measurements were recorded.

- The materials of construction of the door, frame, and wall or partition and the details of the installation, hardware, door frame, and wall anchors, hangers, guides, trim, finish and clearance or lap.
- Test site temperature, barometric pressure, and relative humidity.
- The fire performance of doors under the desired exposure period of 20 minutes for the wood doors, and 1-1/2 hr. for the steel stiffened and polystyrene core doors.
- The temperature measurements in the room, as well on the unexposed side of the doors under test.
- The pressure measurements made in the room and location of such measurements relative to the sill of the door.
- The radiant heat flux measurements from the unexposed side of the doors under test.

- Concentration of unburned hydrocarbons at the inside of the room.
- Total fuel consumed.
- Cotton pad test in accordance with BS 476.
- Video and still photography records of the test.
- Visual observations having a bearing on the performance of the test assembly including the time, duration and size of flaming, if any, on the unexposed side of the door leaf, amount of movement of any portion of the edges of the door adjacent to the door frame from the original position.

TASK 4 - CALIBRATION TESTS

Fire Simulation

HAZARD I fire model was used to estimate the rate of natural gas to be supplied to the room to attain the time-temperature curve specified in NFPA 252. In addition the window opening was also estimated to provide a neutral pressure plane 40 inches above the sill.

The simulations suggested a window sill height of approximately 32 inches, and an opening of 30 inches to obtain the neutral pressure plane at 40 inches above the floor (door sill).

Calibration Tests

Two calibration tests were conducted to verify and adjust the flow rate and the window opening to obtain the desired time-temperature curve, and the neutral pressure plane location. During the calibration tests, the door openings were covered with two layers of 5/8 inch thick gypsum wallboard.

Test Procedure - Calibration Test 1

The first calibration test was initiated igniting the natural gas in the room with the flame ignitors. The sill height was 2 ft. 7 in. and the window opening was initially 2 ft. 6 in. above the sill. A flow rate of 5 SCFH through the gas sampling ports for measuring hydrocarbon concentration, and a flow of 100 SCFH of bottled air were established. The ignition pilots were ignited using a propane torch, and then the gas flow through the burners was initiated. An air flow rate was initially adjusted to provide 20 SCFM of air through each of two auxiliary lines.

The gas and air flows were adjusted to obtain the desired time-temperature history within the room. The window opening was not changed during the test as the neutral pressure plane was maintained within the 40 ± 2 inches above the door sill. The temperatures, pressures, and the unburnt hydrocarbon concentrations were monitored during the test.

Test Procedure - Calibration Test 2

The second calibration test was initiated igniting the natural gas in the room with the flame ignitors. The sill height was 2 ft. 7 in. above the floor and the window opening was

initially 1 ft. 4 in. above the sill. A flow rate of 5 SCFH through the hydrocarbon gas sampling ports, and a flow of 100 SCFH of bottled air were established. The ignition pilots were ignited using a propane torch, and then the gas flow through the burners was initiated.

The gas flow, and the window opening were adjusted to obtain the desired time-temperature history within the room and to maintain the neutral pressure plane 40 inches above the door sill. The temperatures, pressures, and the unburnt hydrocarbon concentrations were monitored during the test.

Results - Calibration Test 1

The temperature, pressure, and location of neutral pressure plane data for Calibration Test 1 are provided in Appendix A.

Results - Calibration Test 2

Observations - The test observations during the test are summarized in Table 3.

Table 3- Test Observations: Calibration Test 2

Time into the test (min:sec)	Observations
1:25	Flames come out from the window opening.
2:50	Intermittent flashing of flames out of the window opening.
3:30	Intermittent flames out of the window.
5:00	Sooty flames out of the window.
7:00	Fire in the room appears sooty and dark; window opening height adjusted to 24 inches.
7:30	Steady flames out of the window.
15:00	Flames out of the window appear to be intermittent; window height adjusted to 22 inches.
41:00	Window height adjusted to 24 inches.
54:00	Window height adjusted to 26 inches.
90:00	Test terminated.

Temperature Data - The time-temperature fire exposure in the fire test room, as measured by the control thermocouples, is shown in Figure 7.

Pressure Data - The pressure at the top of the test sample, and 40 inches above the floor are shown in Figure 8.

Location of Neutral Pressure Plane - The location of the neutral pressure plane was calculated by interpolating or extrapolating the data at 40 inches and 84 inches using a

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straight line estimation. The location of the neutral pressure plane during the test is depicted in Figure 9.

Unburnt Hydrocarbons - The concentration of unburnt hydrocarbons during the test is presented in Figure 10.

Natural Gas Flow - The natural gas flow used during the test is shown in Figure 11.

Test Data - The tabulated data for the Calibration Test 2 are provided in Appendix B.

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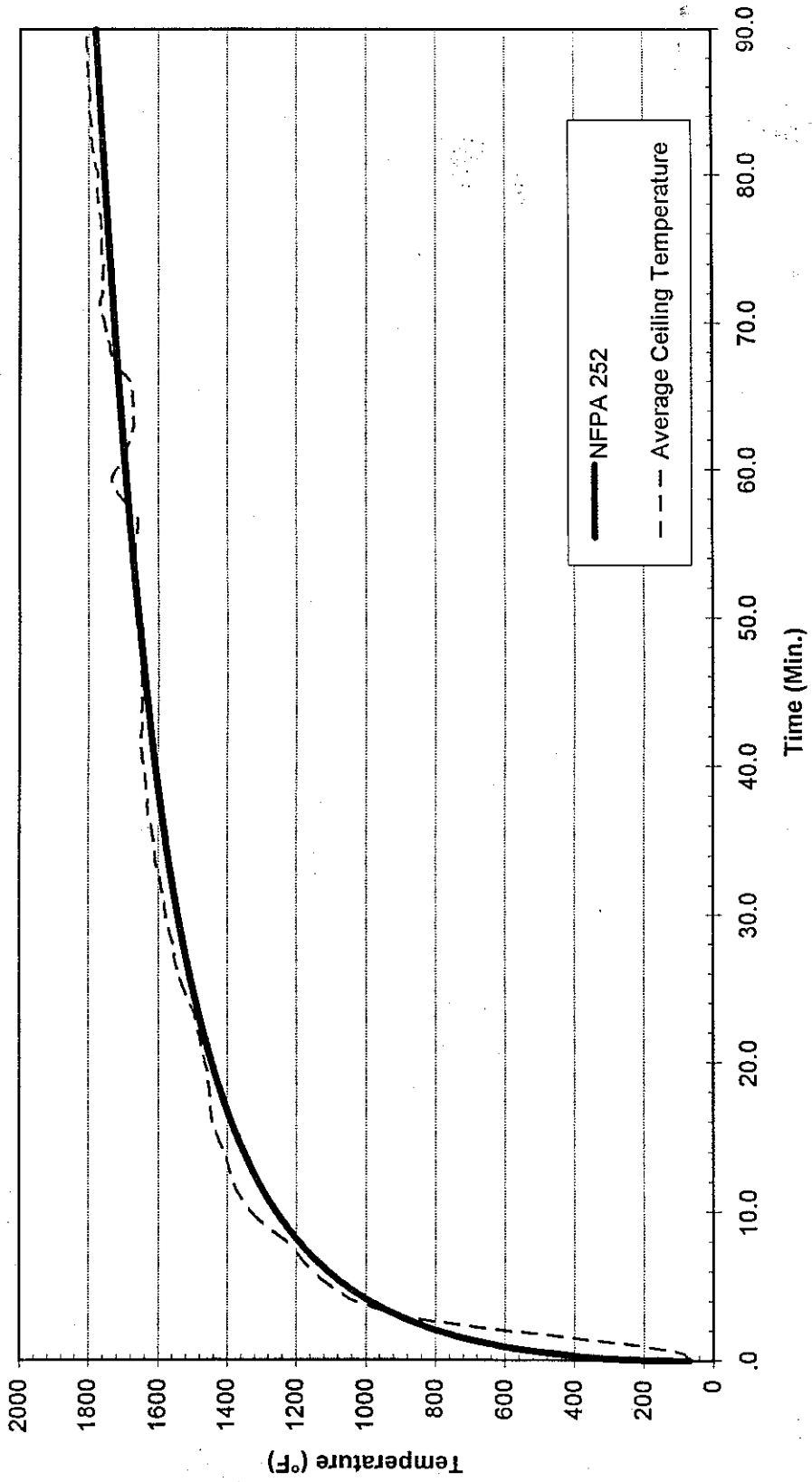


Figure 7. Time-Temperature Exposure: Calibration Test 2

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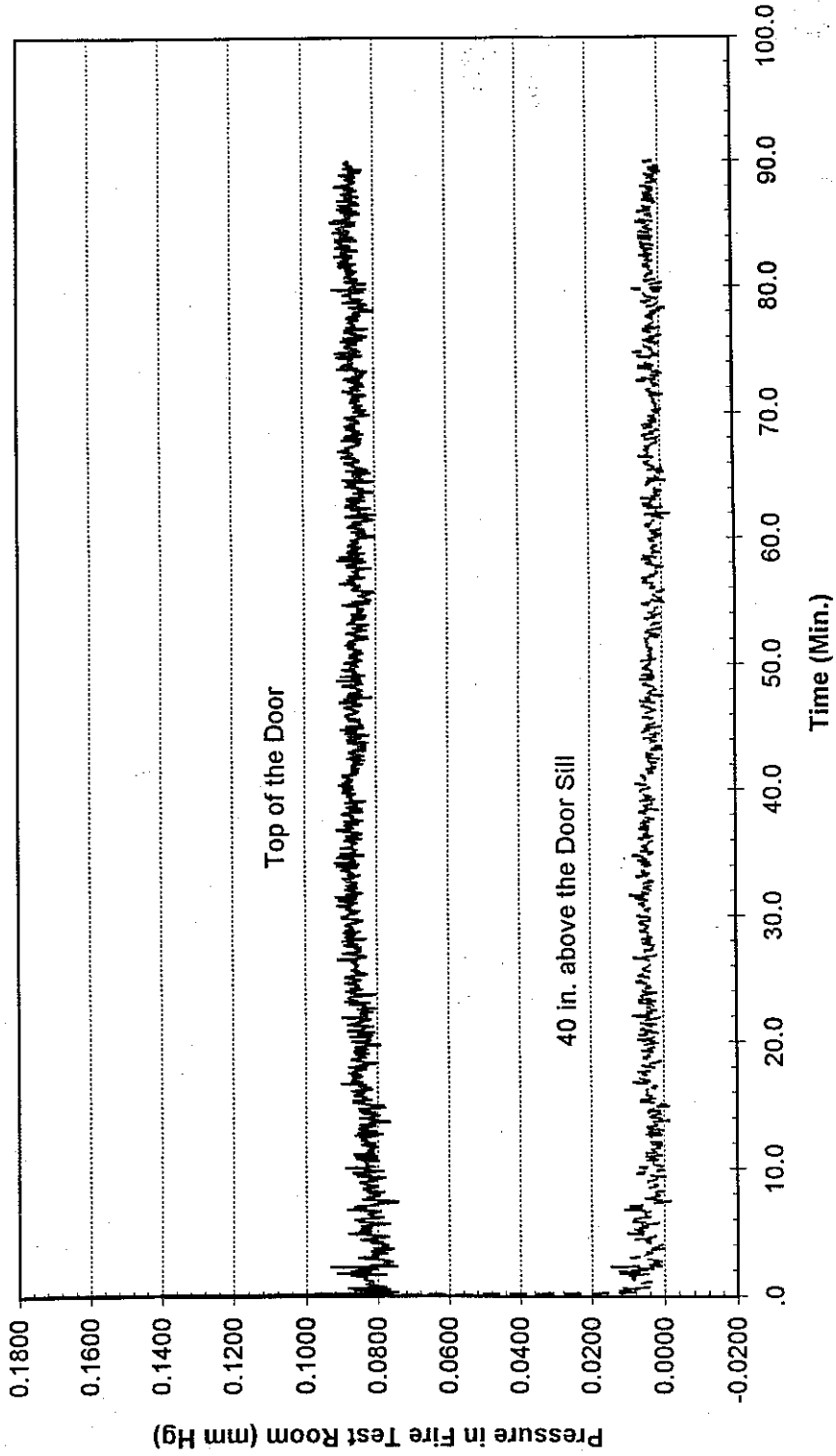


Figure 8. Pressure in the Fire Test Room: Calibration Test 2

National Fire Door Fire Test Project

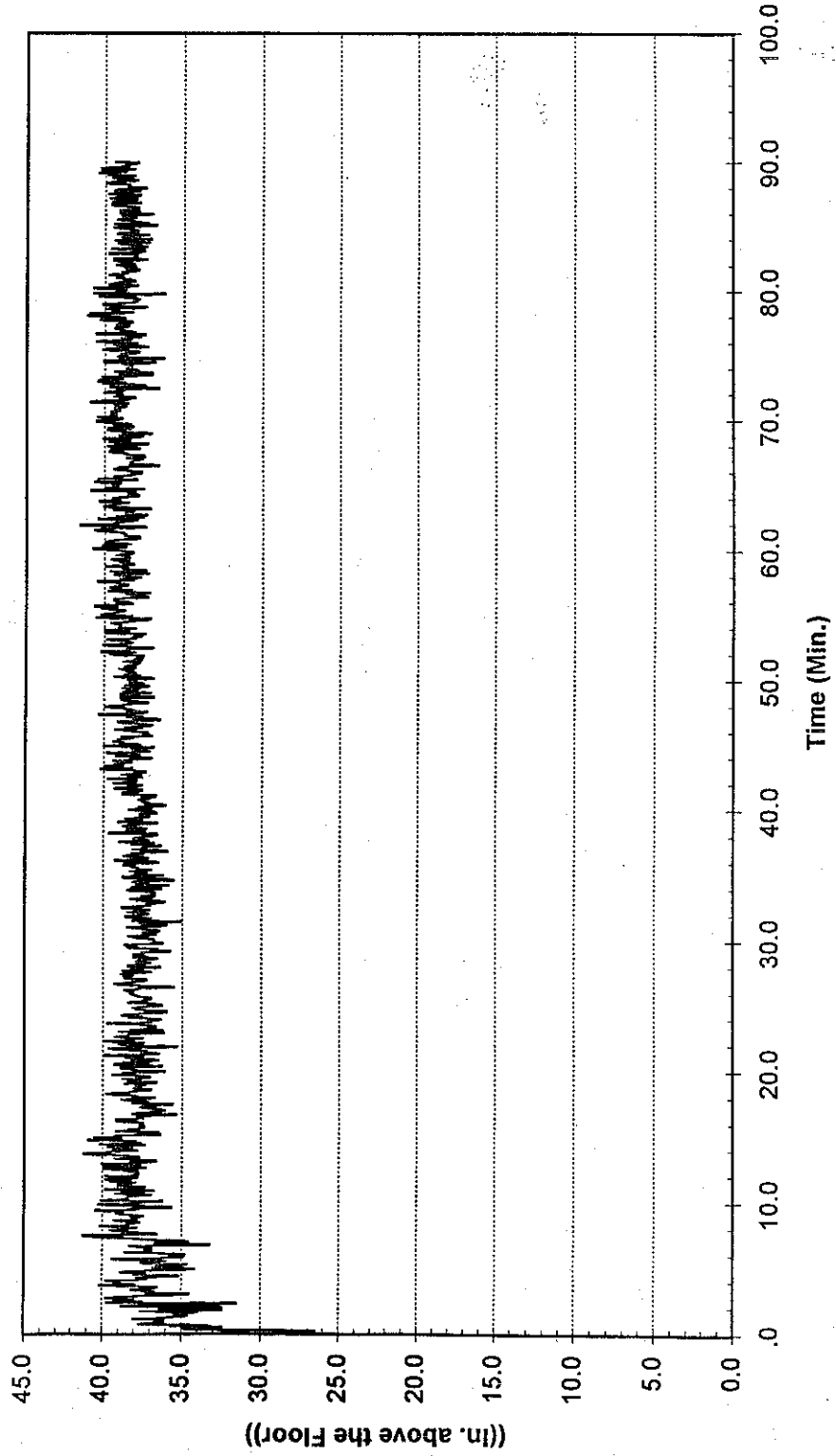


Figure 9. Location of the Neutral Pressure Plane: Calibration Test 2

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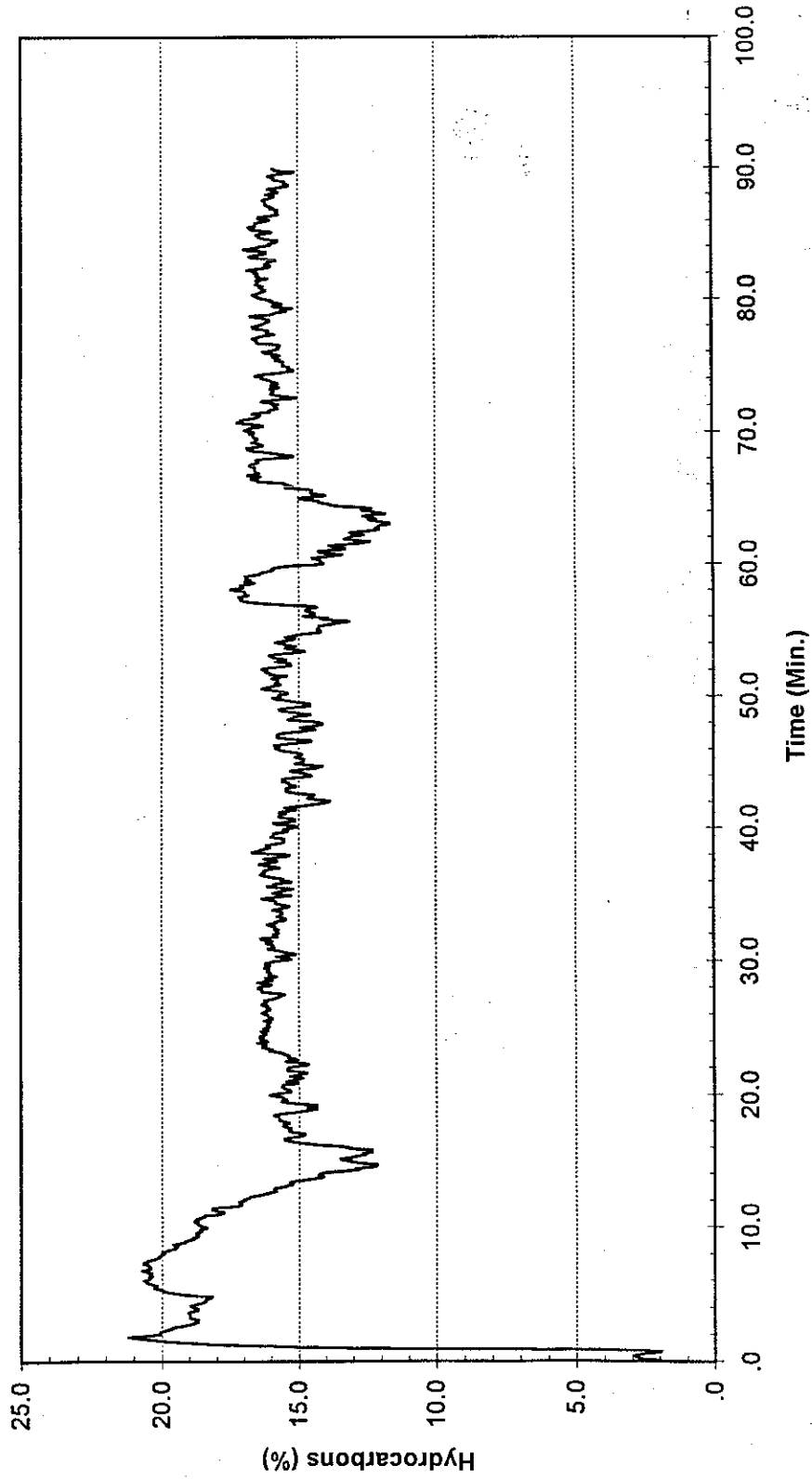


Figure 10. Unburnt Hydrocarbons: Calibration Test 2

National Fire Door Fire Test Project

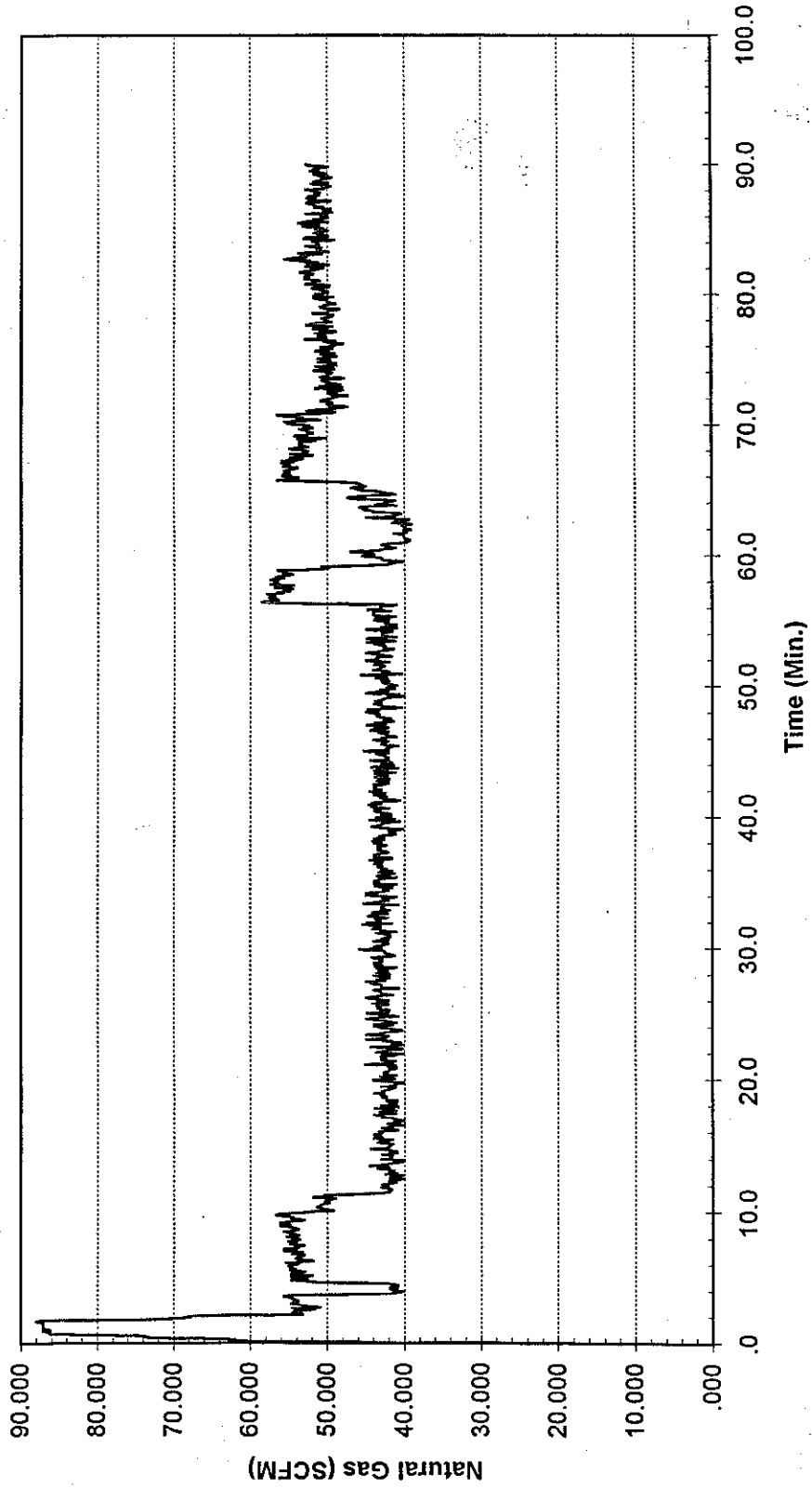


Figure 11. Natural Gas Flow: Calibration Test 2

TASK 5 - ROOM BURN TESTS

Room burn tests were conducted on three fire door assemblies, using the protocol obtained from the calibration tests.

The test series and the test duration are identified as shown in Table 4.

