NATIONAL WHOLESALE/RETAIL OCCUPANCY FIRE RESEARCH PROJECT TECHNICAL REPORT TASK 1

FLAMMABLE LIQUIDS

Prepared by

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Foreword

The National Wholesale/Retail Occupancy Fire Research Project was initiated in February 1992 with the goal of documenting the performance of ceiling sprinklers and combination of ceiling sprinklers and in-rack sprinkler systems for protecting the storage of flammable/combustible liquids in wholesale and retail occupancies. Task 1 of the project, reported here, pertains to the protection strategies for flammable liquids. Task 2 of the project, covered in a companion report, pertains to the protection of combustible liquids.

Retailing in the United States is currently undergoing rapid and significant changes. The unparalleled growth of warehouse type bulk merchandise retail stores has led fire authorities to multiple interpretations of existing codes with regard to warehouse showrooms. Code-writers seek further documentation on effective strategies for protecting rack as well as shelved displays of flammable/combustible liquids. This report documents several successful fire tests of cost-effective fire protection measures.

The Research Foundation expresses gratitude to the author, William M. Carey, P.E.. The Foundation and the author thank the project's Technical Advisory Committee for their contributions in all respects: technical expertise, review, as well as the financial resources to conduct this landmark initiative. Of course, participation does not necessarily constitute a participant's endorsement of every statement in the report.

NATIONAL WHOLESALE/RETAIL OCCUPANCY
FIRE RESEARCH PROJECT

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REPORT OF THE

NATIONAL WHOLESALE/RETAIL OCCUPANCY

FIRE RESEARCH PROJECT

TASK I-PROTECTION OF FLAMMABLE LIQUIDS

PREPARED BY

UNDERWRITERS LABORATORIES INC.
PROJECT 92NK9354/NC987

FOR THE

NATIONAL FIRE PROTECTION

RESEARCH FOUNDATION

MARCH, 1993

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E X E C U T I V E S U M M A R Y

The Flammable and Combustible Liquids Code, NFPA 30, provides recommended practices for safe storage of such liquids. The 1987 Edition of NFPA 30, Section 4-5.6.4 states "Class I and Class II liquids in plastic containers shall be stored in a separate area designated exclusively for this storage and designed in accordance with Section 4-4 or 4-5.7, as applicable. No other storage shall be located in this area." This would prohibit Class I and Class II liquids in plastic containers in general warehouse.

The research project covered by this report was initiated to provide additional information on the fire performance characteristics of packaging systems and self supporting plastic containers containing flammable liquids. The objectives of the project were to develop: (i) a fire test method to determine the fire hazard of flammable liquids stored in containers; and (ii) fire performance information on specific liquid/container package configurations with respect to protection by selected representative sprinkler systems in a typical general purpose warehouse. ILL. A is a flow chart representation of the activities of this research project.

This project was initiated with review of literature and fire records to obtain information on relevant fire tests and actual fires involving flammable liquids. A survey of typical warehouse facilities was conducted to understand current warehousing practices and the level of fire protection available in warehouses. This situation analysis helped in the selection of parameters for the tests conducted during this project.

In the development of a fire performance test, various fire tests were conducted on different packaging systems by varying carton type, container and liquid. Of the four carton designs tested, three were of fire retardant construction while the fourth was untreated. The containers were high-density polyethylene (HDPE)-F style (pint, half gallon, gallon), HDPE-cylindrical (pint, quart), HDPE/Nylon-F style (gallon) and HDPE/Nylon-cylindrical (pint). The liquids were representative of Class IB, Class IC, and Class II categories as defined in NFPA 30. The sample packaging systems were placed on a pallet under an exhaust hood. A 3 in. diameter cellulosic bundle soaked with eight fl. oz. of gasoline in a polyethylene bag was used as the ignition source. The heat release rate from the burning sample was obtained by oxygen consumption calorimetry and used as input to a computer fire program to determine the temperature of a simulated sprinkler rated at 165°F and having a RTI of 300 $ft^{\frac{1}{2}}$-$s^{\frac{1}{2}}$. The simulated sprinkler was assumed to be at a 25 ft high ceiling and at 10 ft spacings. A water spray system was located above the sample and calibrated for a design of a required delivered density (RDD) of 0.3 gpm/ft^2. The water spray system was activated when the simulated sprinkler temperature reached activation as calculated by DETACT-QS. A total of twenty-one pallet-scale tests were conducted with flammable or combustible liquids in plastic containers and packaged in cartons.

Results showed that packaging systems with untreated cartons led to a very rapid fire growth. On the other hand, the tests with some fire retarded cartons of the specific design investigated showed a relatively slower fire growth rate, and the fire could be controlled for pint and quart containers with Class IB and Class II liquids by the water spray system. For half gallon and gallon containers, water spray was able to control the fire only for Class IB liquids. It was observed that a Class II liquid had a greater tendency to pool than a Class IB liquid and thus the control was more difficult for the half gallon and gallon size containers.

To analyze fire growth rate, a growth factor was defined with respect to t^2 fires. Analysis of heat release rate data from the pallet scale tests showed that fires with growth rate factors less than 0.02 were controllable with the water spray system.