Table 4 - Room Burn Test Series

Fire Test Number	Sample Type	Test Duration (min.)
1	Two single swing wood particle board core doors, 3'0" x 7'0", one door swinging into the room, and one door swinging out of the room. (using calibration test procedure 1)	20
2	Two single swing wood particle board core doors, 3'0" x 7'0", one door swinging into the room, and one door swinging out of the room. (using calibration test procedure 2)	20
3	Single swing polystyrene core hollow metal door, 3'0" x 7'0", high, swinging into the room and a pair of polystyrene core hollow metal doors, 6'0" x 7'0", swinging into the room. (using calibration test procedure 2)	90
4	Single swing steel stiffened door, 3'0" x 7'0" high, swinging into the room and a pair of steel stiffened doors, 6'0" x 7'0", swinging into the room. (using calibration test procedure 2)	90*

* NOTE: After the standard 90 minute test was completed, the top latch corner of the single swing steel stiffened door was mechanically deformed to open a deflection amount equal to 1-1/2 times the door thickness from its original position and the test was continued for an additional 10 minutes.

Test Samples

The test samples consisted of a (i) wood door assembly; (ii) polystyrene core door assembly; and a (iii) steel stiffened door assembly. The doors and the appropriate hardware were obtained from the manufacturers and are described herein.

The manufacture of all doors, door frames, and hardware devices was witnessed and selected by a representative of an independent safety certification laboratory. The construction of these samples is considered proprietary. The specific construction details are on file with the independent safety certification laboratory.

Single Swing Wood Door Assembly

Doors - The doors were 3 ft. 0 in. by 7 ft. 0 in. by 1-3/4 in. thick, and were rated for 20 minutes. The core material of the door was wood particleboard. The rails and stiles were made from untreated lumber. The door faces were oak with crossbands of untreated poplar. An adhesive was used to attach the faces, and the stiles and rails to the core.

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Hardware - The door hardware consisted of mortise type lock. There were three steel door hinges (4-1/2 in. x 4-1/2 in x 0.134 in) on each door.

Frames - The fire door frames were made from 16 gauge steel and with 2 inch faces, and 5/8 inch stop. The frames were provided with masonry anchors and corners welded.

Assembly - One door was installed to swing into the fire test room, and the other to swing out.

Steel Covered Composite Fire Door Assembly

Doors - The single swing doors were 3 ft. 0 in. by 7 ft. 0 in. by 1-3/4 in. thick, and the double doors were 6 ft. 0 in. by 7 ft. 0 in. and were rated for 3 hours. The core material of the door was a polystyrene foam board. The door faces were manufactured from 18 gauge MSG steel.

Hardware - The door hardware on the single door, and the active leaf of the pair of doors consisted of a mortise type lock. The inactive leaf of the pair of doors incorporated surface mounted flush bolts. There were three steel door hinges (4-1/2 in. x 4-1/2 in. x 0.134 in) on each door.

Frames - The fire door frames were made from 16 gauge steel and with 2 inch faces, and 5/8 inch stop. The frames were installed with masonry anchors and corners welded.

Assembly - The single swing door was installed to swing into the fire test room. The pair of doors was installed to swing into the room.

Steel Stiffened Fire Door Assembly

Doors - The single doors were 3 ft. 0 in. by 7 ft. 0 in. by 1-3/4 in. thick, and the double doors were 6 ft. 0 in. by 7 ft. 0 in. and were rated for 3 hours. The steel stiffeners were spaced 2-1/2 in. from sides, and 6 in. on the center. Fiberglass insulation was assembled between the stiffeners. The door faces were manufactured from 18 gauge MSG steel.

Hardware - The door hardware on the single swing door, and the active leaf of pair of doors consisted of mortise type lock. The inactive leaf of the pair of doors incorporated surface mounted flush bolts. There were three steel door hinges (4-1/2 in. x 4-1/2 in. x 0.134 in) on each door.

Frames - The fire door frames were made from 16 gauge steel and with 2 inch faces, and 5/8 inch stop. The frames were installed with masonry anchors and corners welded.

Assembly - The single swing door was installed to swing into the fire test room. The pair of doors was installed to swing into of the room.

Results

Test 1 - Single Swing Wood Door Assembly

Test 1 was conducted on the wood door assemblies using the procedure described in "Calibration Test 1" and the test data for the test are presented in Appendix C.

Test 2 - Single Swing Wood Door Assembly

The test data and observations on the wood door assemblies using the procedure described in "Calibration Test 2" are described herein.

Observations - The test observations are tabulated in Table 5.

Table 5 - Observations Test 2

Time (min:sec)	Observations
00:00	Steel Damper set at 18".
00:34	Heavy smoke escaping along top and sides of the single door swinging in.
1:00	Exposed side - doors burning.
1:35	Flashover.
2:30	Raised Steel Damper to 20".
3:35	Smoke escaping between frame and block on single door swinging out.
4:00	Slight char to frame on single door swinging out.
4:00	Raised Steel Damper to 25".
5:00	Lowered Steel Damper to 22".
5:30	Flame escaping between the left corner of the stationary wall (South wall) and top left corner of moveable door assembly (single door swinging out). Insufficient packing on exposed side.
6:15	Lowered Steel Damper to 18".
6:27	Slight charring on single door swinging in - top right.
6:50	Cotton pad test on single door swinging out - no char.
7:33	Bowing beginning on single door swinging out.
7:48	Cotton pad test on single door swinging in - no char.
8:15	Door knob and plate sweating with slight smoke on both doors.
8:33	Crackling from single door swinging out.
9:35	Raised Steel Damper to 20".
10:00	Raised Steel Damper to 22".
10:13	Single door swinging out bowing 1/2" on top at latch side.
11:25	Lowered Steel Damper to 20".
12:08	Frame on single door swinging out (top left) seems disfigured.
12:37	Hissing from right door single door swinging in.
13:00	Cotton pad test on single door swinging out - slight char.

Time (min:sec)	Observations
14:30	Char to top right corner of single door swinging in.
17:25	Lowered Steel Damper to 20".
18:00	Lowered Steel Damper to 17".
19:00	Excess sweating on frame (top) of single door swinging out.
20:00	Test terminated.

Clearances and Deflections - The amounts of door clearances and deflections are tabulated in Table 6.

Table 6 - Clearances and Deflections Test 2

	Measurement Pt.	Clearances (in.)	
		Pre-Test	Post-Test
Single Door Opening Out	Top	1/8	1/8
	Hinge Side	1/8	1/8
	Bottom	1/4	1/2
	Latch Side	1/8	3/16
Single Door Opening In	Top	1/8	1/8
	Hinge Side	1/8	1/16
	Bottom	1/4	1/4
	Latch Side	1/8	1/16
	Measurement Pt.	Deflection (in.) Into Room	
Time (mins.)		0:00	20:00
Single Door Opening Out	Midpoint	0	*
Single Door Opening In	Midpoint	0	*

* No measurable deflection

Temperature Data - The time-temperature fire exposure to the test samples as measured by the control thermocouples is shown in Figure 12. The temperatures at the ceiling recorded by the ISO 3008 thermocouples are shown in Figure 13. The temperatures recorded at the fire door test samples are presented in Figure 14 and Figure 15 for the door opening outwards and inwards, respectively. The temperatures at the sidewall are shown in Figure 16; and the window opening temperatures are shown in Figure 17.

Pressure Data - The pressure at the top of the test sample, and 40 inches above the floor are shown in Figure 18.

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Location of Neutral Pressure Plane - The location of the neutral pressure plane was calculated by interpolating the data at 40 inches and 84 inches using a straight line interpolation. The location of the neutral pressure plane during the test is depicted in Figure 19.

Cotton Pad Test - The results of the cotton pad test are summarized in Table 5.

Test Data - The tabulated data for Test 2 are presented in Appendix D.

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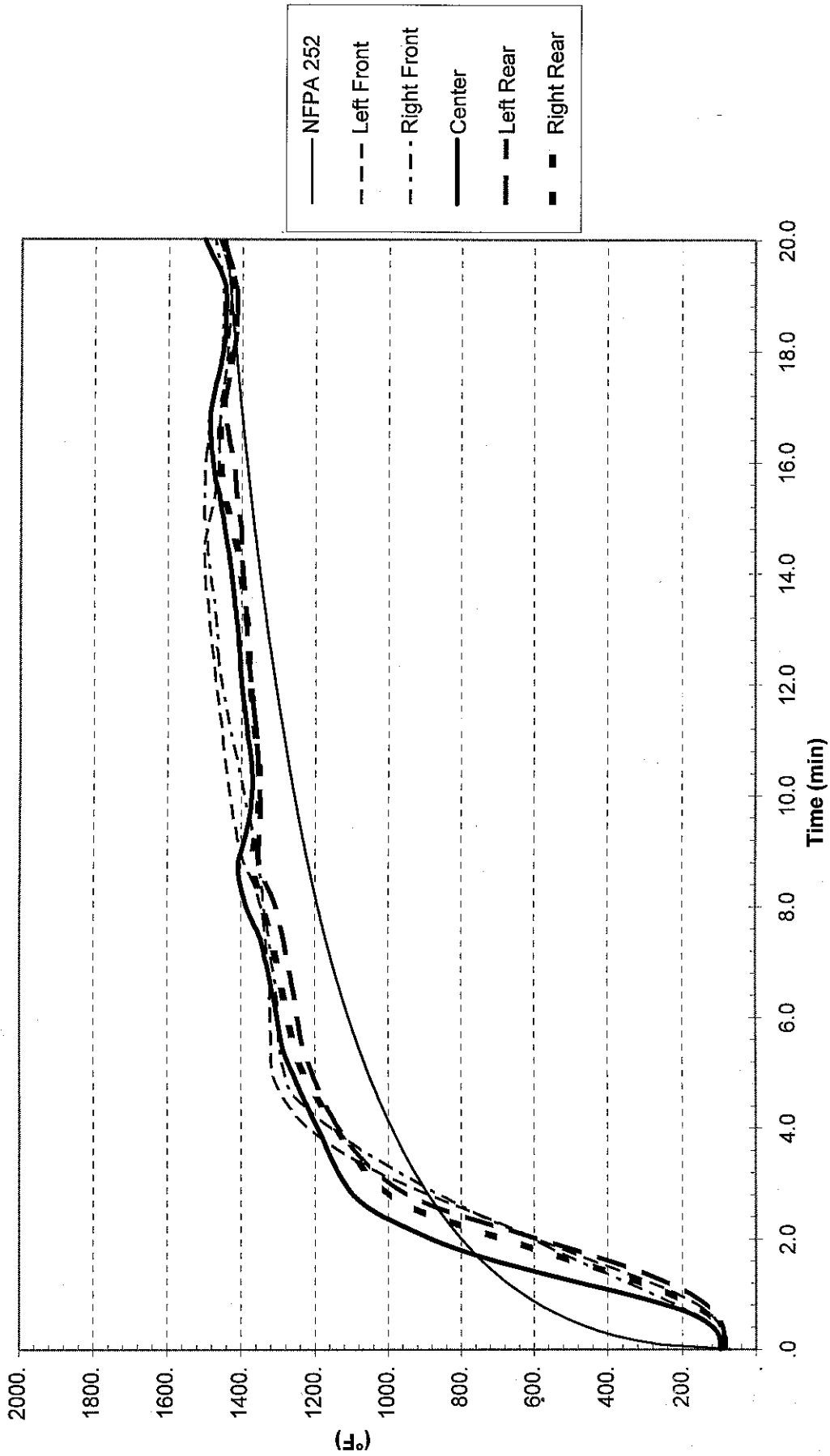


Figure 12. Time-Temperature Exposure: Test 2

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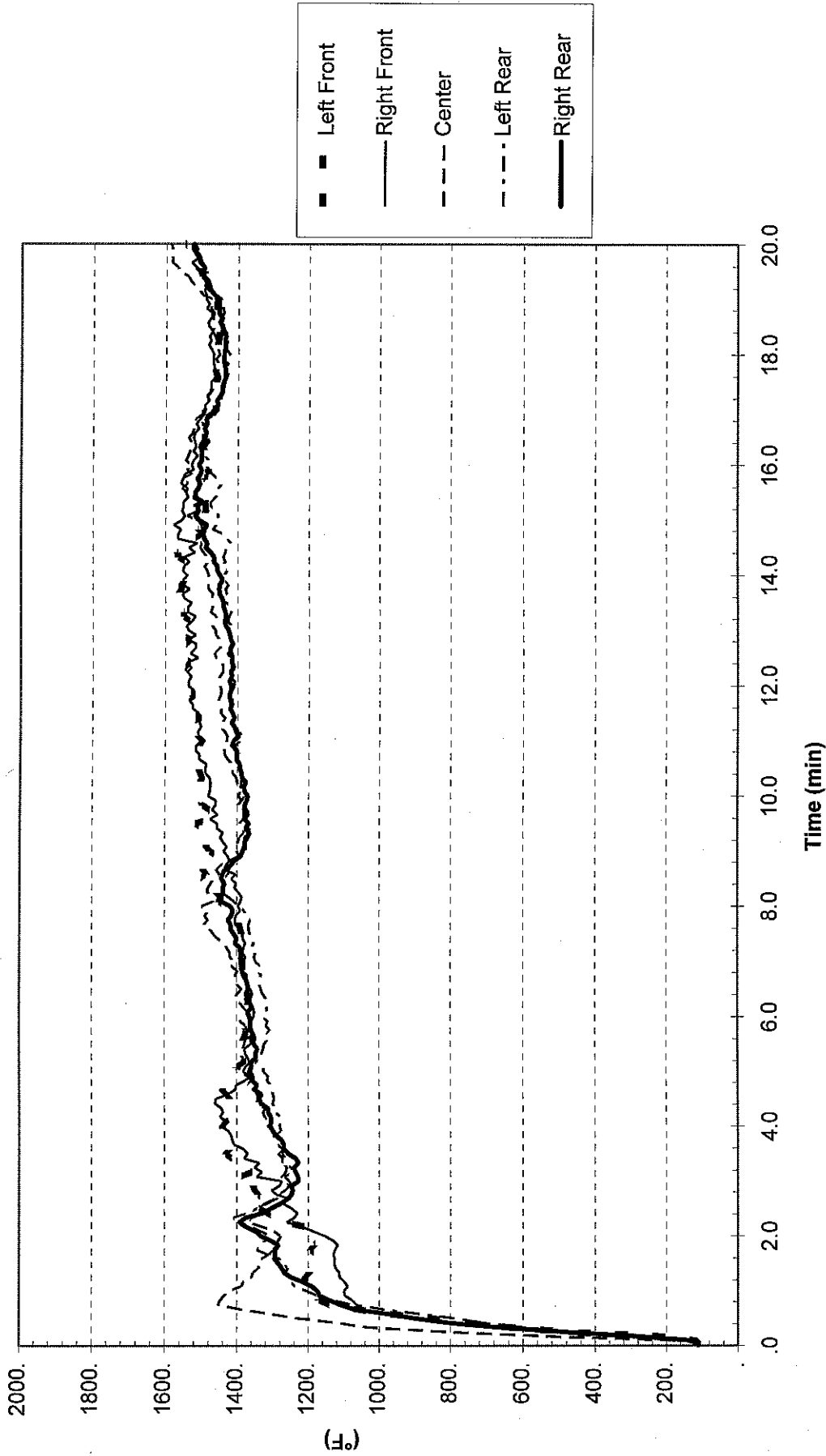


Figure 13. Ceiling Temperatures Measured by Bare Bead Thermocouples: Test 2

National Fire Door Fire Test Project

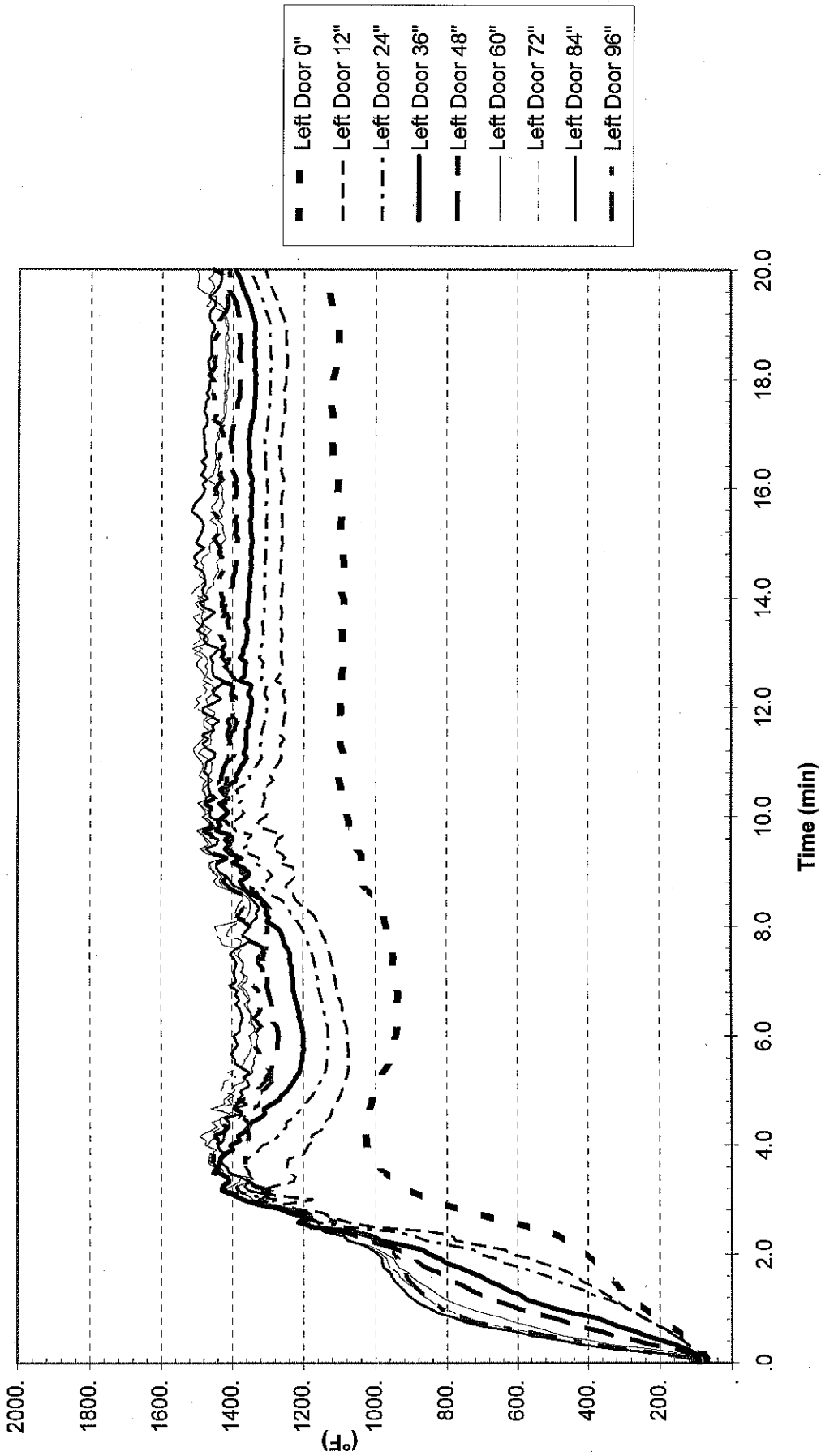


Figure 14. Temperatures Measured at the Single Door Opening Out: Test 2

National Fire Door Fire Test Project

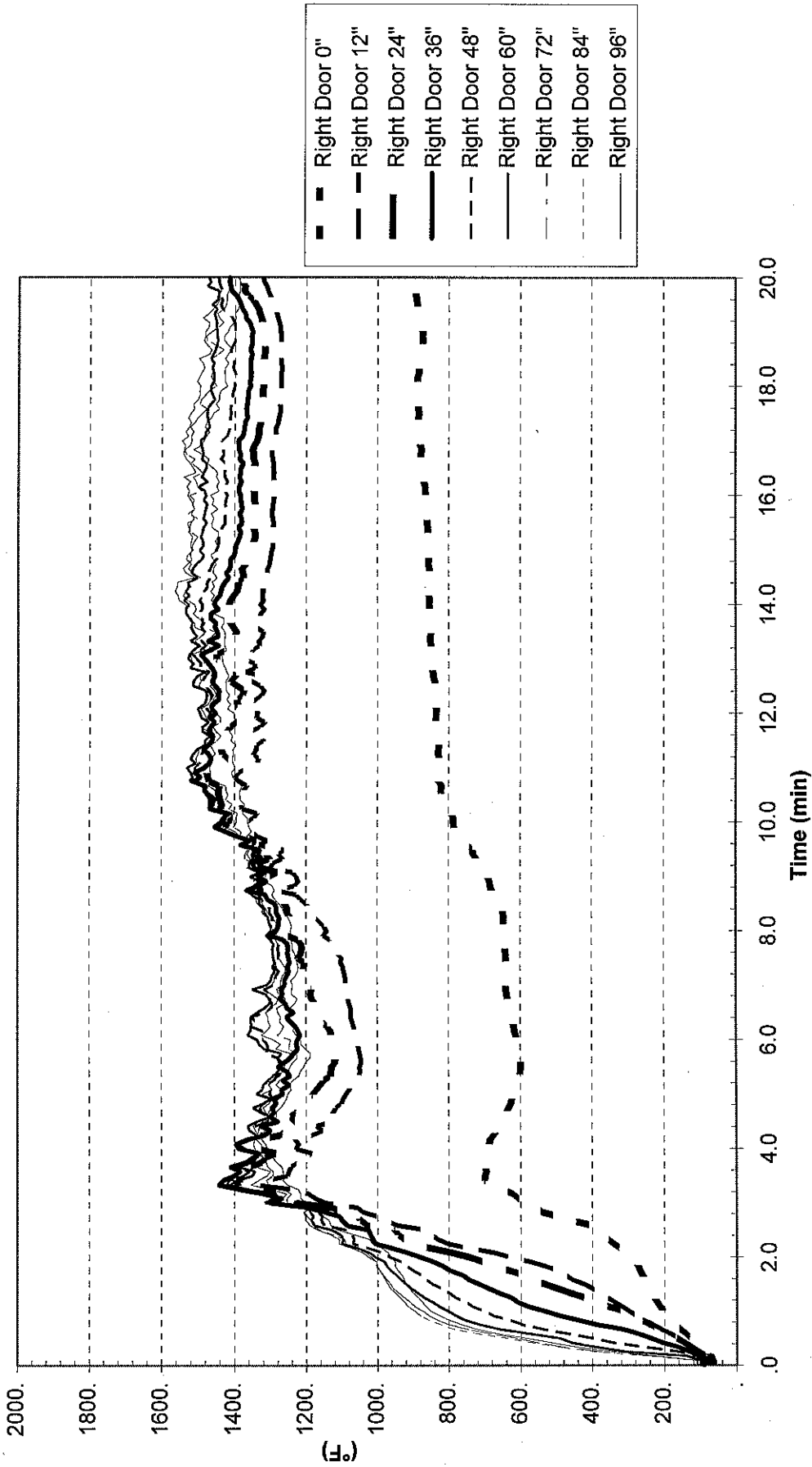


Figure 15. Temperatures Measured at the Single Door Opening In: Test 2

National Fire Door Test Project

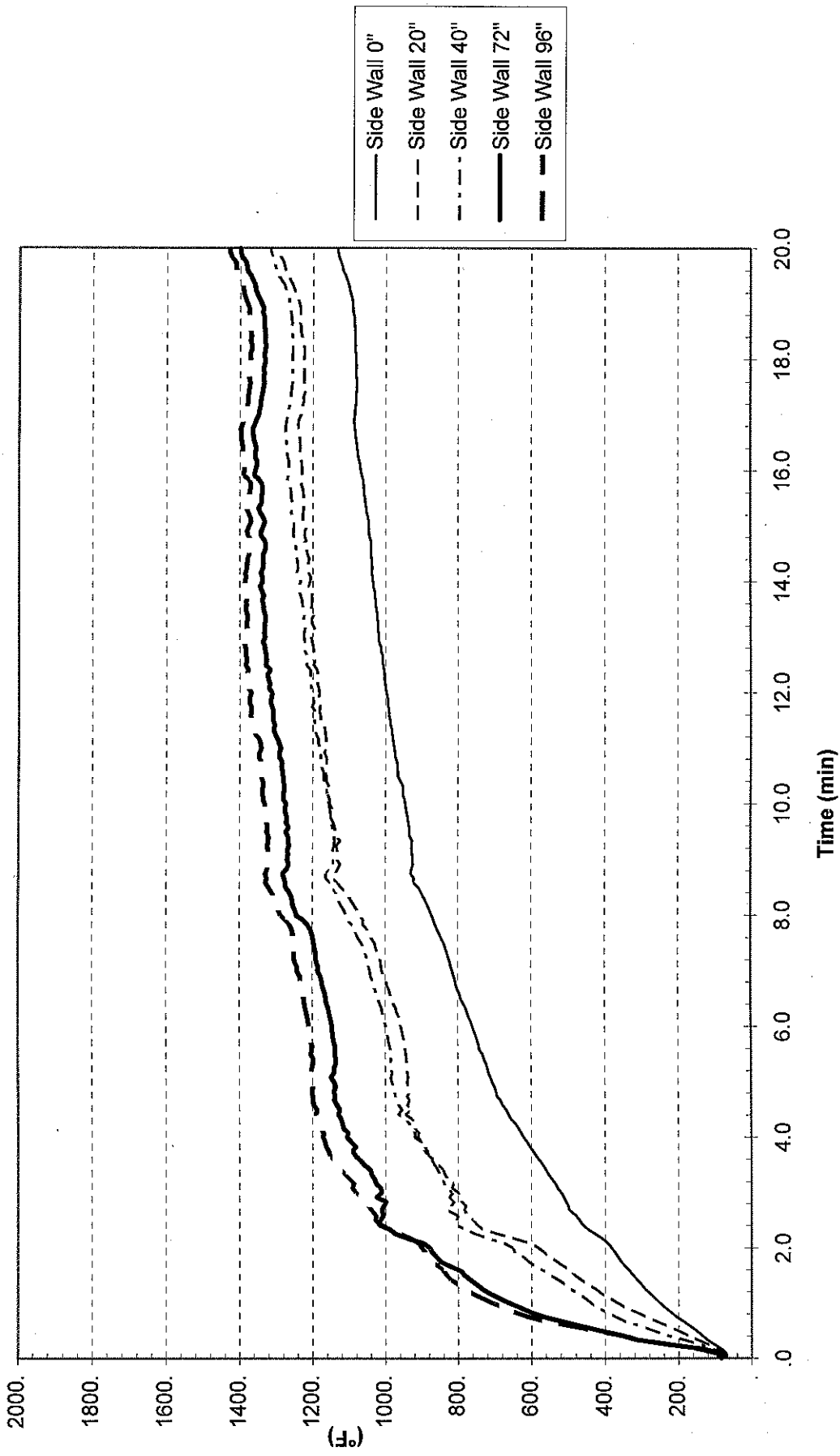


Figure 16. Temperatures Measured at the Side Wall: Test 2

National Fire Door Test Project

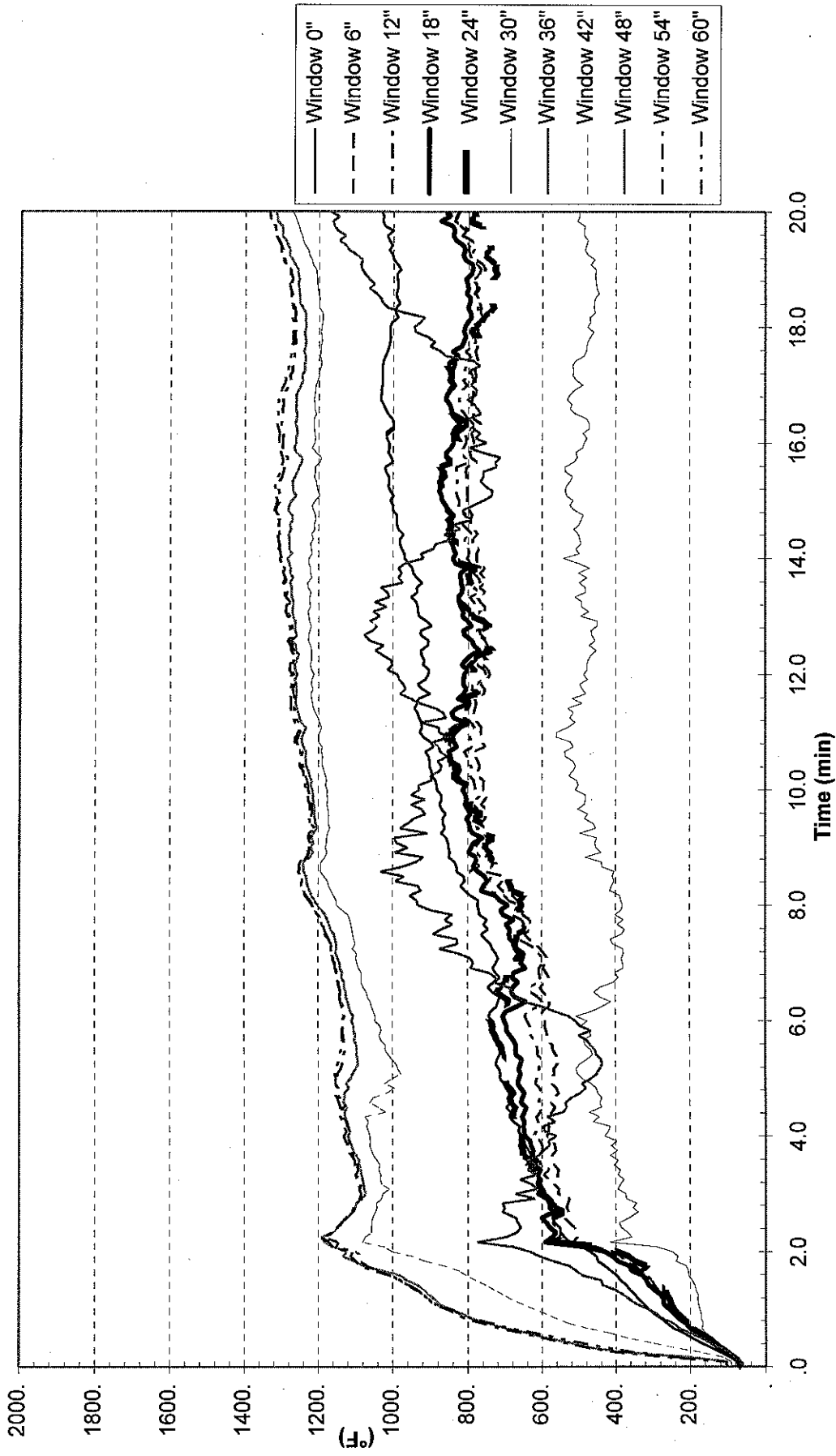


Figure 17. Temperatures Measured at the Window Opening: Test 2

National Fire Door Test Project

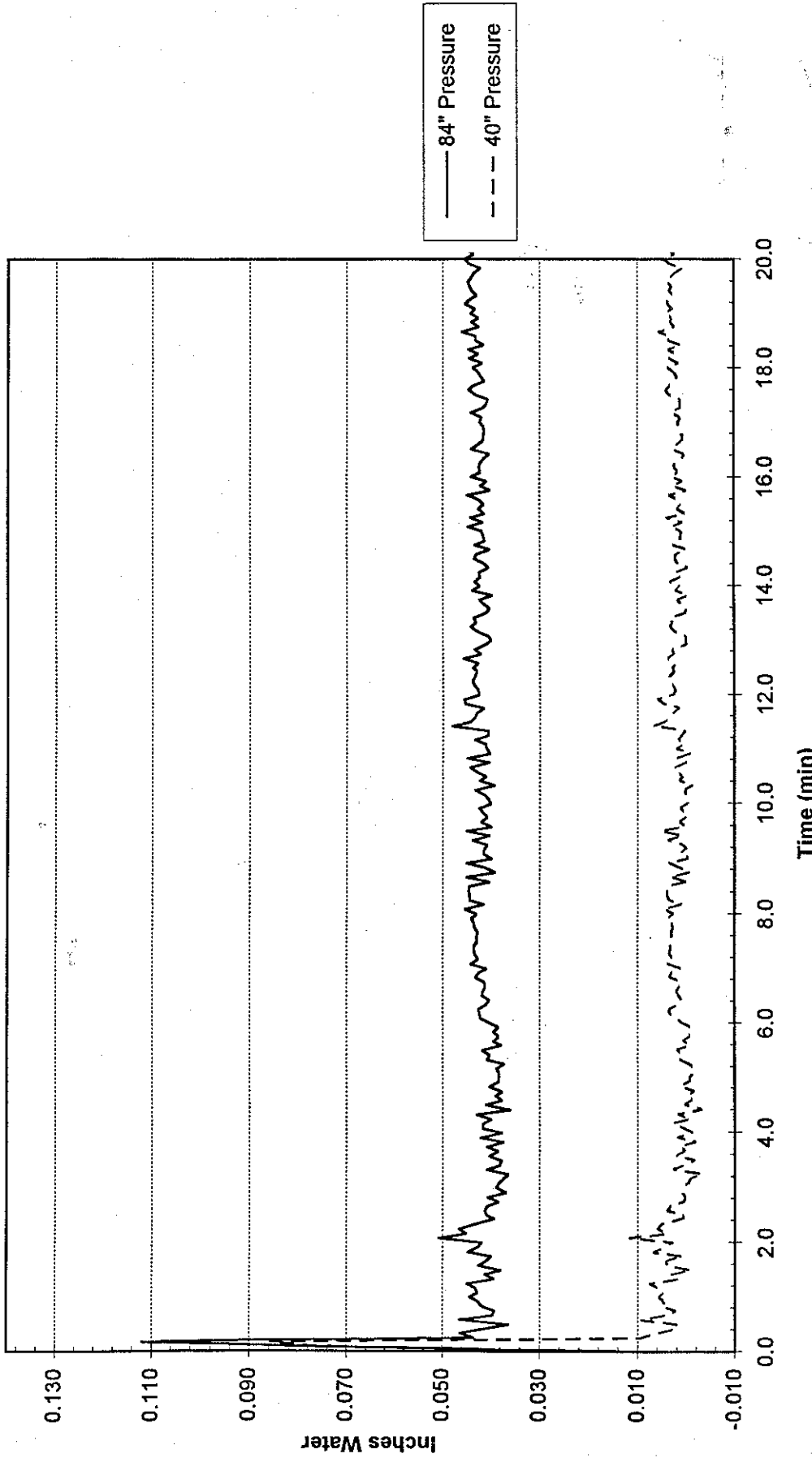


Figure 18. Pressure in the Fire Test Room: Test 2

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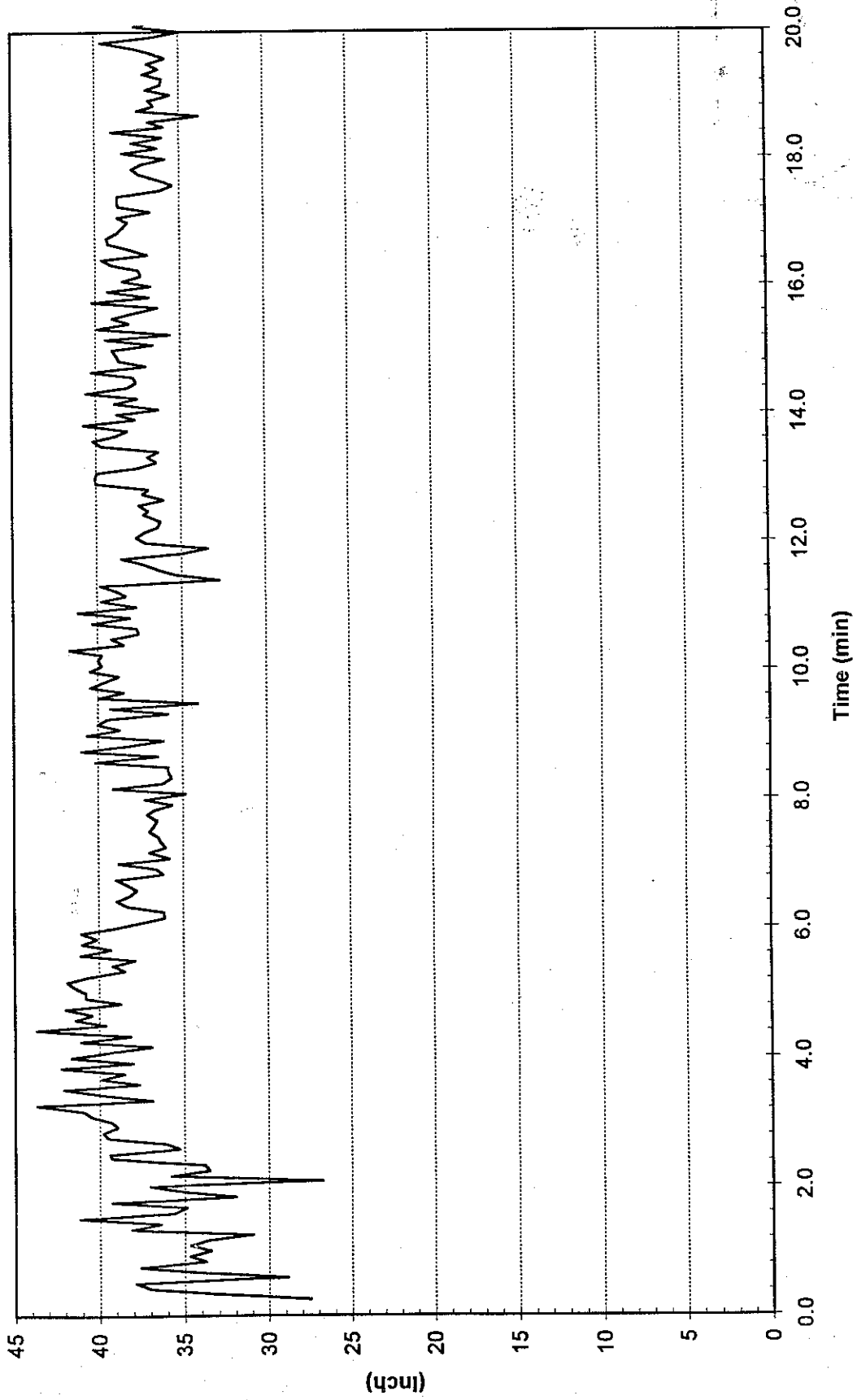


Figure 19. Location of the Neutral Pressure Plane: Test 2

Test 3 - Steel Covered Composite Fire Door Assembly

The test data and observations on the steel covered composite fire door assemblies using the procedure described in "Calibration Test 2" are described herein.

Observations - The test observations are tabulated in Table 7.

Table 7- Observations Test 3

Time (min:sec)	Observations
00:00	Steel Damper set at 18".
00:35	Slight smoking on all three doors.
1:20	Doors beginning to discolor from both smoke and polystyrene.
1:25	Flashover
2:33	Slight bowing on top of Active door.
2:40	Raised Steel Damper to 20".
3:00	1/8" gap at meeting edge of double doors from sill to lock assembly.
3:50	Raised Steel Damper to 22".
5:15	Lowered Steel Damper to 18".
7:10	Lowered Steel Damper to 16".
7:25	Cotton pad test to double doors - nothing.
8:20	Polystyrene melting and dripping to sill under each door.
8:55	Buckling beginning on all three doors.
9:22	Both sills ignited on the unexposed side.
12:20	Active door moved away from the inactive door by 3/4" just above sill.
13:02	Flashover to ceiling.
13:15	Large amounts of black smoke emitting from meeting edge of double doors.
15:00	Raised Steel Damper to 20".
17:40	Raised Steel Damper to 24".
21:00	Very slight smoke from all three door. Seems to be subsiding.
23:40	Intermittent smoke on all three doors.
24:51	Crackling from double doors.
34:30	Flashover burst.
36:15	Raised Fire Damper to 26".
39:26	Lock assembly on double doors beginning to solder.
44:55	Single door smoking between frame and block.
50:00	Raised Steel Damper to 27".
59:22	Lock assembly on single door beginning to solder.
60:00	No change.
1:02:00	Lowered Steel Damper to 26".
1:14:30	No change.
1:27:30	Large flashover spurt.
1:28:40	Large flashover spurt.

1:30:00	Test Terminated.
---------	------------------

Clearances and Deflections - The amounts of door clearances and deflections are tabulated in Table 8.

Table 8 - Clearances and Deflections Test 3

		Clearances (in.)		Clearances (in.)	
		Pre-Test		Post-Test	
Single Door	Top	3/16		1/8	
	Hinge Side	1/8		3/16	
	Bottom	1/4		1/2	
	Latch Side	1/8		1/16	
Inactive Door	Top	3/16		1/16	
	Hinge Side	1/8		3/16	
	Bottom	1/4		1/2	
	Latch Side	1/8		1/4	
Active Door	Top	3/16		1/16	
	Hinge Side	1/8		1/4	
	Bottom	1/4		3/16	
	Latch Side	1/8		1/4	
	Measurement Pt.	Deflection (in.) Into Room			
Time (mins.)		0:00	9:00	17:00	30:00
Single Door	Midpoint	0	1/8	-1/8	-1/8
Inactive Door	Midpoint	0	1-3/8	1-1/8	1-5/8
Active Door	Midpoint	0	1-7/8	1-3/8	1-3/8

Temperature Data - The time-temperature fire exposure to the test samples as measured by the control thermocouples is shown in Figure 20. The temperatures at the ceiling recorded by the ISO 3008 thermocouples are shown in Figure 21. The temperatures recorded at the single fire door test sample are presented in Figure 22. The temperatures at the double fire door test sample are presented in Figure 23; and for the inactive and the active doors in Figure 23a and Figure 23b, respectively. The temperatures at the sidewall are shown in Figure 24; and the window opening temperatures are shown in Figure 25.

(Note: Due to temporary equipment malfunction, gaps in data are present in the graphs shown in Figure 23a and Figure 23b)

Pressure Data - The pressure at the top of the test sample, and 40 inches above the floor are shown in Figure 26.

Location of Neutral Pressure Plane - The location of the neutral pressure plane was calculated by interpolating the data at 40 inches and 84 inches using a straight line

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interpolation. The location of the neutral pressure plane during the test is depicted in Figure 27.

(Note: Due to temporary equipment malfunction, gaps in data are present in the graphs shown in Figure 26 and Figure 27)

Cotton Pad Test - The results of the cotton pad test are summarized in Table 7

Test Data - The tabulated data for Test 3 are presented in Appendix D.

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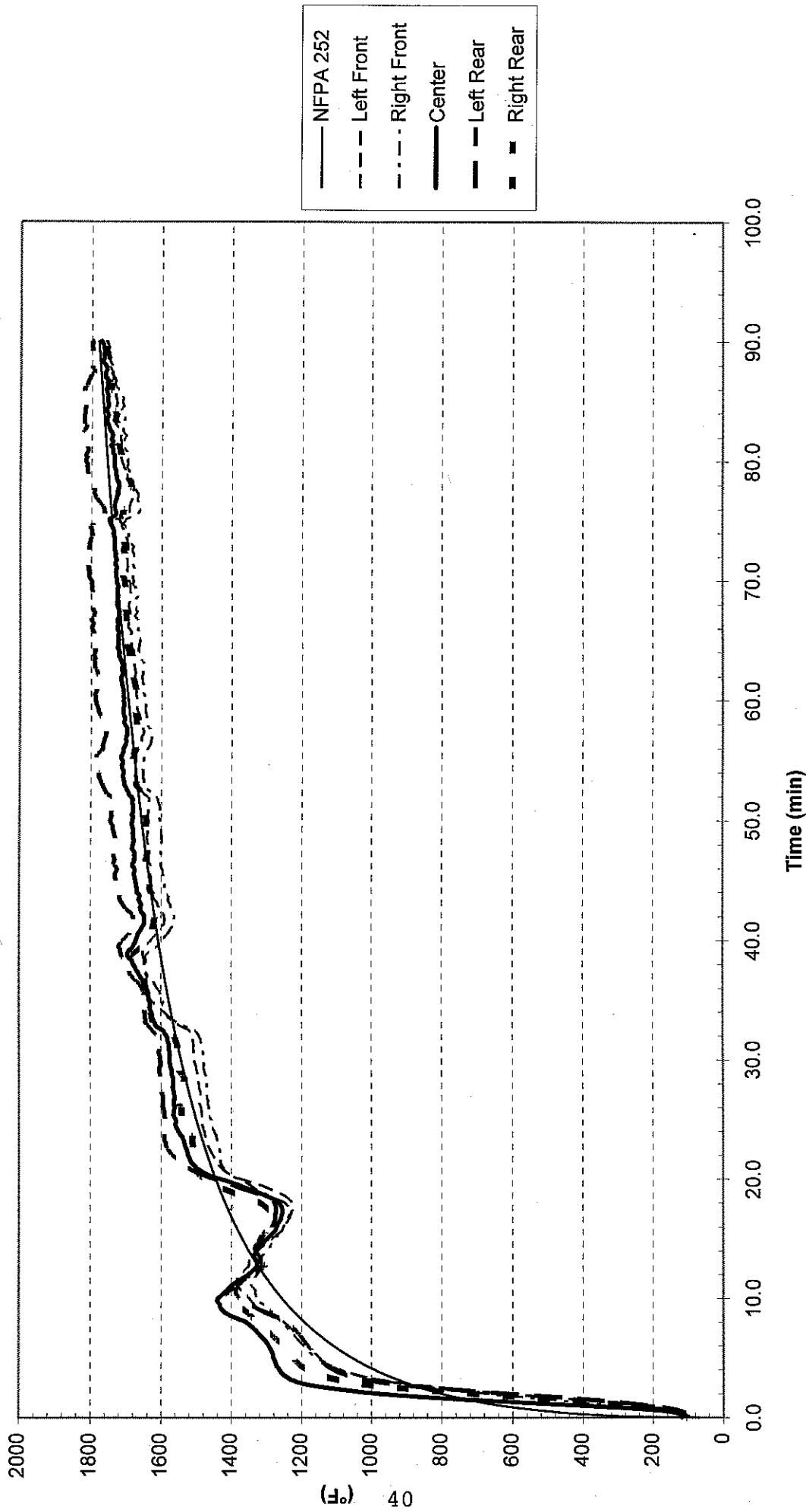


Figure 20. Time-Temperature Exposure: Test 3

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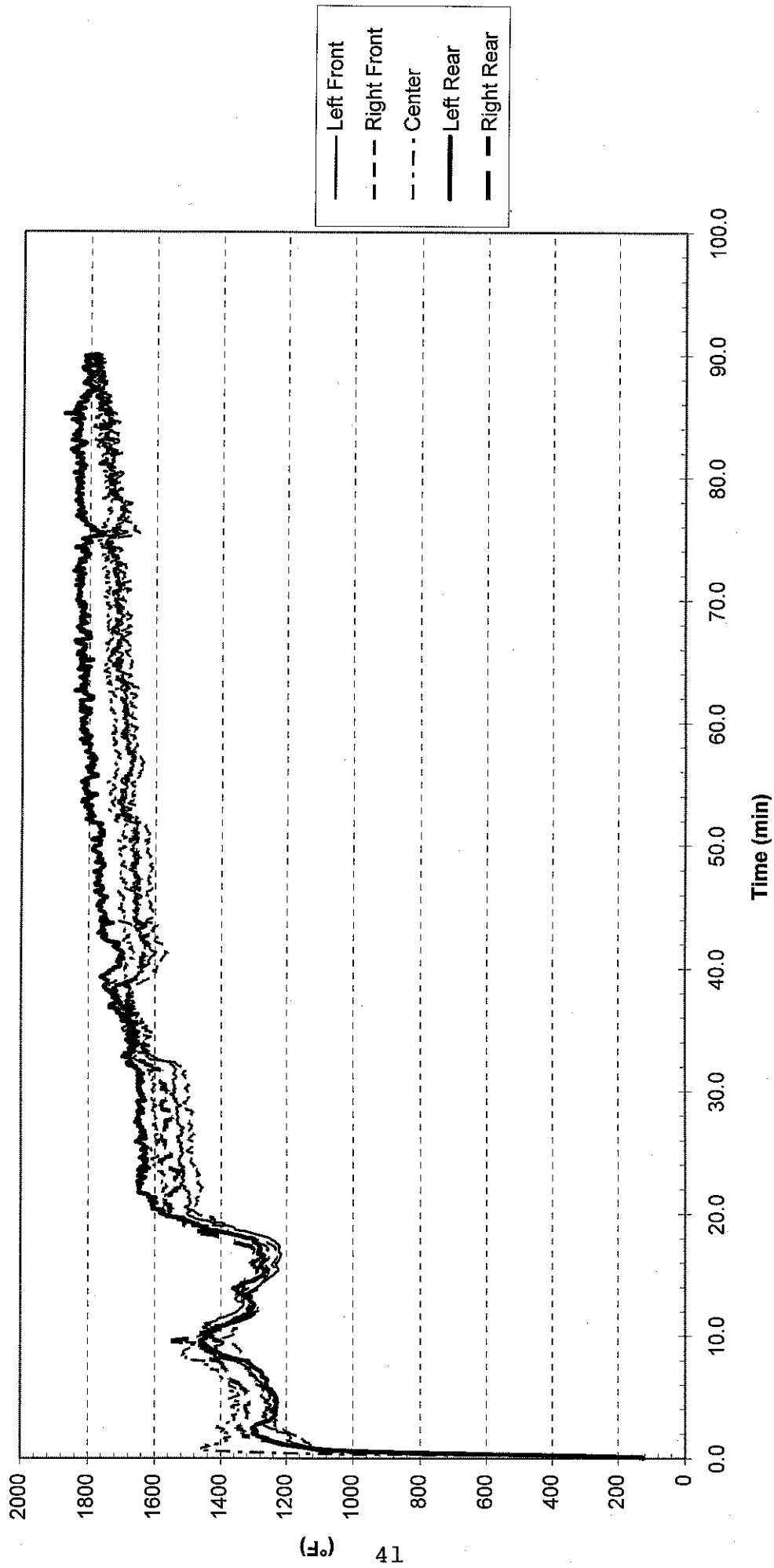


Figure 21. Ceiling Temperature Measured by Bare Bead Thermocouples : Test 3

National Fire Door Test Project

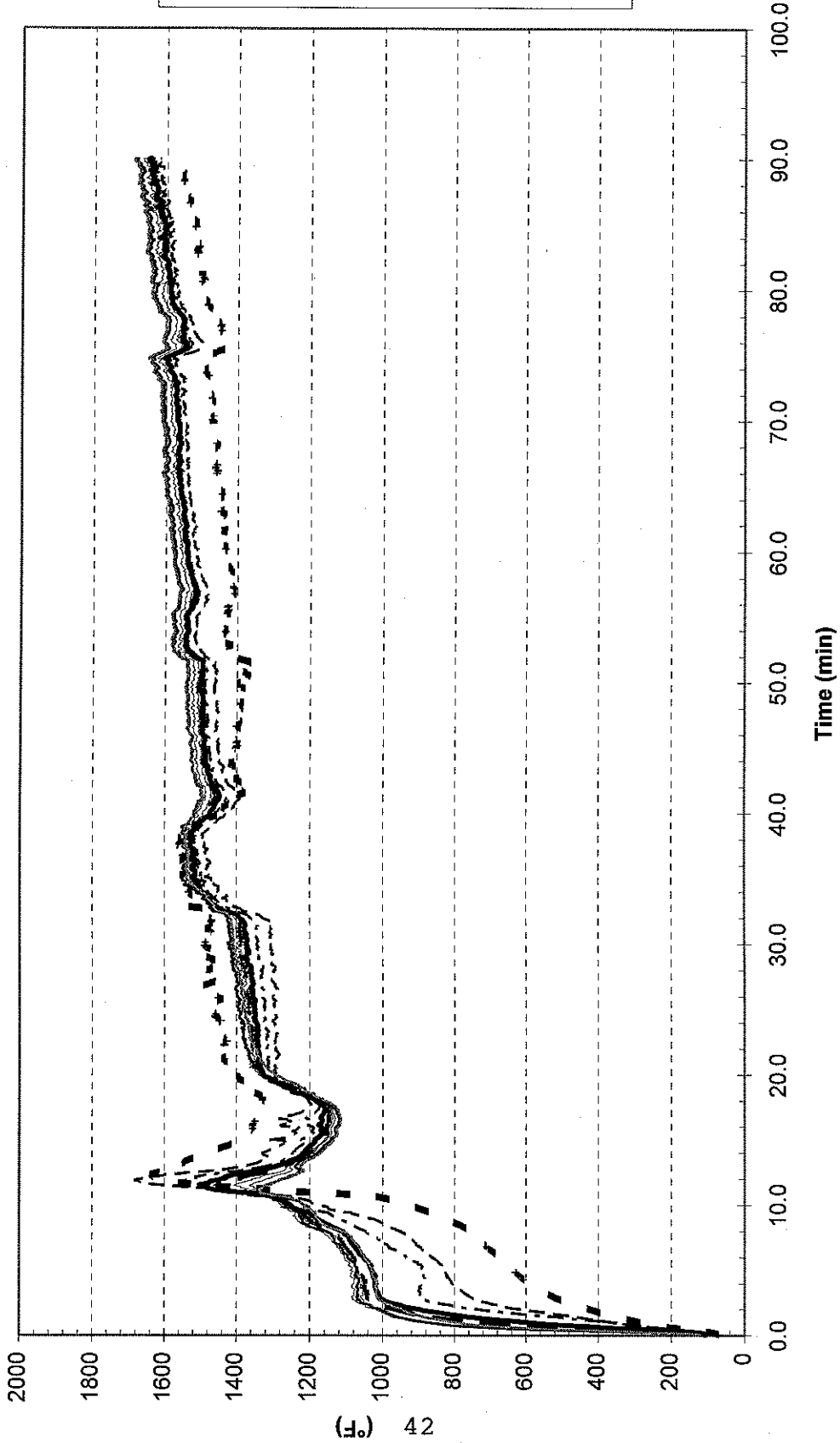


Figure 22. Temperatures measured at the Single Door Assembly: Test 3

National Fire Door Test Project

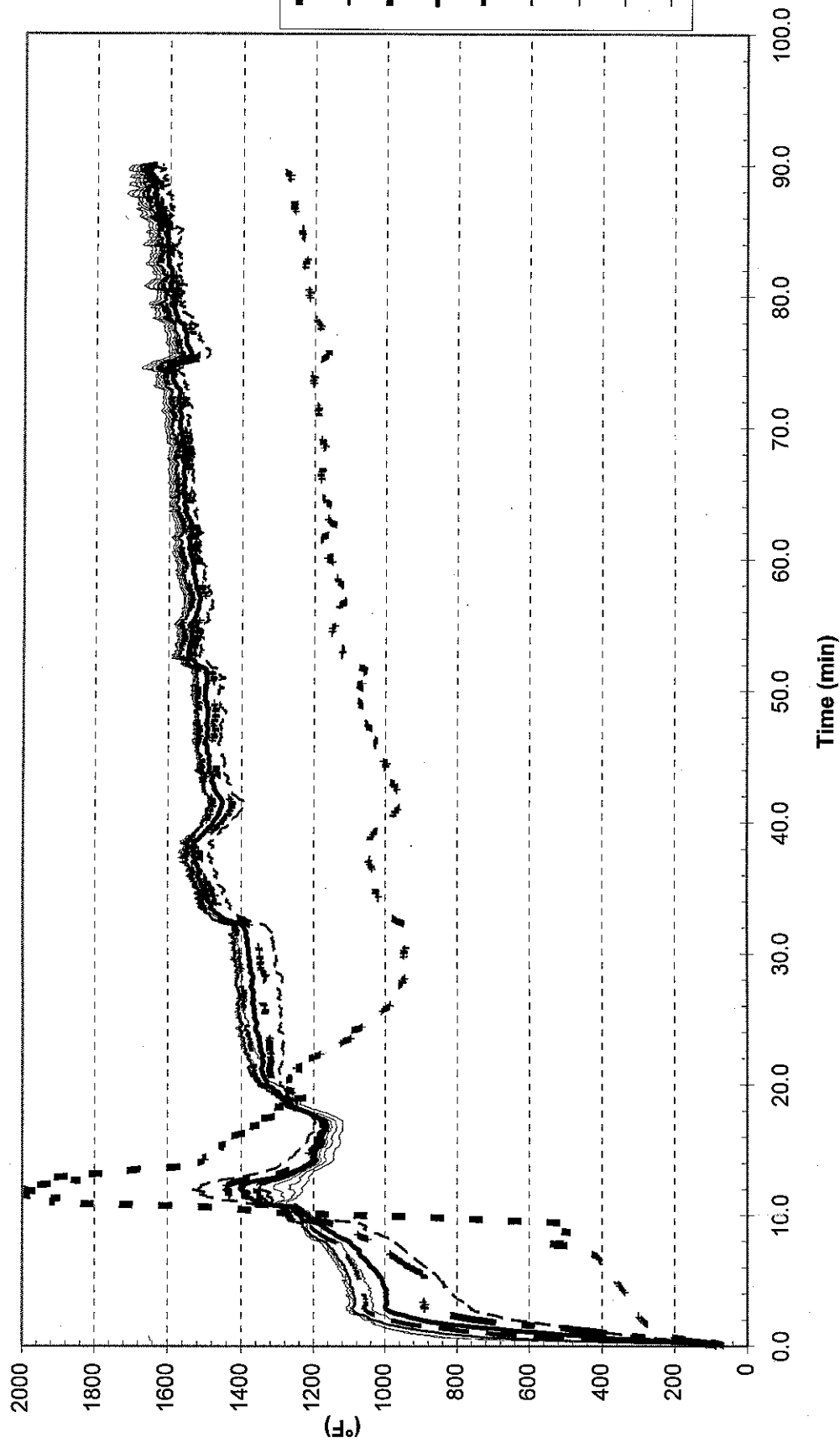


Figure 23. Temperatures Measured at the Double Door Assembly: Test 3

National Fire Door Test Project

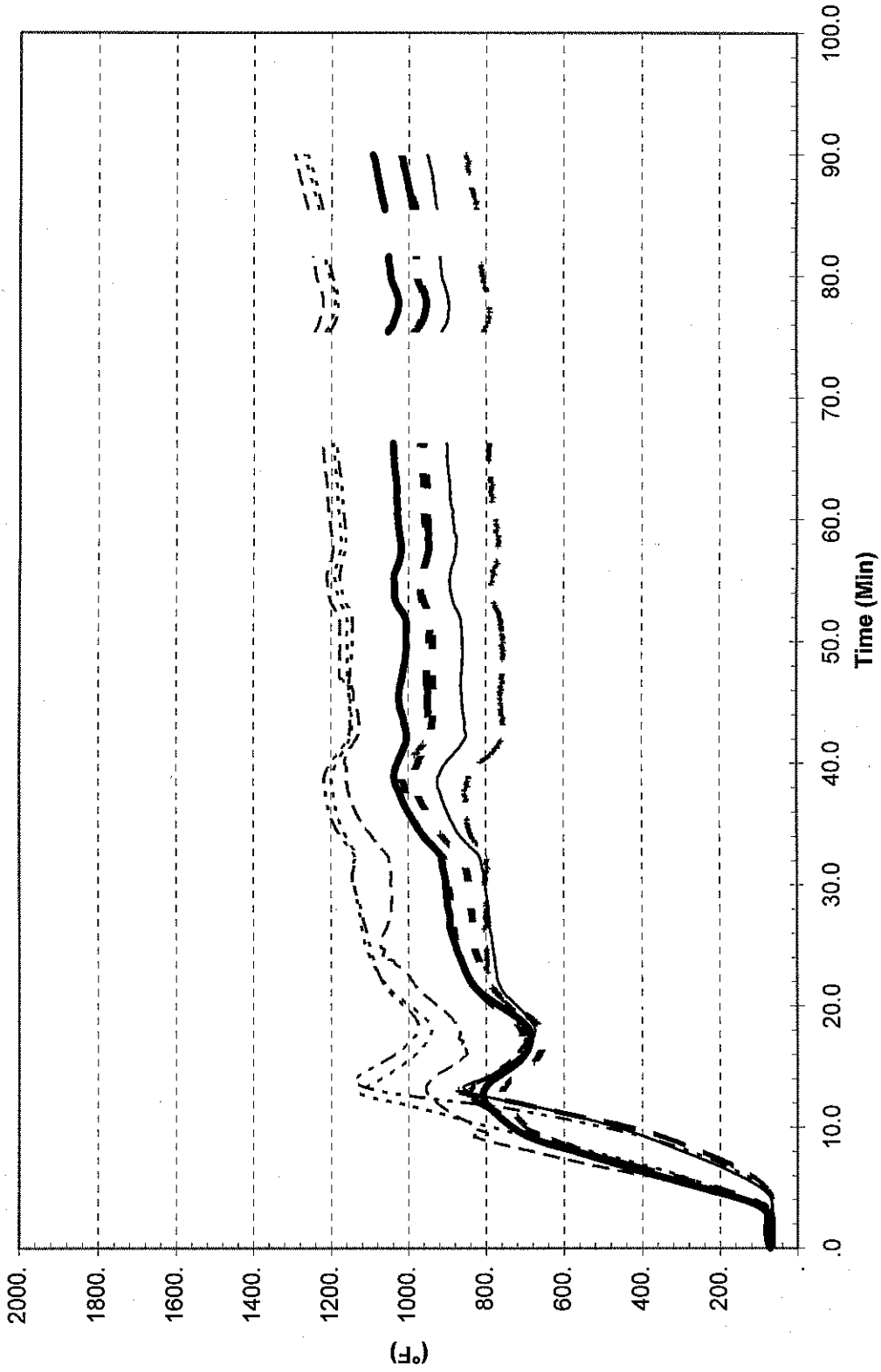


Figure 23-a. Temperatures Measured at the Unexposed Inactive Door: Test 3

National Fire Door Test Project

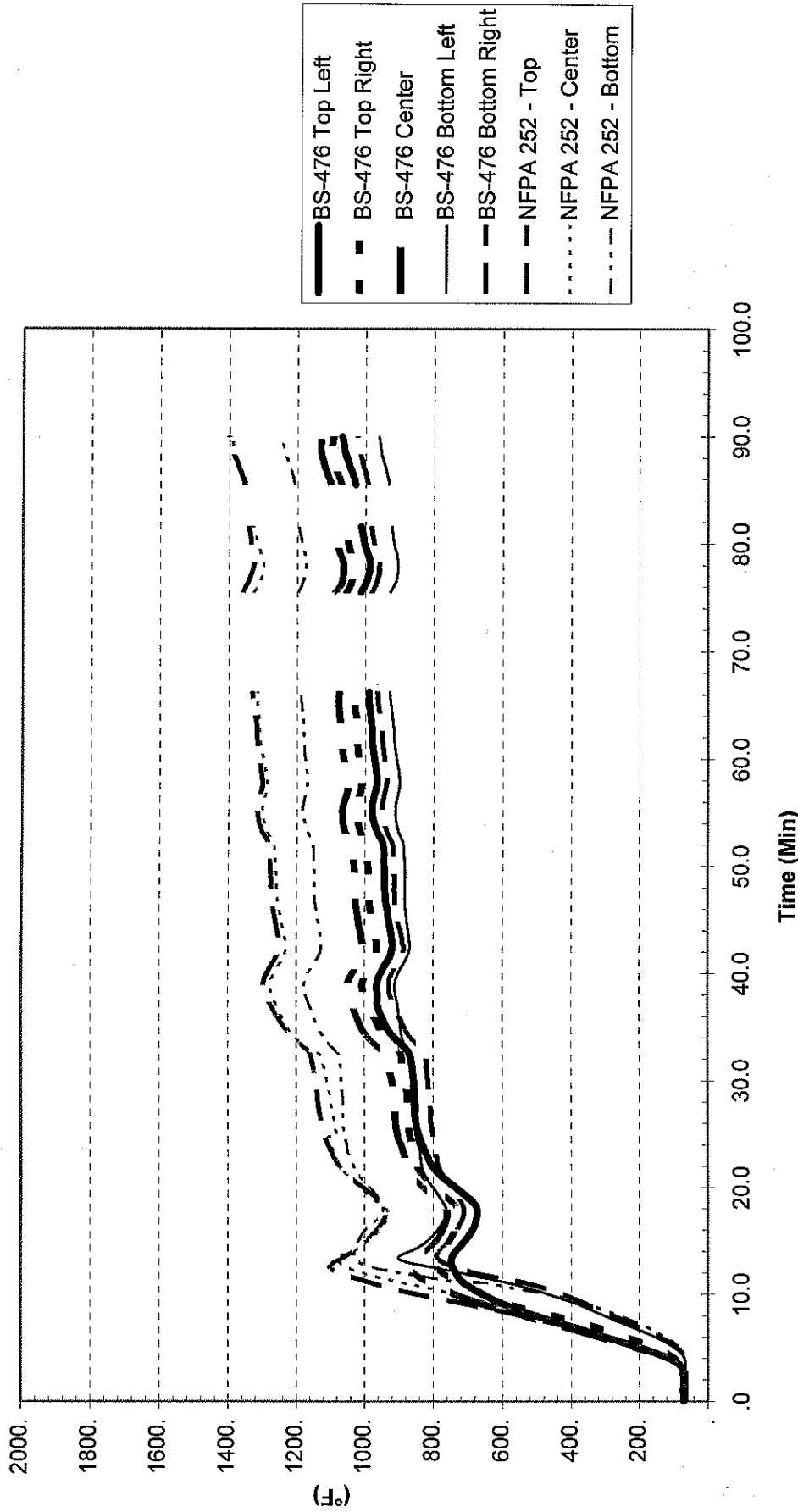


Figure 23-b. Temperatures Measured at the Unexposed Active Door: Test 3

National Fire Door Test Project

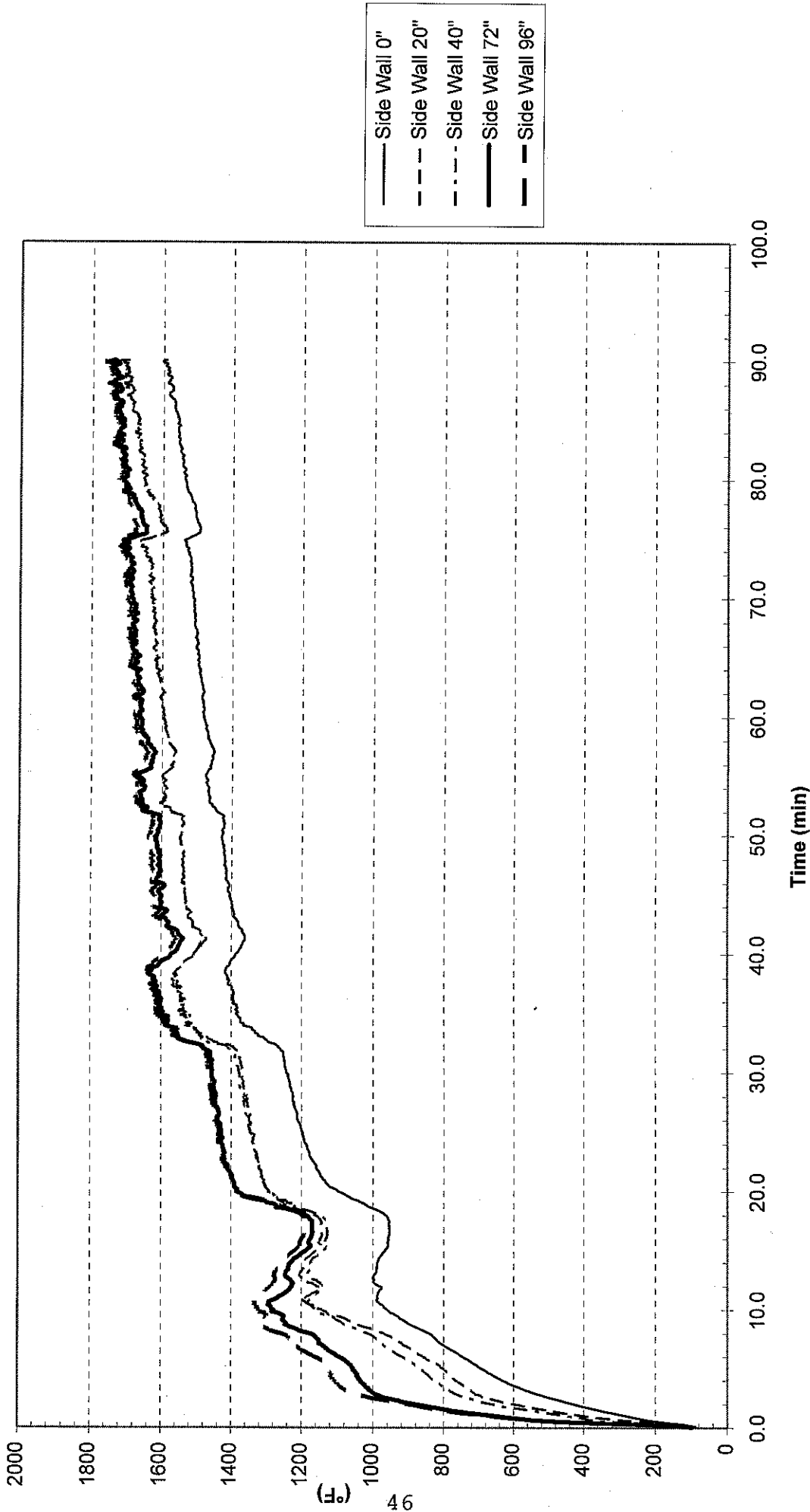


Figure 24. Temperatures Measured at Side Wall : Test 3

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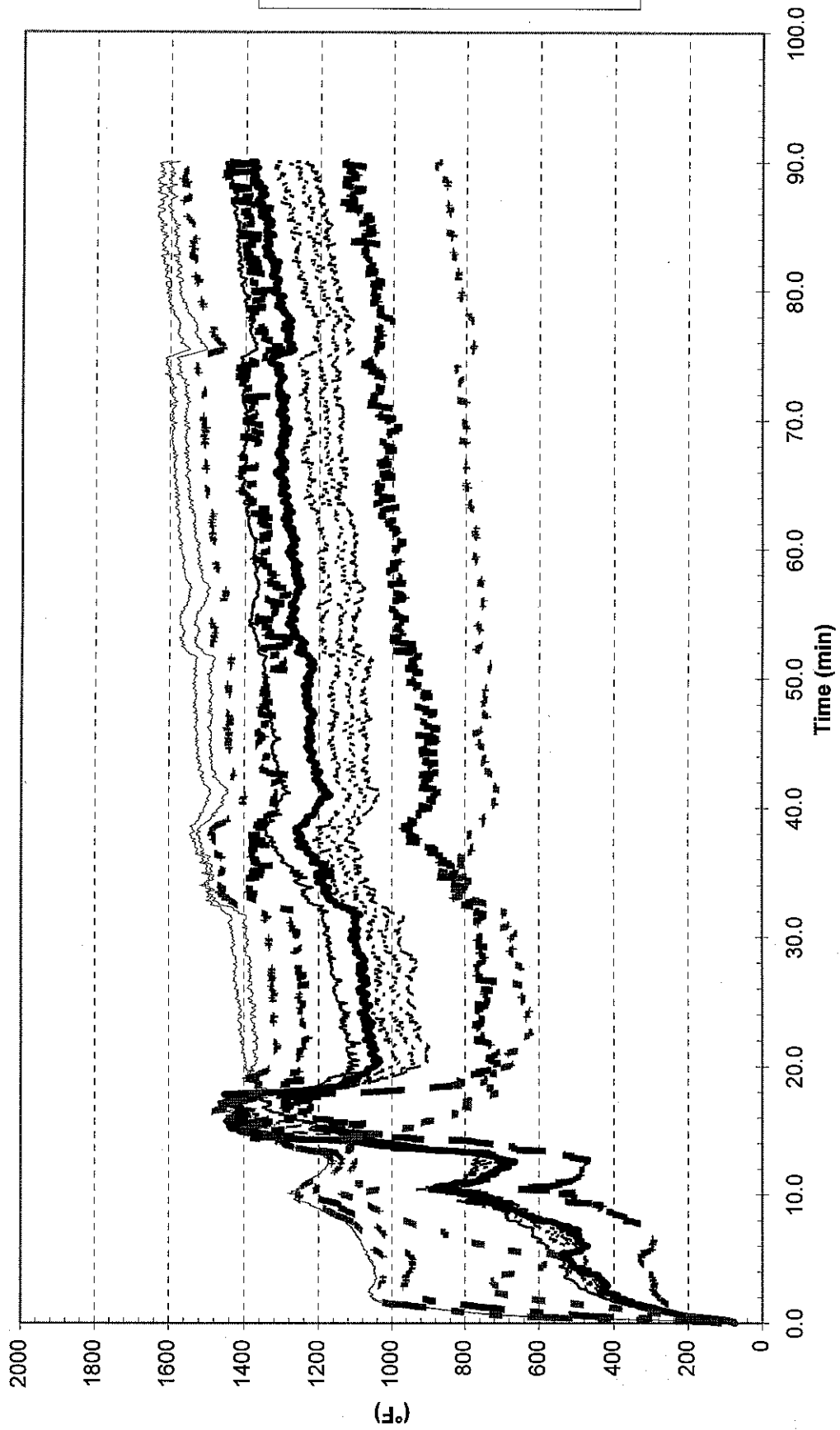


Figure 25. Temperatures Measured at the Window Opening: Test 3

National Fire Door Test Project

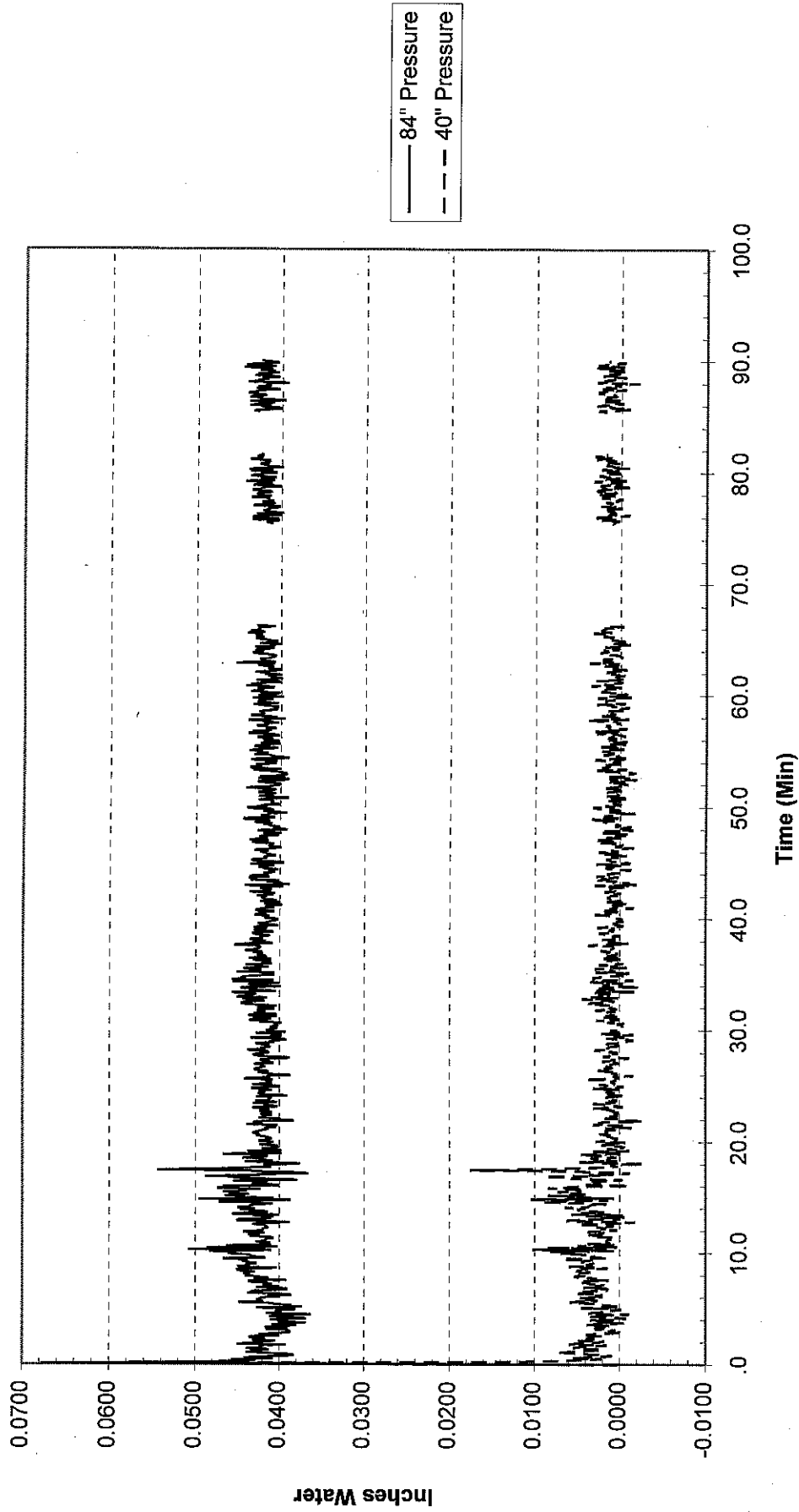


Figure 26. Pressure in the Fire Test Room: Test 3

National Fire Door Test Project

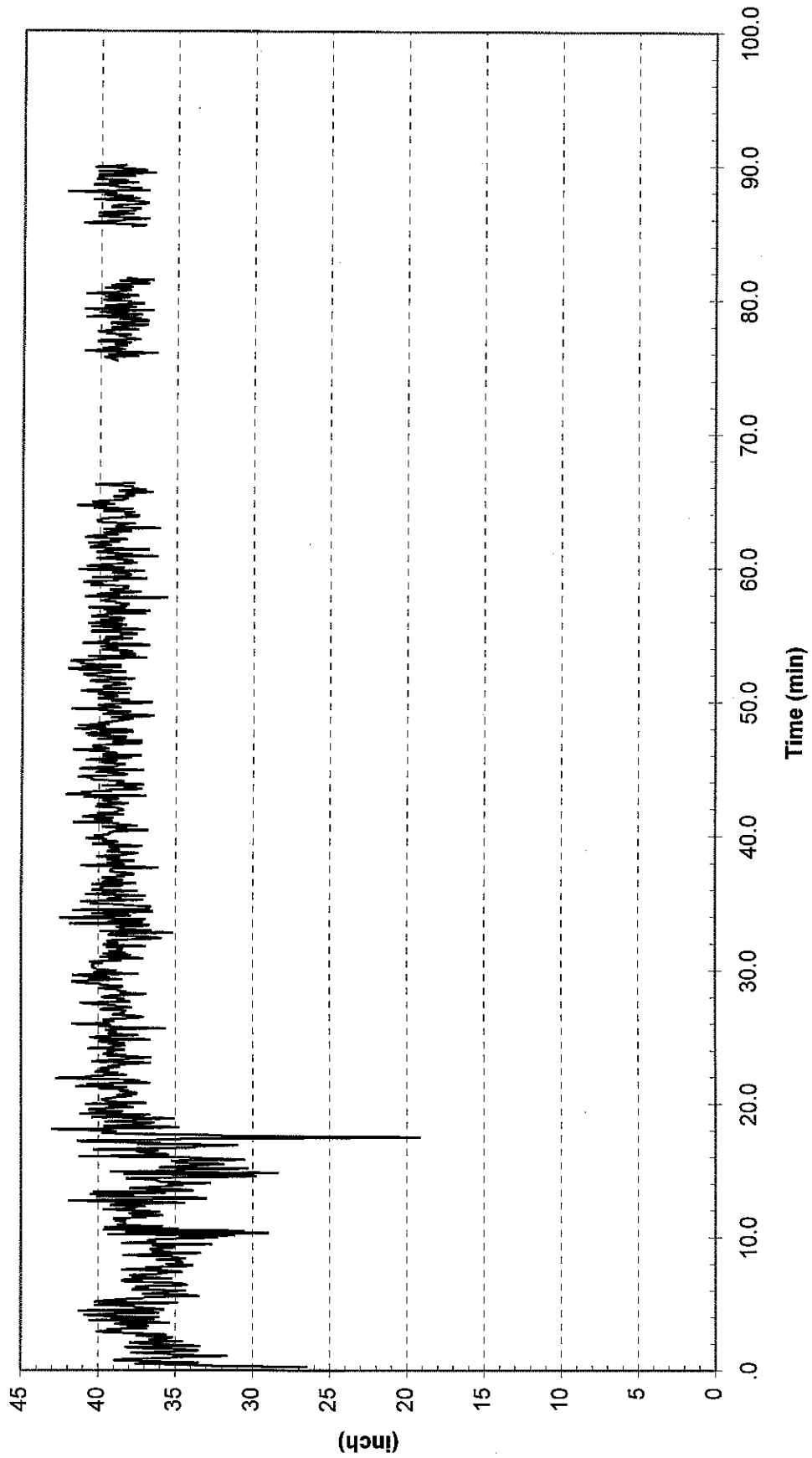


Figure 27. Location of the Neutral Pressure Plane: Test 3

Test 4 - Steel Stiffened Fire Door Assembly

The test was conducted as described in "Calibration Test 2". However, the top latch corner of the single swing door assembly was deflected 1-1/2 times the thickness of the door at the end of 90 minute fire exposure using a screw-nut assembly welded to the door frame. The fire test was continued for an additional 10 minutes, and flaming of the gases from the opening created was observed. The test data and observations on the steel stiffened fire door assembly are described herein.

Observations - The test observations are tabulated in Table 9.

Table 9- Observations Test 4

Time (min:sec)	Observations
00:00	Steel Damper set at 18".
00:00	Some insulation on sill of exposed side - active door.
43:46	Smoke escaping from all doors. Welds popping from all doors.
1:17	Bowing beginning on double doors.
1:17	Flashover.
1:30	Raised Steel Damper to 20".
1:49	Meeting edge at top of double doors sealed from top latch of inactive door to top of frame.
3:35	Lowered Steel Damper to 18".
4:50	Lowered Steel Damper to 16".
6:30	Lowered Steel Damper to 14".
10:18	Lowered Steel Damper to 13".
11:28	Active door moved away from the inactive door by 1/2"-3/4" from lock assembly to sill.
14:15	Single door bowed 1/2"-3/4" away from the stop.
16:39	Meeting edge of double doors tight seal from lock assembly to top of frame.
17:34	Lock assembly on active door beginning to smoke at knob.
18:07	Single door smoking between frame and block on hinge side.
27:37	Meeting edge gap of double doors at 1/4" from lock assembly to sill.
29:25	Double doors completely discolored.
30:00	Cotton pad test on single door - slight discoloring to cotton due to it touching door.
31:00	Cotton pad test on double doors - slight discoloring.
33:18	Single door is bowing at lock assembly approximately 1/4".
33:24	Raised Steel Damper to 19".
35:02	Single door is completely discolored.
36:38	Distance from the door bottoms of the double doors to the sill is approximately 1/8" at the meeting edge only. The rest is approximately 1/4" from sill.
38:29	Bottom latch of the inactive door is beginning to smoke slightly.

40:35	Lock assembly on active door is soldering.
43:33	Meeting edge of double doors approximately 1/8" from lock assembly to sill. Gap between sill and bottom of double doors approximately 1/8" (consistently across).
44:19	Raised Steel Damper to 20".
53:15	Raised Steel Damper to 22-1/2".
60:00	No change.
1:12:02	Soldering continuing to melt on lock assembly of active door.
1:18:15	Raised Steel Damper to 24".
1:25:39	Raised Steel Damper to 25".
1:29:13	Gap at meeting edge of double doors from lock assembly to sill closing to approximately 1/8" - 1/16" seal.
1:30:00	90 minute test completed. Begin 10 min. deformation test on single door.
1:30:13	Beginning to deflect top left corner of single door to 1-1/2 times the door thickness.
1:31:33	Lock assembly holding.
1:32:20	Smoke escaping through the opening created at the top left corner of the door.
1:33:13	Intermittent flaming through the opening.
1:33:52	Lock assembly still holding.
1:35:26	Intermittent burst of flames through the opening.
1:36:00	Raised Steel Damper to 26".
1:39:26	No change
1:40:00	Test Terminated.

Clearances and Deflections - The amounts of door clearances and deflections are tabulated in Table 10.

Table 10 - Clearances and Deflections Test 4

		Clearances (in.)	
		Pre-Test	Post-Test
Single Door	Top	1/8	1/8
	Hinge Side	3/16	3/8
	Bottom	1/4	7/16
	Latch Side	3/16	5/16
Inactive Door	Top	1/8	1/8
	Hinge Side	3/16	1/4
	Bottom	1/2	3/8
	Latch Side	5/32	1/4
Active Door	Top	3/32	1/6
	Hinge Side	3/16	5/16
	Bottom	1/2	7/16
	Latch Side	5/32	1/4

Time (mins.)	Measurement Pt.	Deflection (in.) Into Room			
		0:00	15:00	30:00	45:00
Single Door	Midpoint	0	5/8	1-1/8	1-3/8
Inactive Door	Midpoint	0	5/8	1-1/8	1-3/8
Active Door	Midpoint	0	1-1/8	1-1/8	1-3/8

Temperature Data - The time-temperature fire exposure to the test samples as measured by the control thermocouples is shown in Figure 28. The temperatures at the ceiling recorded by the ISO 3008 thermocouples are shown in Figure 29. The temperatures recorded at the single fire door test assembly are presented in Figure 30. The temperatures recorded at the double door test assembly are presented in Figure 31, and for the active and inactive doors are shown in Figure 31-a and 31-b, respectively. The temperatures at the sidewall are shown in Figure 32, and the window opening temperatures are shown in Figure 33.

Pressure Data - The pressure at the top of the test sample, and 40 inches above the floor are shown in Figure 34.

Location of Neutral Pressure Plane - The location of the neutral pressure plane was calculated by interpolating the data at 40 inches and 84 inches using a straight line interpolation. The location of the neutral pressure plane during the test is depicted in Figure 35.

Cotton Pad Test - The results of the cotton pad test are summarized in Table 9.

Test Data - The tabulated data for Test 4 are presented in Appendix F.

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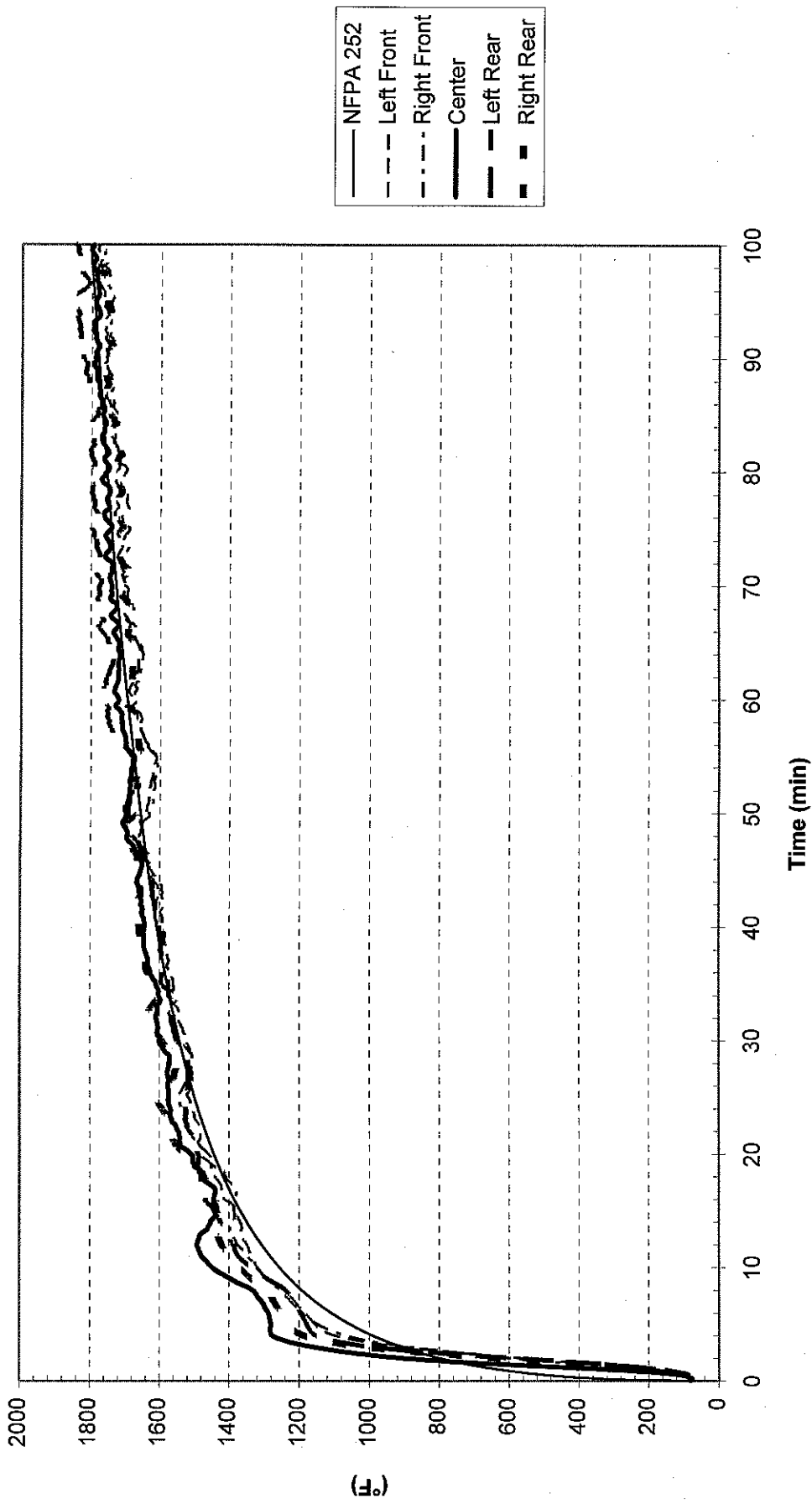


Figure 28. Time-Temperature Exposure : Test 4

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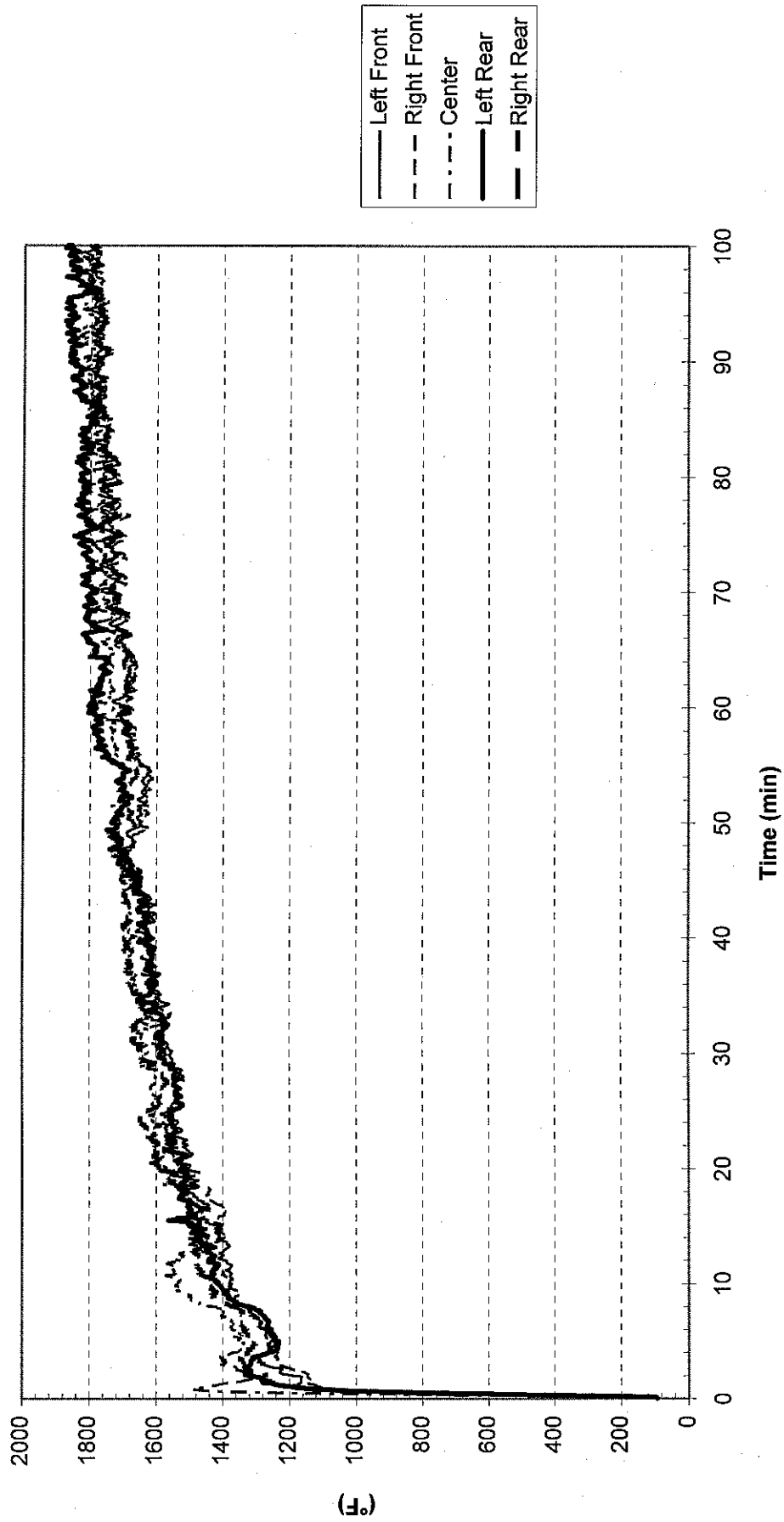


Figure 29. Ceiling Temperature Measured by Bare Bead Thermocouple : Test 4

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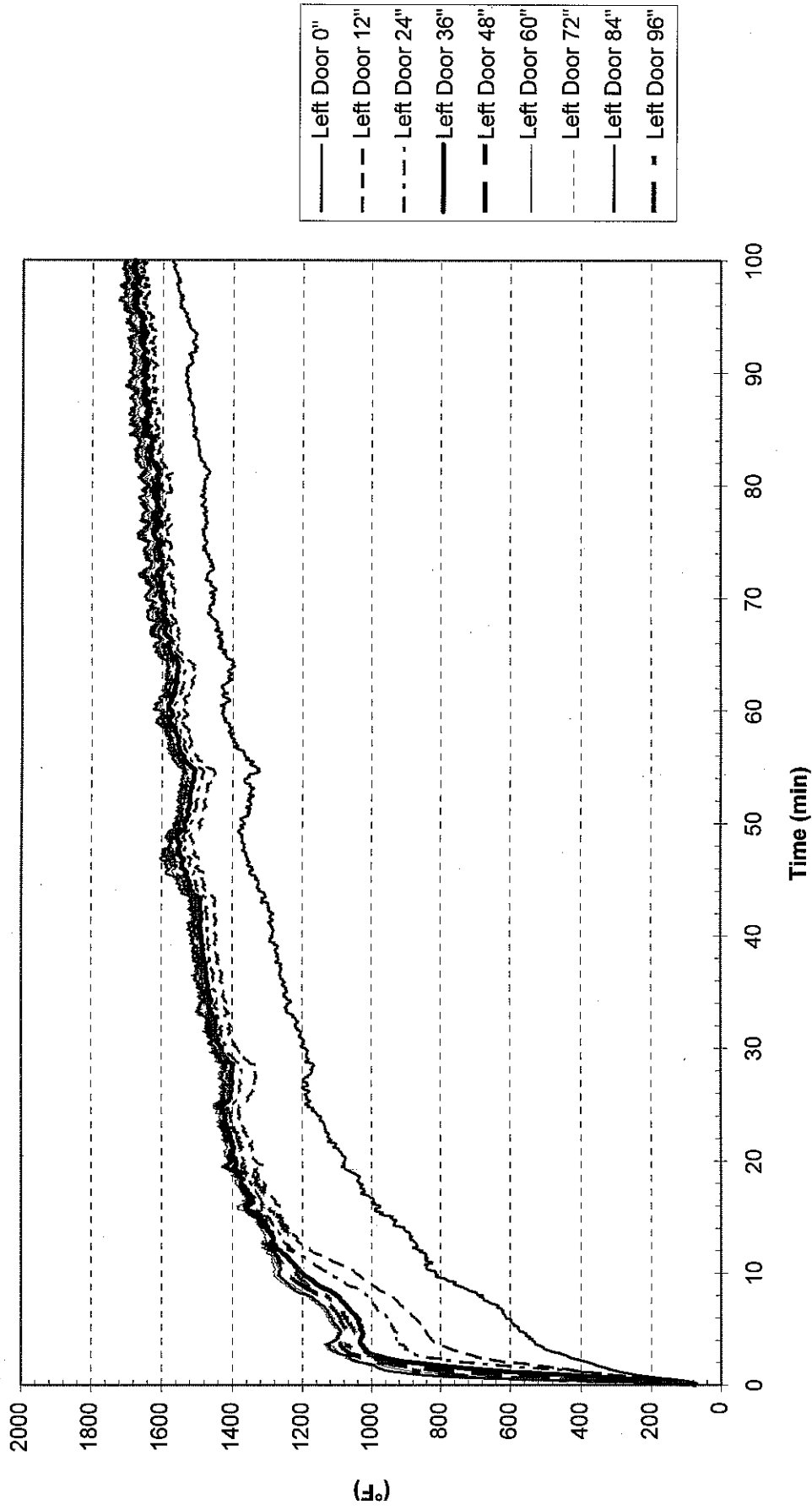


Figure 30. Temperatures Measured at the Single Door Assembly: Test 4

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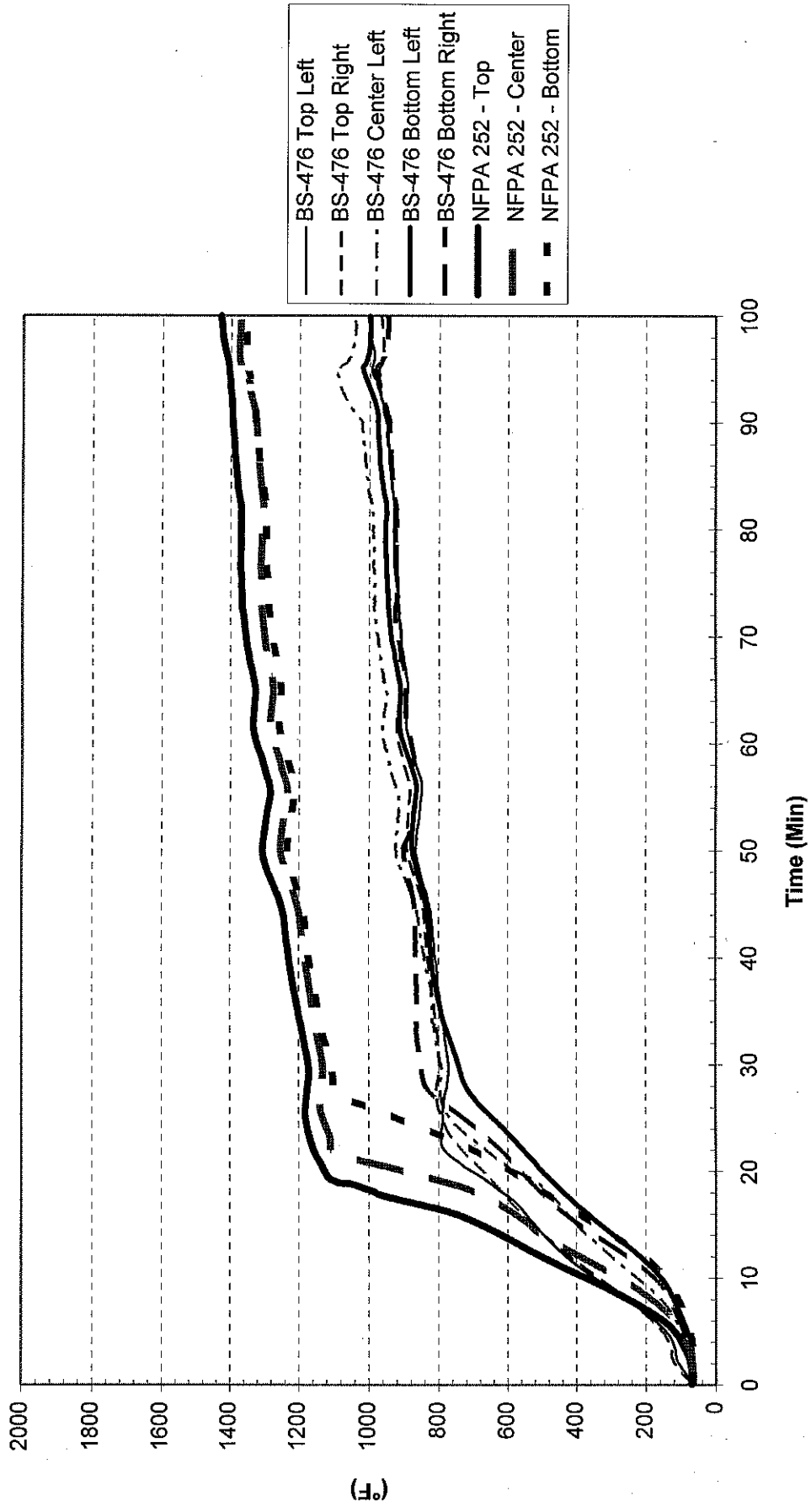


Figure 31. Temperatures Measured at the Double Door Assembly: Test 4

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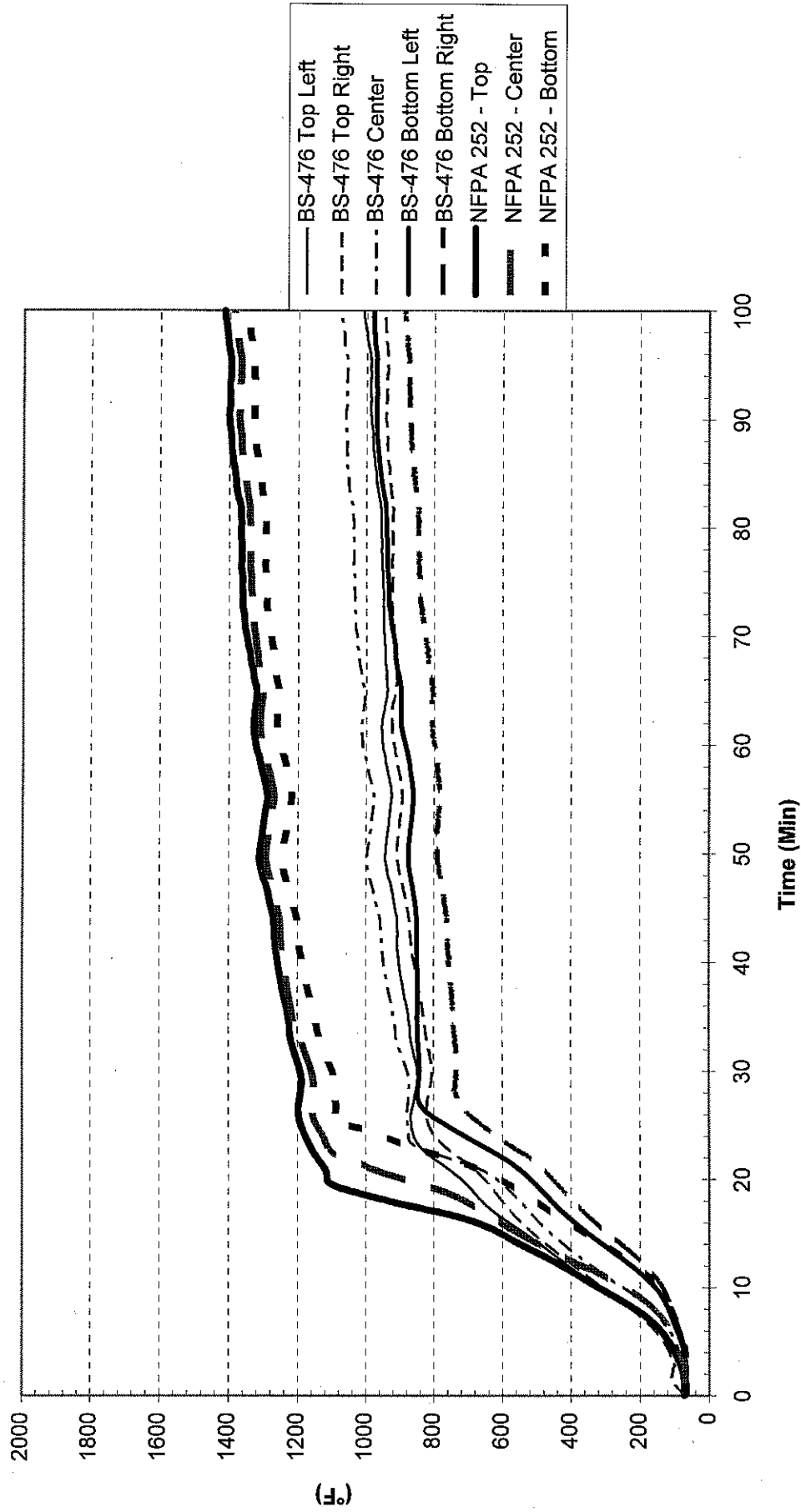


Figure 31-a. Temperatures Measured at the Unexposed Active Door: Test 4

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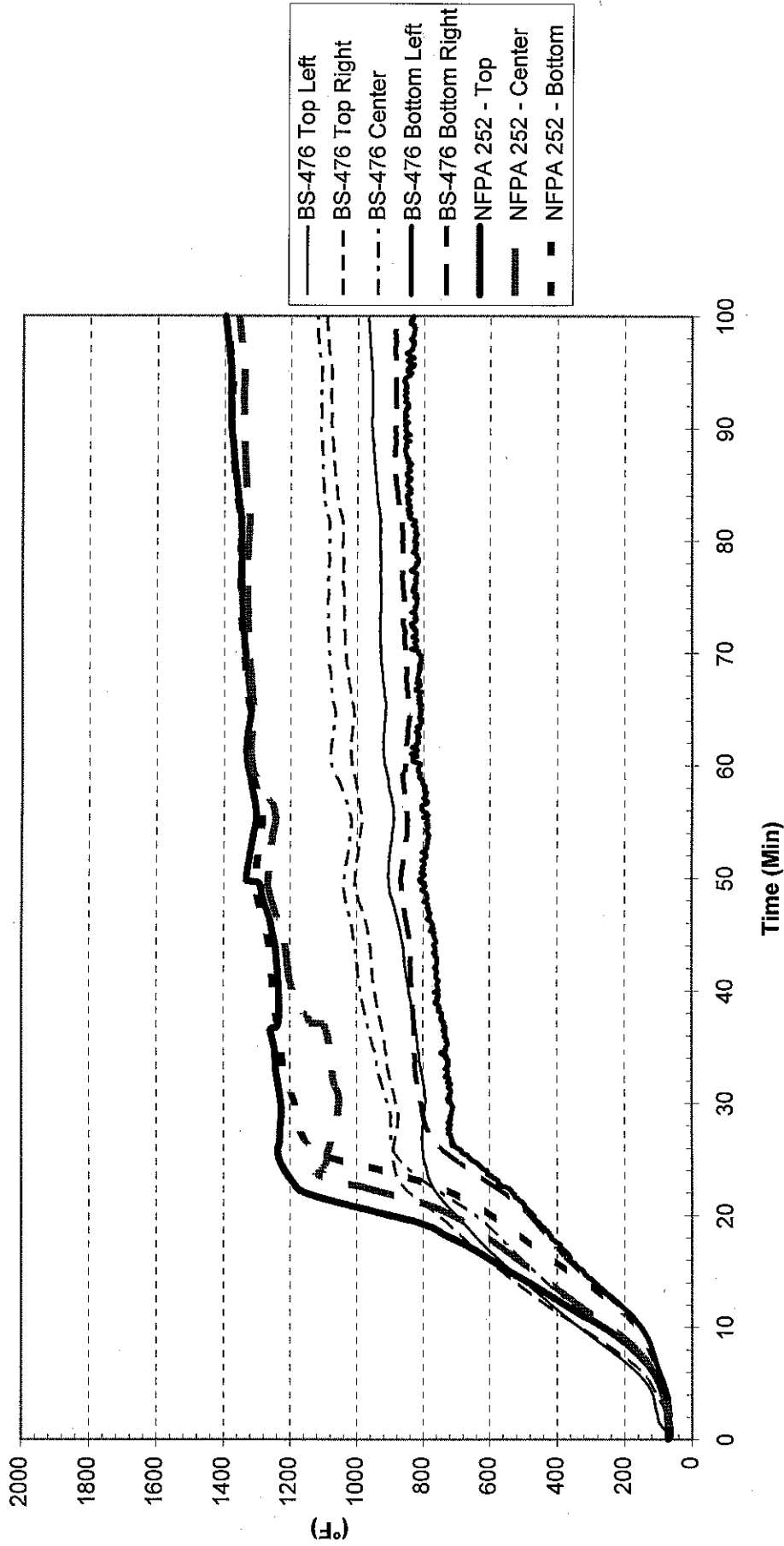


Figure 31-b. Temperatures Measured at the Unexposed Inactive Door: Test 4

National Fire Door Test Project

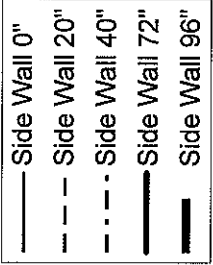
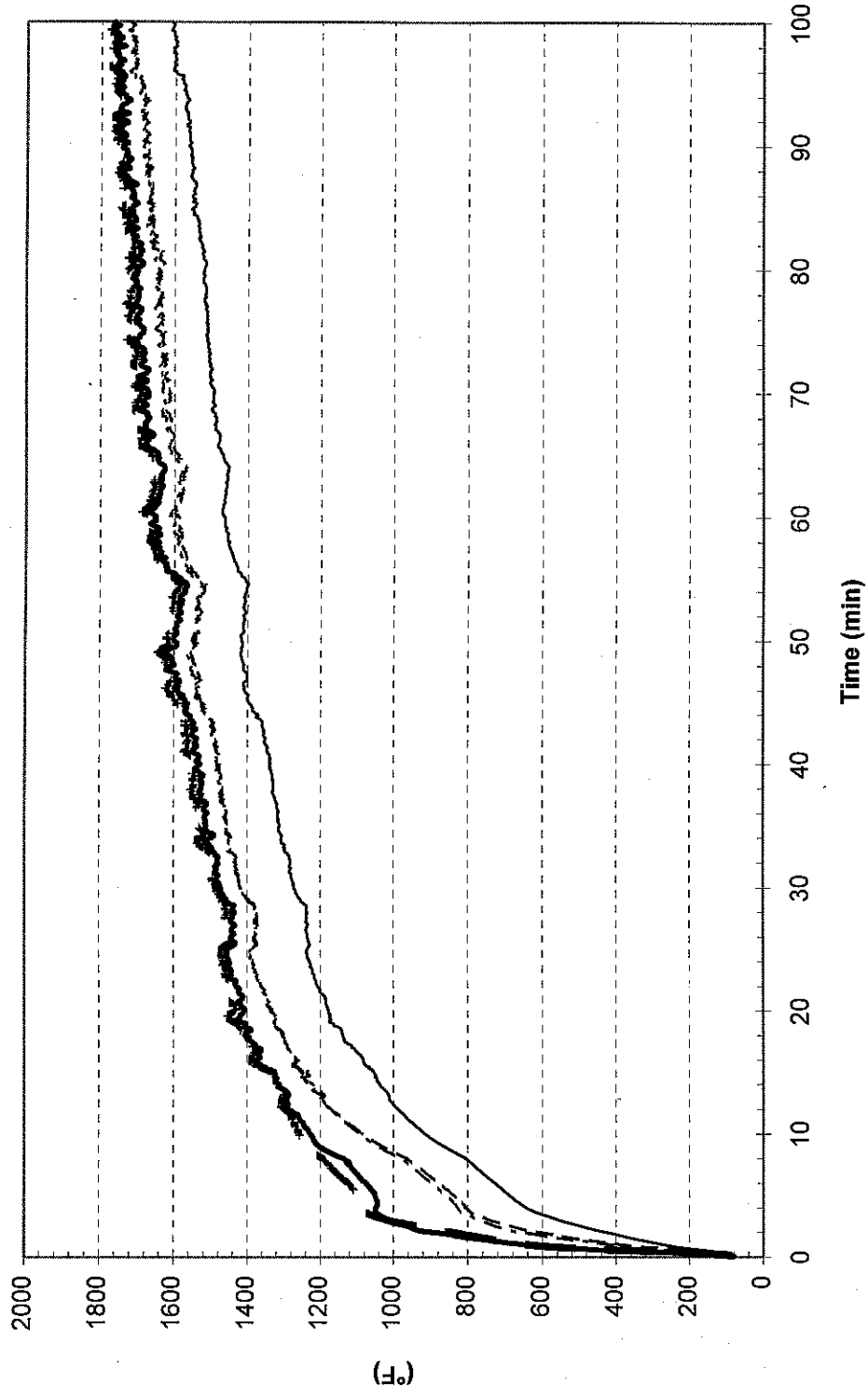


Figure 32. Temperatures Measured at the Side Wall: Test 4

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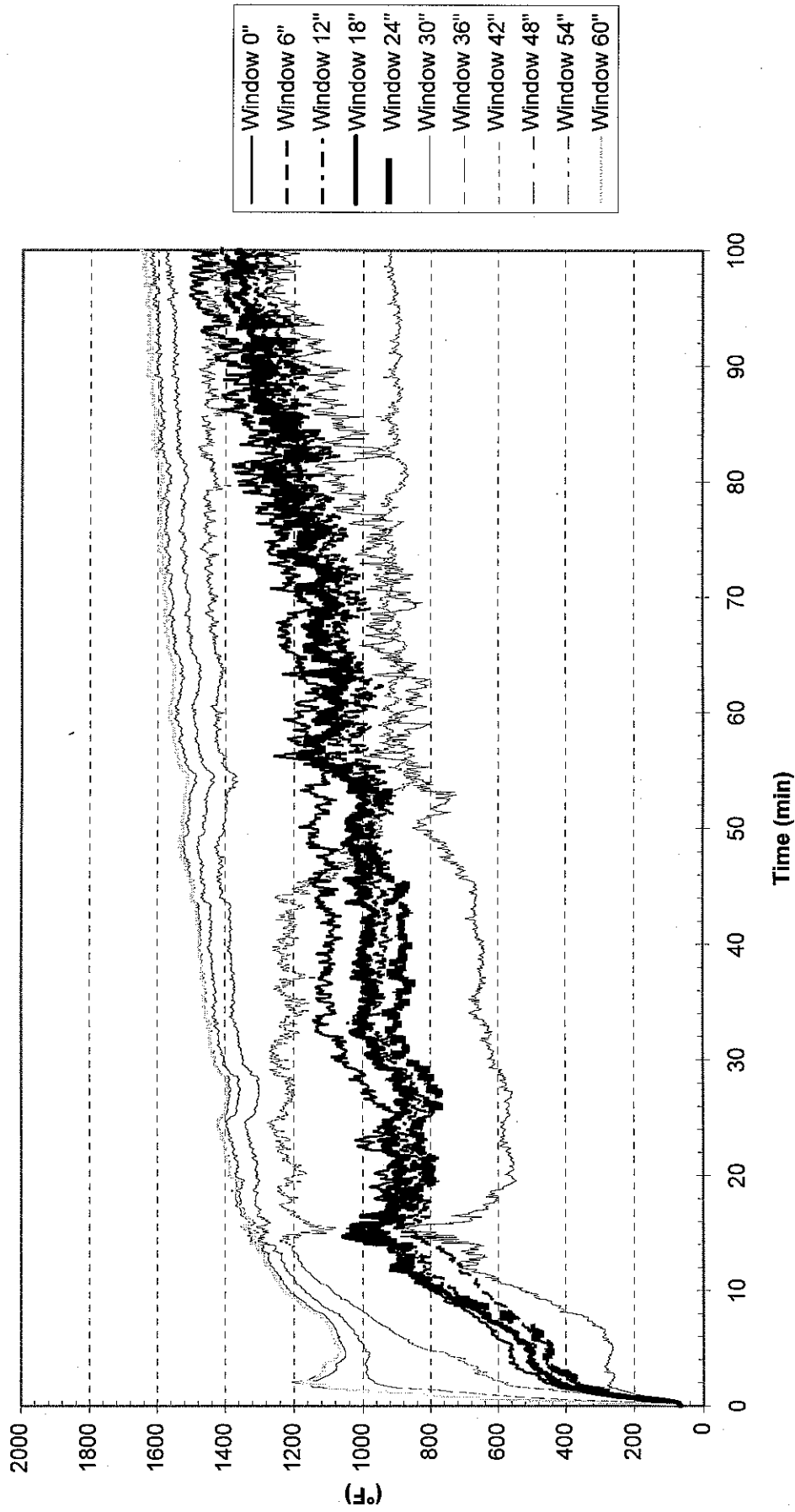


Figure 33. Temperatures Measured at the Window Opening: Test 4

National Fire Door Test Project

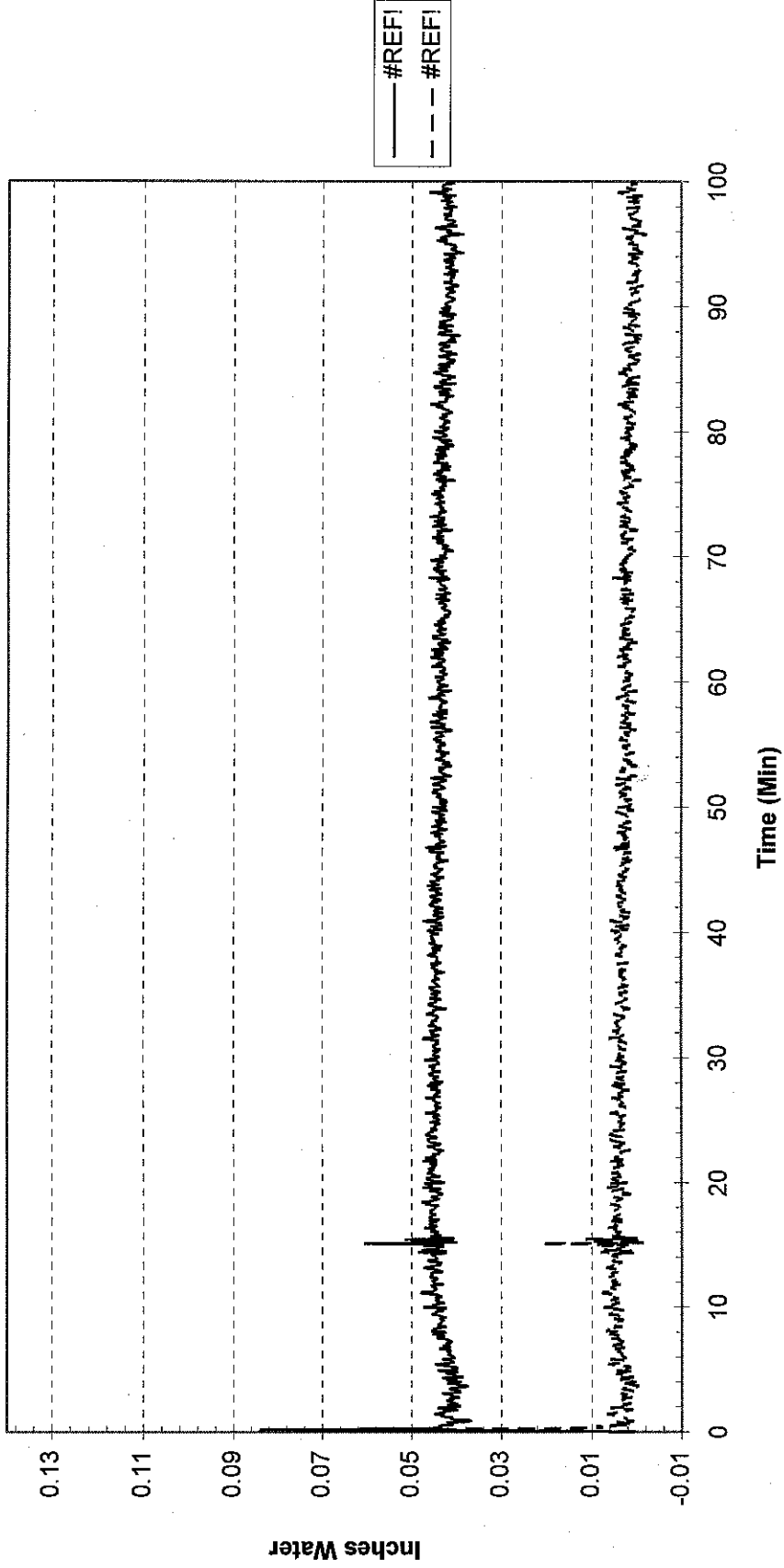


Figure 34. Pressure in the Fire Test Room: Test 4

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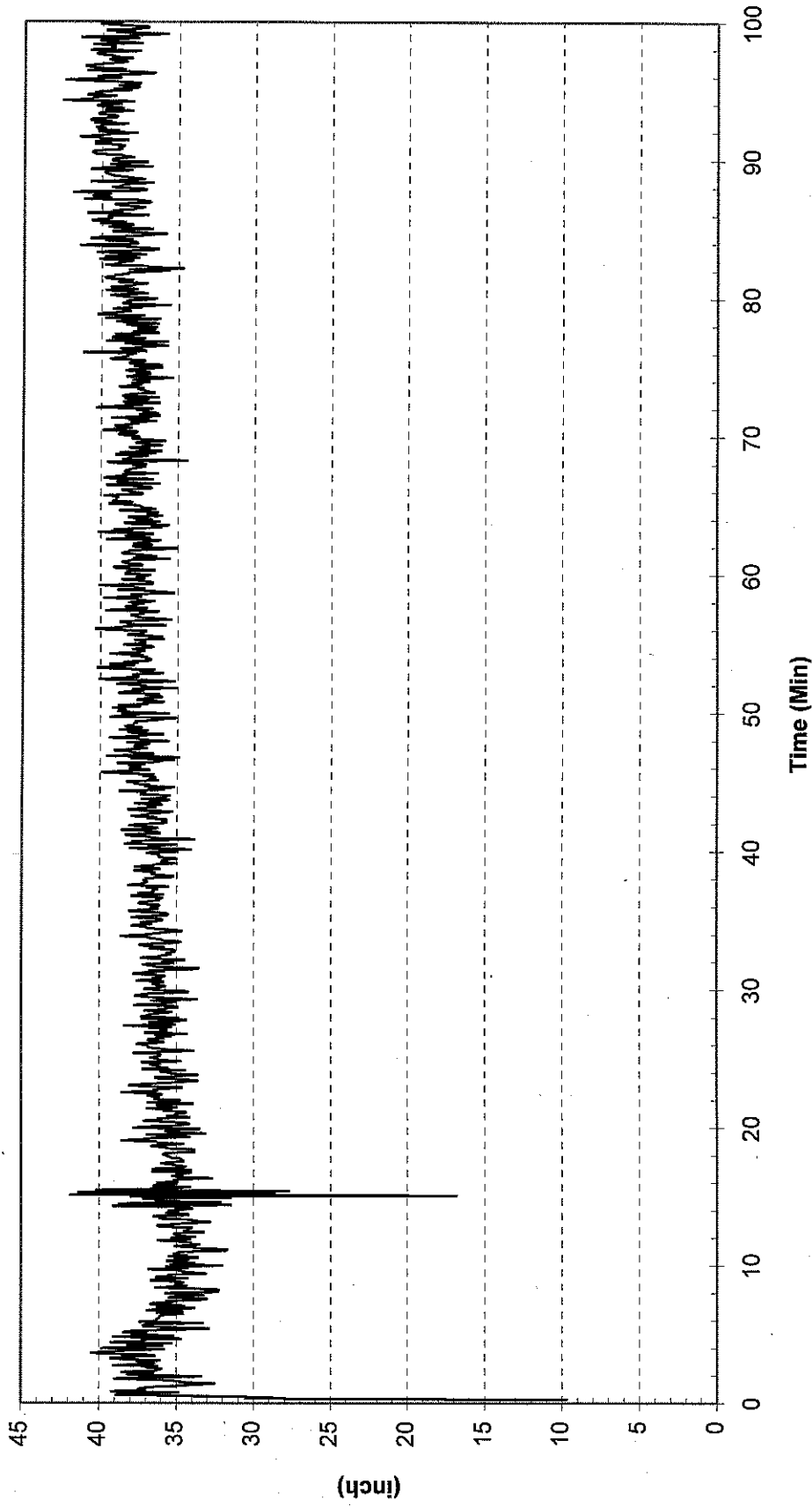


Figure 35. Location of the Neutral Pressure Plane: Test 4

Unburnt HydroCarbons - Test 2, Test 3 and Test 4

Concentrations of Unburnt Hydrocarbons - The concentrations of unburnt hydrocarbons for Test Numbers 2, 3 and 4 are shown in Figures 36, 37 and 38, respectively. The maximum concentrations are summarized in Table 11.

Table 11 - Maximum Concentration of Unburnt Hydrocarbons

Test Number	Maximum Concentration %
2	16.2
3	19.9
4	17.1

Fuel Consumed - Test 2, Test 3 and Test 4

Fuel Consumed - The natural gas consumed for Test Numbers 2, 3 and 4 are presented in Figures 39, 40 and 41, respectively. The total gas consumed for each test is summarized in Table 12.

Table 12 - Total Natural Gas Consumed

Test Number	Total Gas Consumed (cu. ft.)
2	669
3	4009
4	4463

Heat Flux From Door Assembly - Test 2, Test 3 and Test 4

Heat Flux From Door - The heat flux from the door assemblies in Test Numbers 2, 3 and 4 are presented in Figures 42, 43 and 44 respectively.

WEATHER CONDITIONS - TESTS 1, 2, 3 AND 4

Weather Conditions - All fire tests were conducted inside the test building and the outside weather conditions (wind direction, wind velocity, temperature and barometric pressure) were recorded on each test day. The readings are summarized in Table 13.

Table 13 - Weather Conditions

Test No.	Date	Temperature °F	Wind Direction	Wind Velocity mph	Barometric Pressure In.-Hg
1	1/23/95	26	NW	16.12	29.98
2	2/22/95	48	S	19.58	29.83
3	2/22/95	51	NW	28.79	29.88
4	2/23/95	51	NW	28.79	29.88

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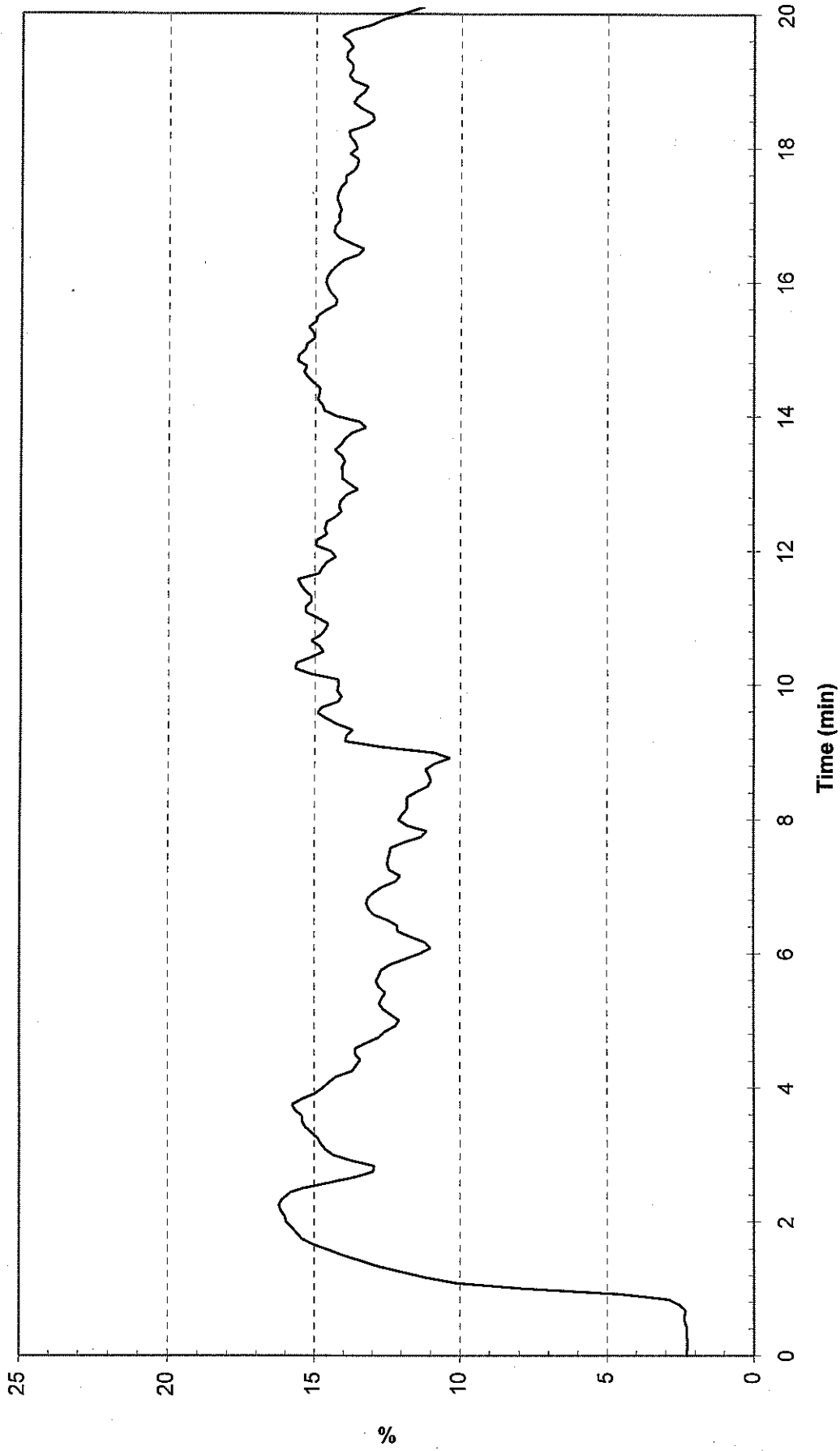


Figure 36. Unburnt HydroCarbons : Test 2

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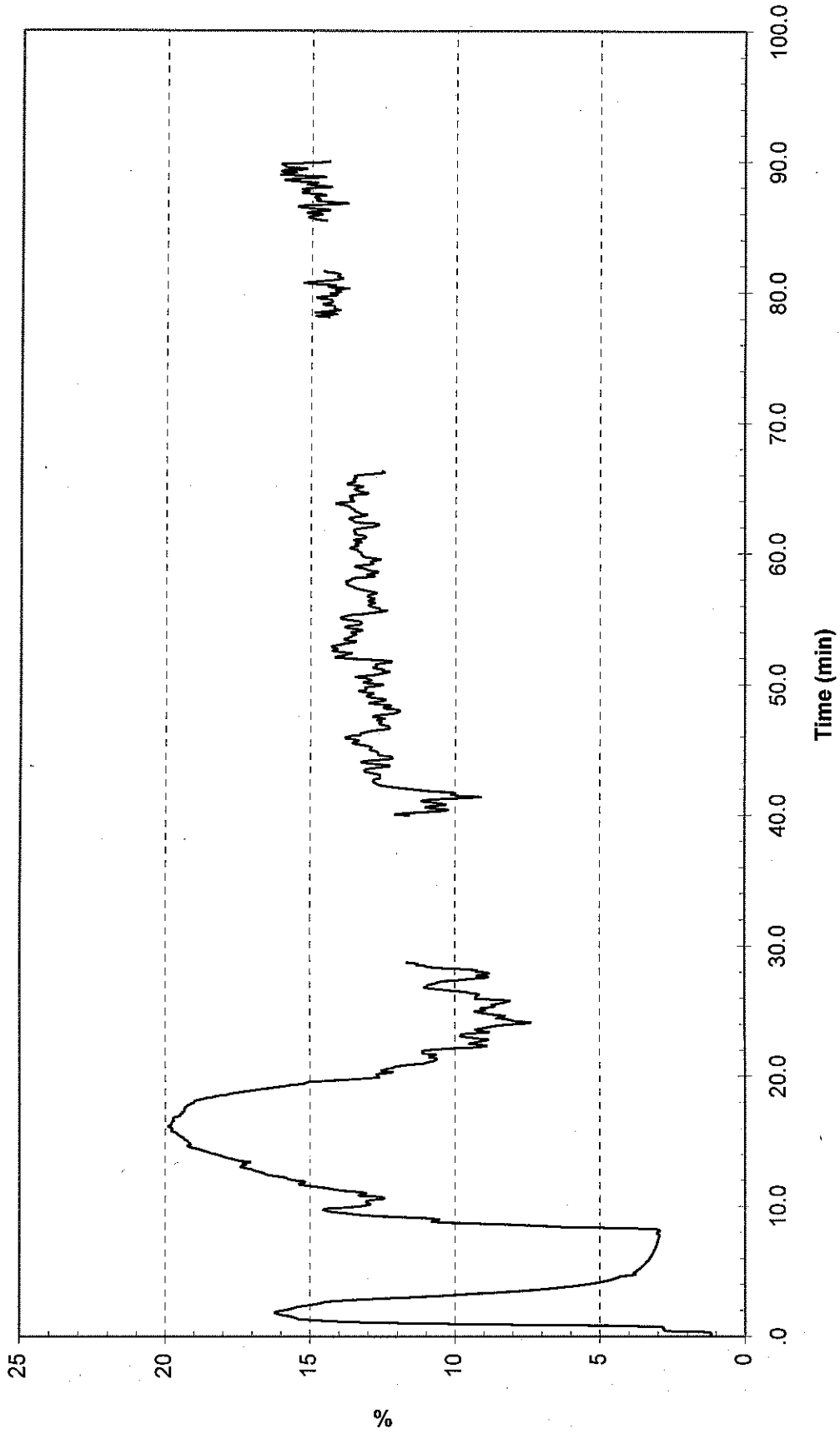


Figure 37. Unburnt Hydrocarbons: Test 3

National Fire Door Test Project

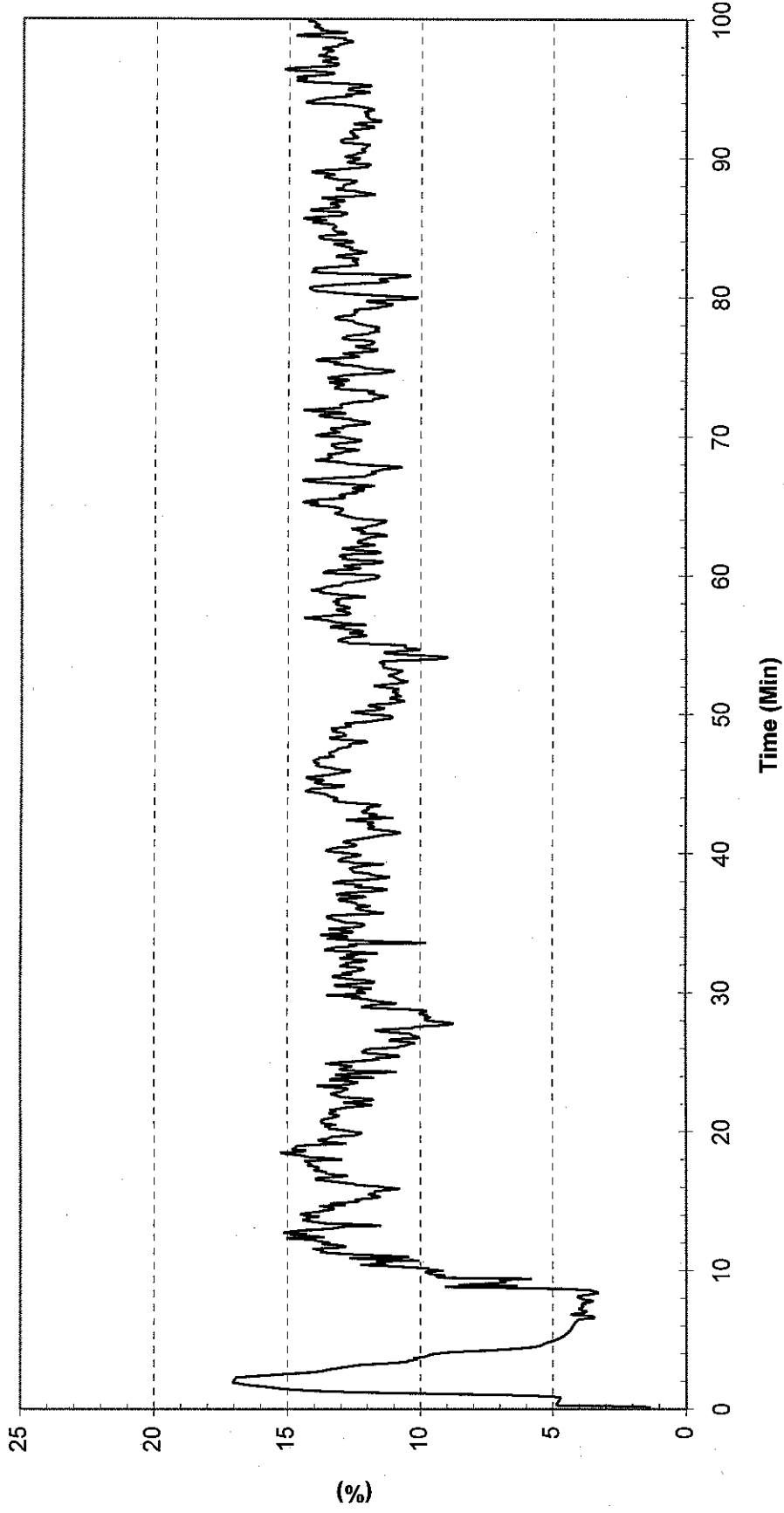


Figure 38. Unburnt Hydrocarbons: Test 4

National Fire Door Test Project

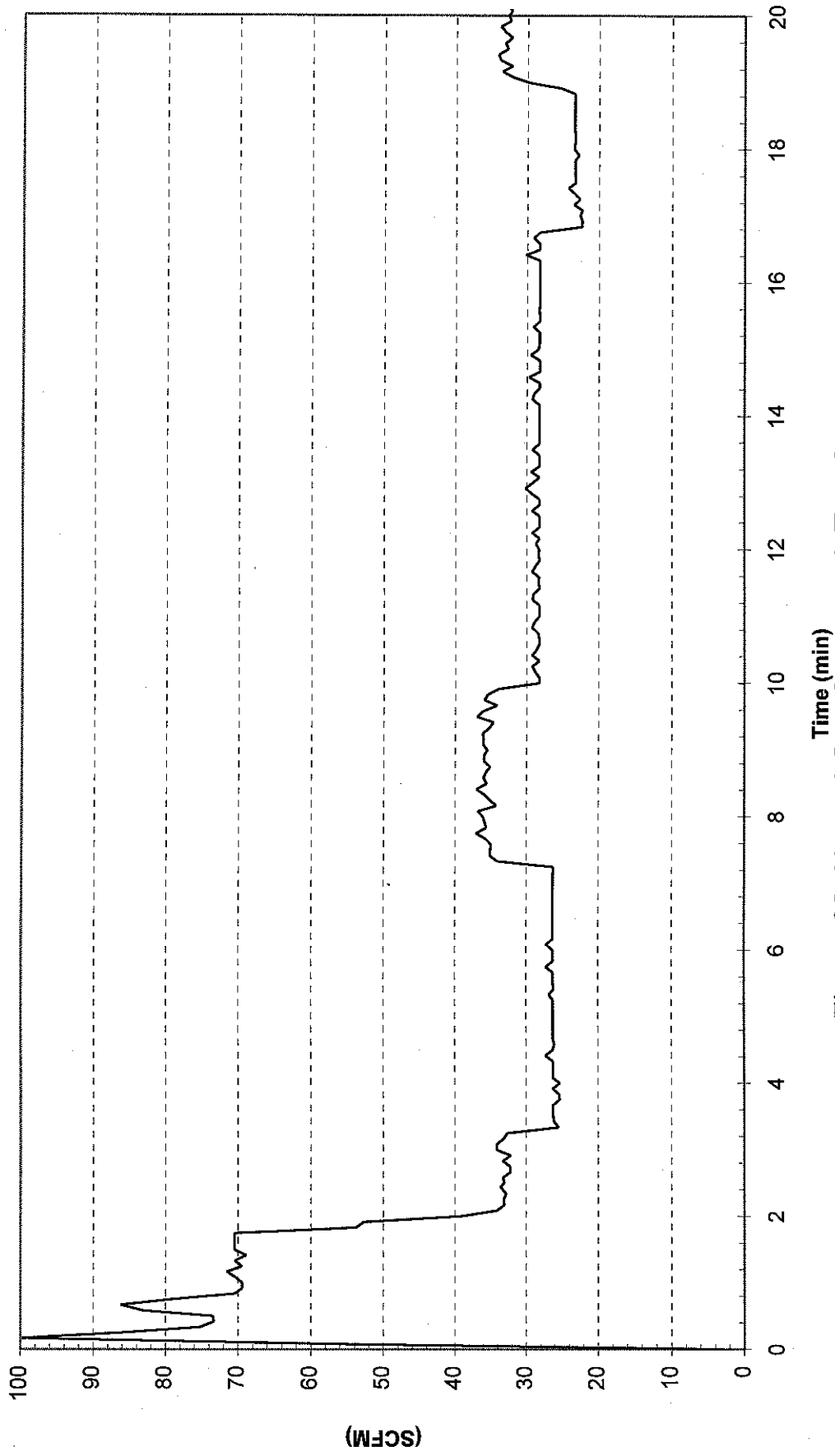


Figure 39. Natural Gas Consumed: Test 2

National Fire Door Test Project

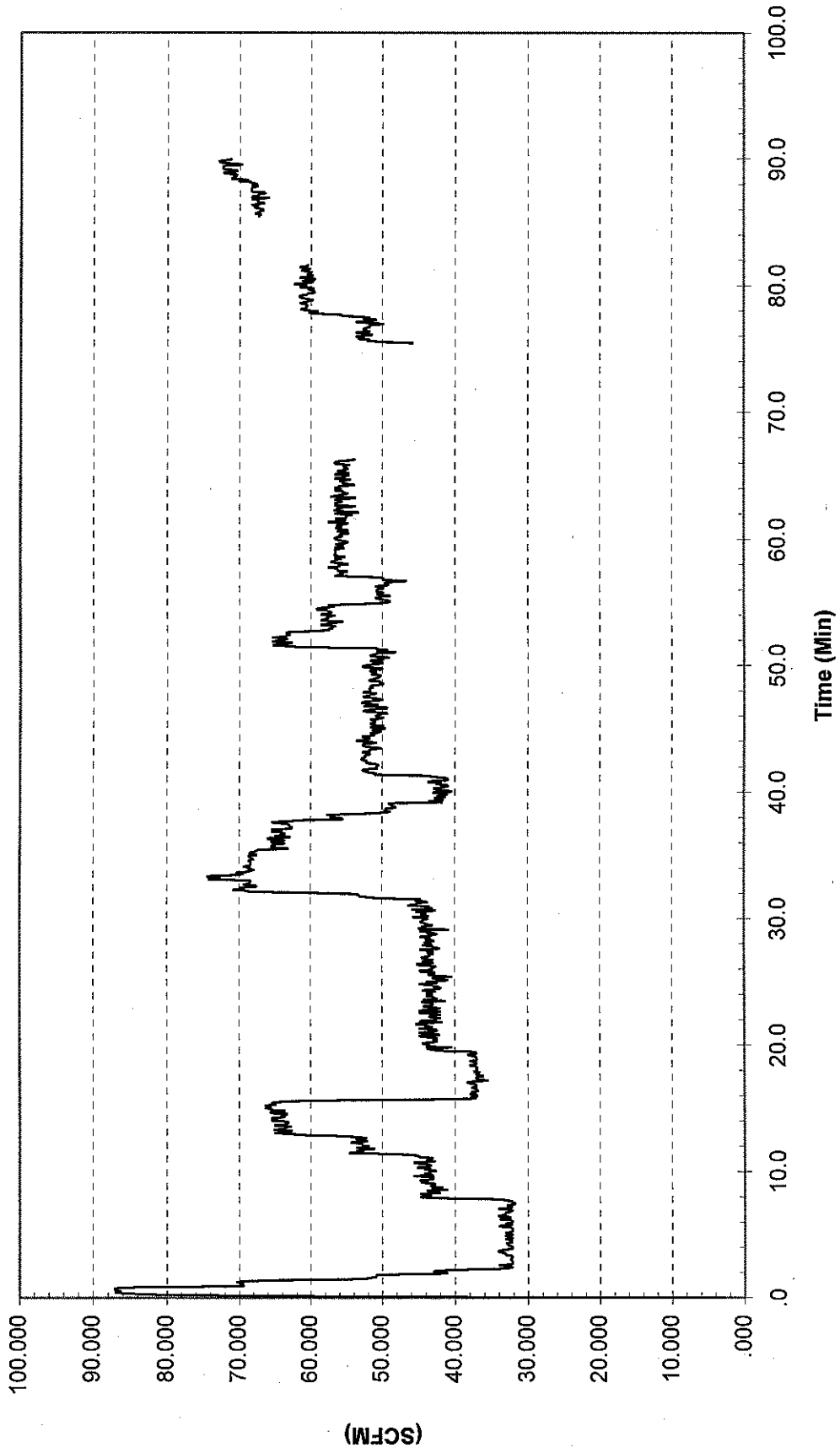


Figure 40. Natural Gas Consumed: Test 3

National Fire Door Test Project

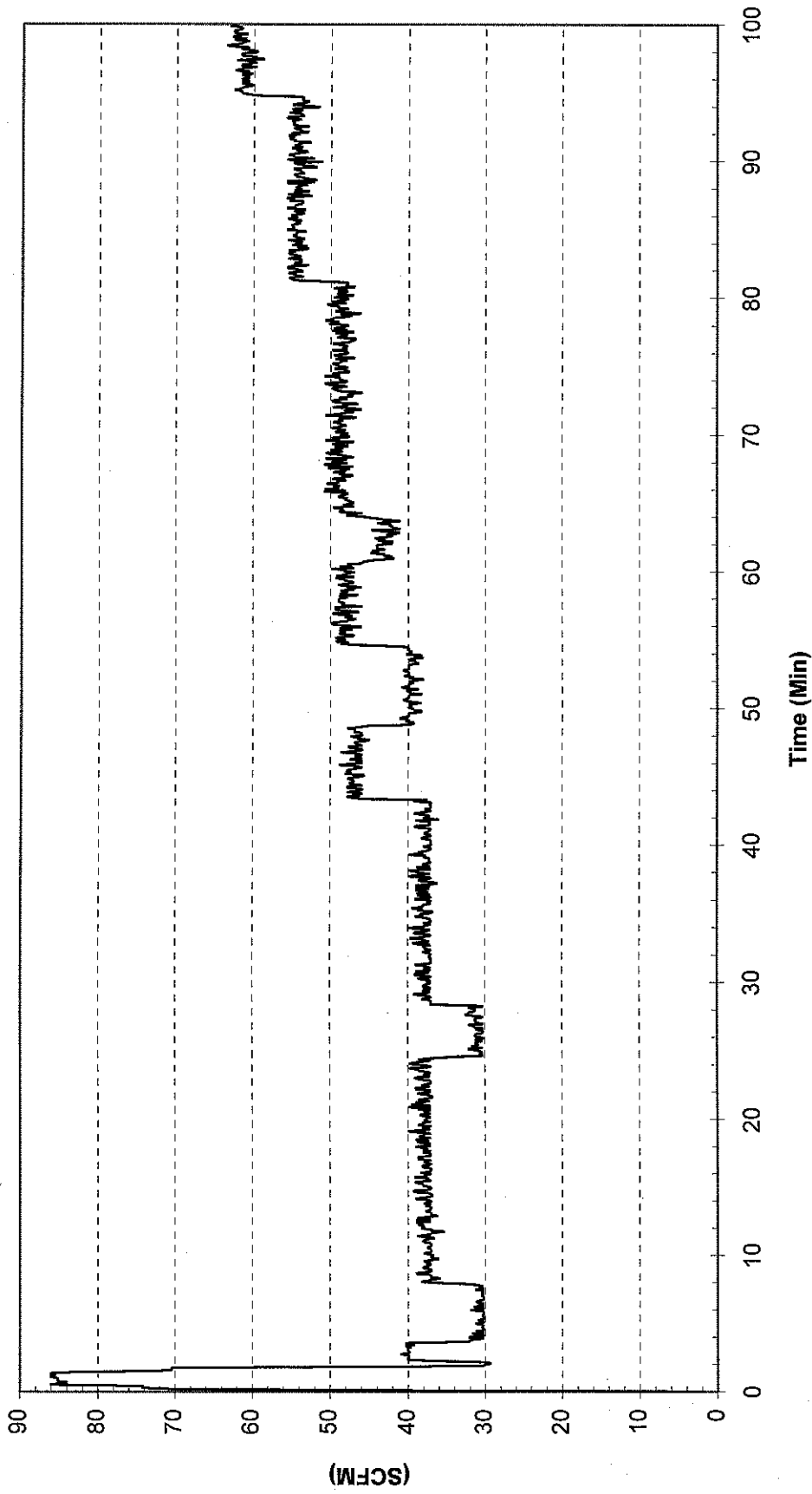


Figure 41. Natural Gas Consumed: Test 4

National Fire Door Test Project

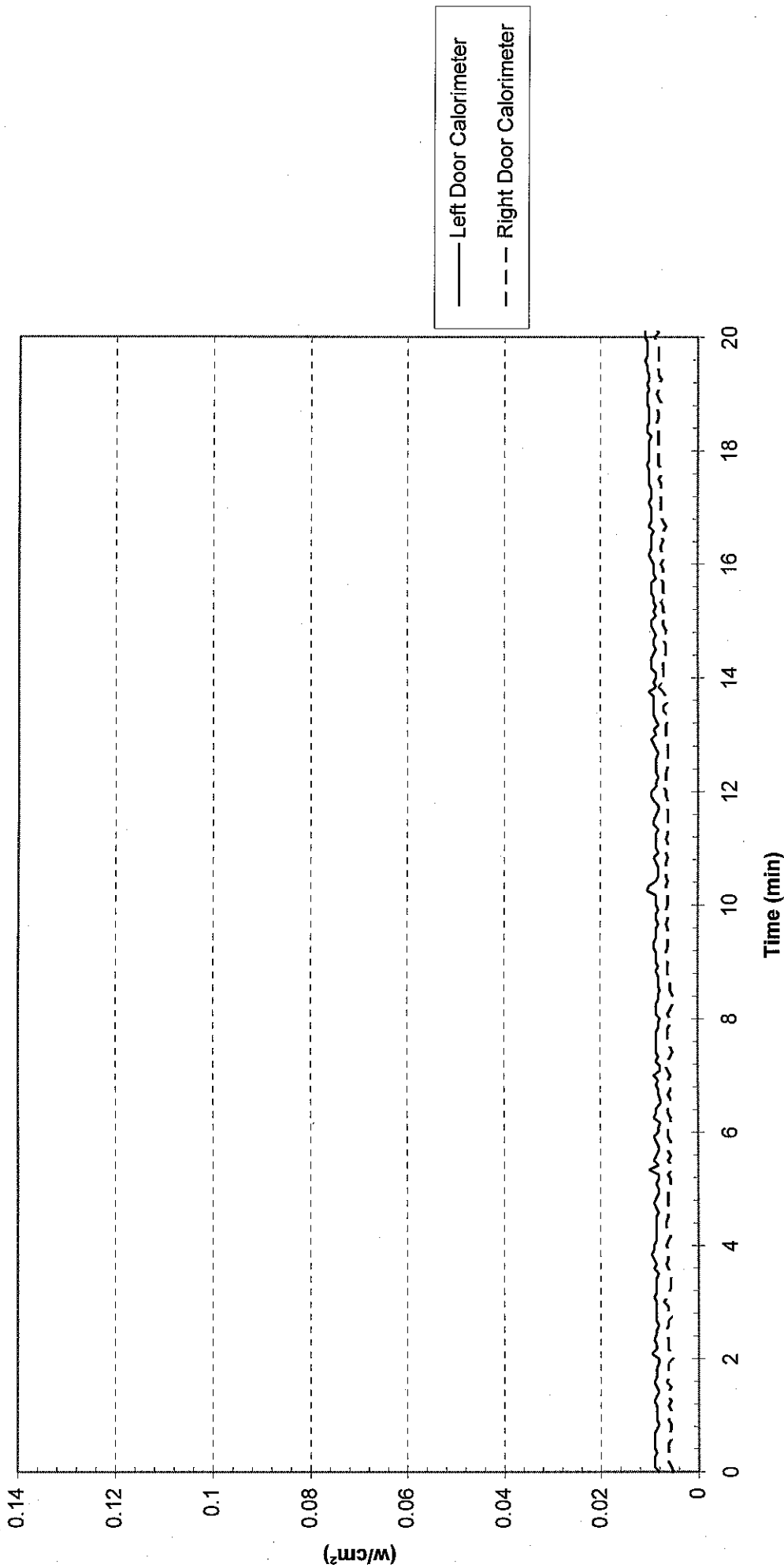


Figure 42. Heat Flux From Doors : Test 2

National Fire Door Test Project

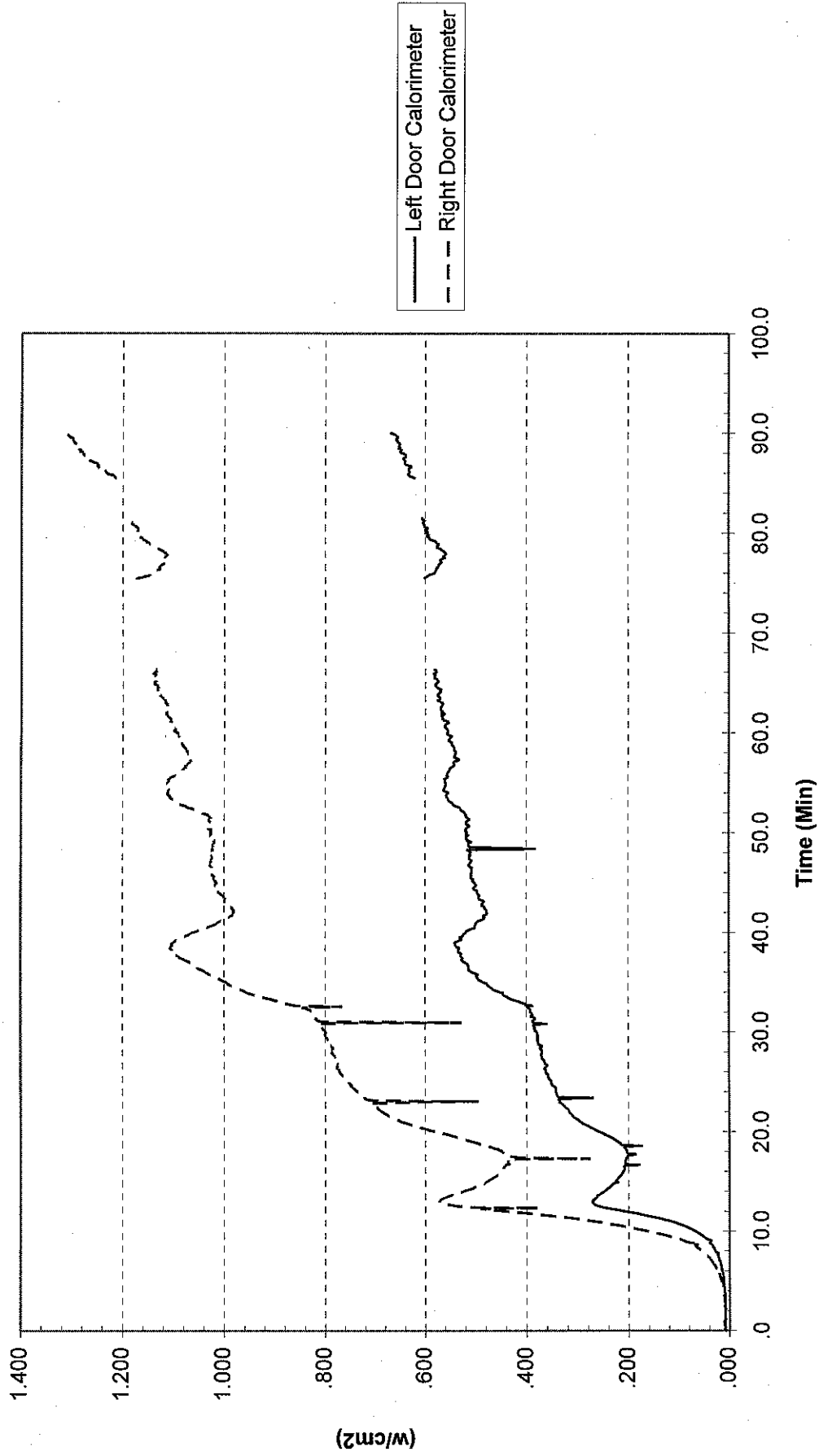


Figure 43. Heat Flux From Door: Test 3

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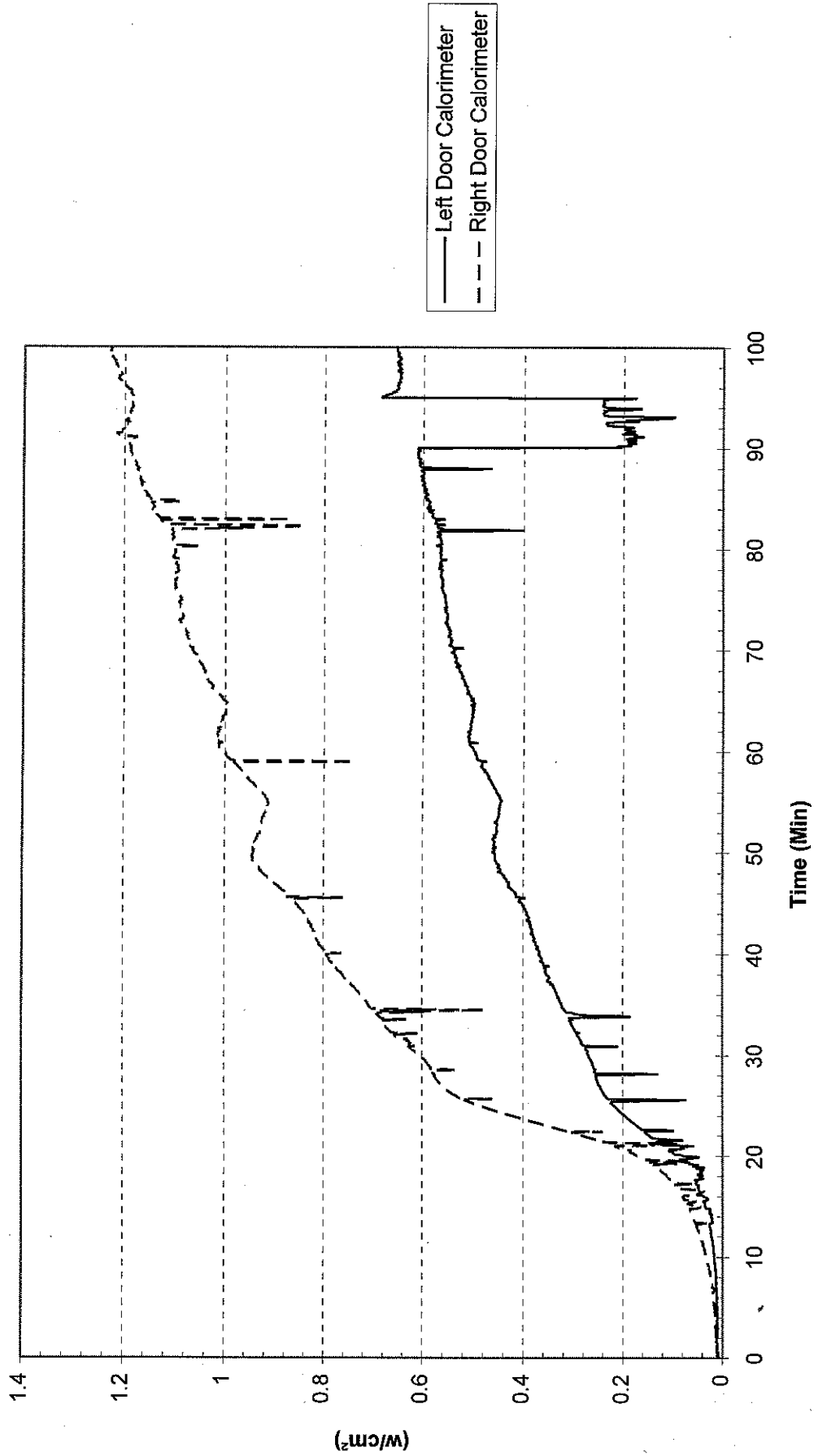
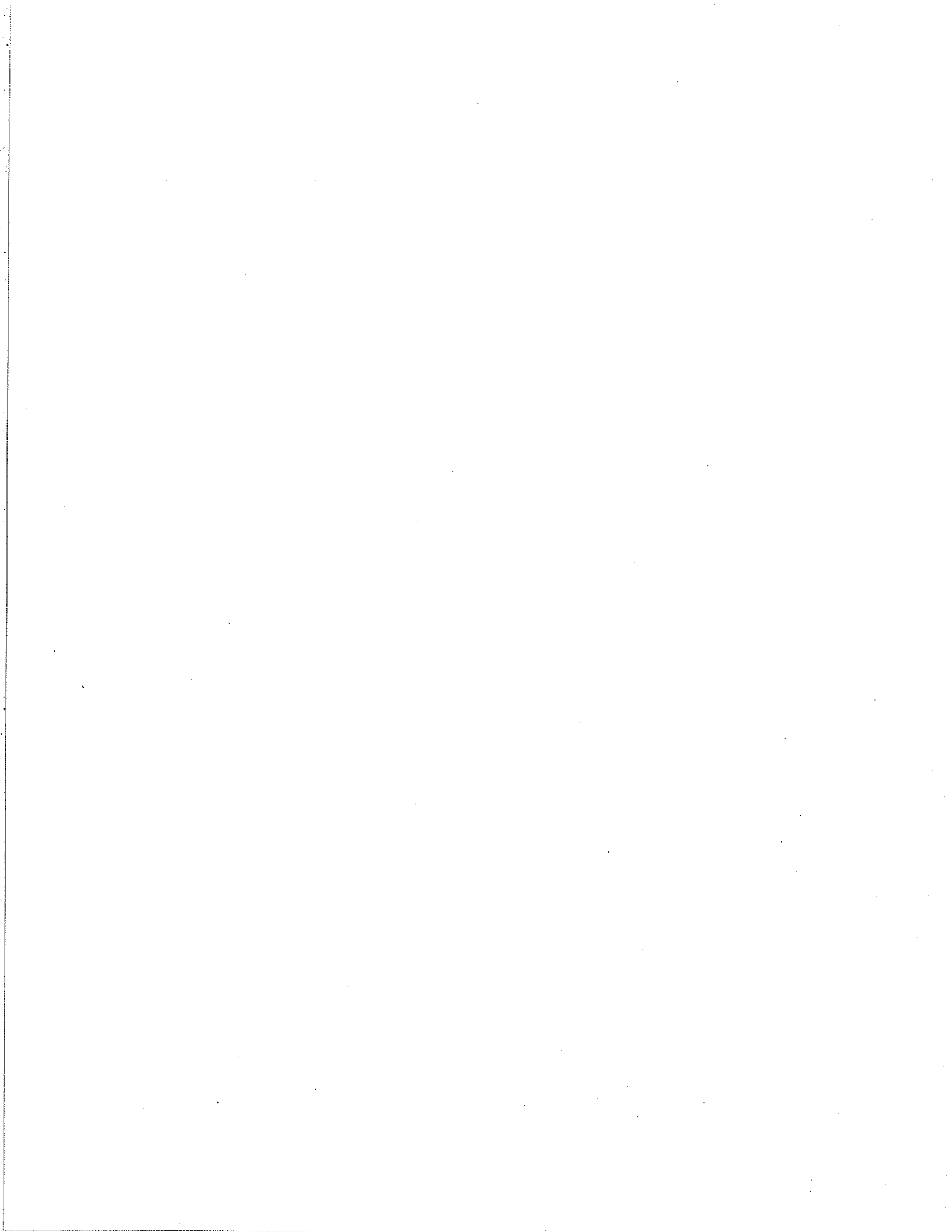


Figure 44. Heat Flux from Doors: Test 4



SUMMARY

The general observations and measurements for the three tests conducted with ventilation control post flashover fires were as follows:

1. None of the samples ignited the cotton pad during the first 10 minutes of their test.
2. None of the samples moved from the stop of the frame in which they were installed an amount greater than permitted in NFPA 252 during their 20 minute or 90 minute fire exposure.
3. None of the samples separated at their meeting edges an amount greater than permitted in NFPA 252.
4. None of the test assemblies had visible flames on their unexposed faces during their 20 minute or 90 minute fire exposure.

The maximum unexposed surface temperature attained during the fire exposures of 20 and 90 minutes are summarized in Table 14.

Table 14 - Results Summary

Door	Thermocouple Type and Location	Maximum Temperature, °F		
		Test 2	Test 3	Test 4
Left Door (Single Swing)	BS-476 Top Left	93	1012	951
	BS-476 Top Right	99	1078	953
	BS-476 Center Left	95	1050	1022
	BS-476 Bottom Left	89	1004	977
	BS-476 Bottom Right	89	1016	944
	NFPA 252 Top	95	1299	1395
	NFPA 252 Center	95	1388	1326
	NFPA 252 Bottom	85	1259	1328
Right Door (Single Swing or Inactive of pair)	BS-476 Top Left	93	1093	956
	BS-476 Top Right	101	1020	1079
	BS-476 Center	103	1020	1111
	BS-476 Bottom Left	84	952	858
	BS-476 Bottom Right	85	872	888
	NFPA 252 Top	97	1295	1379
	NFPA 252 Center	108	1270	1342
	NFPA 252 Bottom	89	1262	1378
Right Door (Active door of Pair)	BS-476 Top Left	-	1069	986
	BS-476 Top Right	-	1100	943
	BS-476 Center	-	1133	1062
	BS-476 Bottom Left	-	962	970
	BS-476 Bottom Right	-	1023	871
	NFPA 252 Top	-	1401	1400
	NFPA 252 Center	-	1395	1371
	NFPA 252 Bottom	-	1248	1328

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Table 15 - Heat Flux

Location	Maximum, W/cm²		
	<u>Test 2</u>	<u>Test 3</u>	<u>Test 4</u>
Left (Single) Door Calorimeter	0.011	0.666	0.613
Right (Single or Pair)Door Calorimeter	0.009	1.312	1.189

Table 16 - Amount of Natural Gas Used, ft³

<u>Test 2</u>	<u>Test 3</u>	<u>Test 4</u>
669	4009	4463

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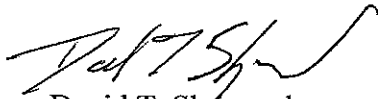
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