A single 55 gallon drum test was also conducted to determine the ability of the drum to contain the liquid when exposed to the test ignition source. The test showed that the drum did not rupture and there was no leakage of liquid.

PDG/RKL:ml
pc lbry

Two large-scale tests were conducted to verify the results from the pallet-scale tests. The large-scale tests consisted of four pallet loads of cartons with flammable liquids in plastic containers. The pallets were placed in a 2 by 2 array with a 6 in. flue space between cartons on adjacent pallets. The configuration was tested in a 40 by 40 by 25 ft test facility. A sprinkler system fitted with large orifice sprinklers at 10 ft spacings and rated at 165°F and having an RTI of 287 $ft^{\frac{1}{2}}$-$s^{\frac{1}{2}}$ was installed at the ceiling. The design water delivery rate of the sprinkler system was 0.3 gpm/ft^2. A 3 in. diameter cotton cellulosic bundle with eight fl. oz. of gasoline in a polyethylene bag was used as an ignition source. The packaging system selected for one test consisted of fire retardant (FR) cartons with pint containers and kerosene (Class II) while in the other test the packaging system consisted of gallon containers in FR cartons with isopropyl alcohol (Class IB) as the liquid. In the small-scale partial pallet tests of these packaging systems, the fires developed slowly and could be controlled when the water spray system was applied. In the corresponding large-scale tests, the fires were also controlled upon activation of the sprinklers.

This report is divided in two volumes. Volume 1 of the report describes the tests and the results, and Volume 2 provides a time record of heat release rate data obtained.

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LIST OF ABBREVIATIONS AND DEFINITIONS

C	Centigrade.
cfm	Cubic feet per minute.
Class IB Liquid	A flammable liquid having a flash point below 73°F (22.8°C) and a boiling point at or above 100°F (37.8°C).
Cardboard Commodity	Tri-wall corrugated cardboard cartons on wood pallets.
Case-Cut	The removal of the upper portion of the cardboard carton for customer access allowing the lower "tray" portion of the carton to remain.
Control	A condition in which, following sprinkler operation, relatively low ceiling temperatures are maintained and the spreading of fire is reduced by the pre-wetting of adjacent commodities. Manual intervention is required to extinguish the fire.
Deg	Degree.
Display (Hand-Pick)	Rack storage display of uncartoned, case-cut cartoned or fully cartoned commodities.
ELO	Extra large orifice. K Factor: 11.0 - 11.5
F	Fahrenheit.
Fig.	Figure.
ft	Feet.
gal	Gallon.
gpm	Gallons per minute.
gpm/ft^2	Gallons per minute per square foot.
heptane	Class IB flammable liquid.
Ill.	Illustration.
in.	Inch.
In-hg	Inches of mercury.
K Factor	Sprinkler discharge coefficient.
LO	Large orifice. K Factor: 7.4 - 8.2
min	Minute.
Mixed Rack Storage (with or without) Display	Rack storage with palletized commodities above and display (hand-pick) commodities below.
MPH	Miles per hour
NFPRF	National Fire Protection Research Foundation.
No.	Number.
QR	Quick response.
qt	Quart.
RTI	Response Time Index, in units of $(ft \cdot s)^{1/2}$.
s	Second.
STD	Standard orifice sprinkler.
Suppression	A condition in which, following sprinkler operation, the fire is extinguished without manual intervention.
TAC	Technical Advisory Committee.
UFC	Uniform Fire Code
UL	Underwriters Laboratories Inc.

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A C K N O W L E D G E M E N T S

UL wishes to thank the members of the National Fire Protection Research Foundation Technical Advisory Committee for their support and technical guidance. Special acknowledgements are given to the following members of the National Fire Protection Research Foundation Research Team who offered their expertise and direction during this fire research project: Mr. David C. Tabar, Sherwin-Williams Company and Chairman of the National Wholesale/Retail Occupancy Fire Research Project, and Mr. Richard P. Bielen, National Fire Protection Research Foundation. In addition, the authors recognize the contributions of Mr. David P. Nugent, Schirmer Engineering Corporation.

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1.0 INTRODUCTION

GENERAL:

Retailers in the United States are currently undergoing rapid and significant changes with the introduction of warehouse style sales occupancies. It is further recognized that the customer mix in today's stores range from the "do-it-yourself" to the commercial or "wholesale" customer. Stores of this type may contain large quantities of flammable liquids which are stored on racks in:

(1) full pallet loads,

(2) individual cartons of containers,

(3) display (hand-pick) configurations of uncartoned or case-cut commodity, and

(4) individual containers.

Retailers, building code officials, Fire Service, manufacturers and insurance carriers expressed interest in a research project to determine the effectiveness of various fire sprinkler systems on different types of rack storage arrangements. The purpose of the research was to develop fire test data related to effective, cost-efficient fire sprinkler systems for the protection of flammable liquids stored on racks in wholesale/retail occupancies.

The National Fire Protection Research Foundation (NFPRF) coordinated the National Wholesale and Retail Occupancy Fire Research Project to assist in:

(1) determining the effectiveness of ceiling sprinklers and a combination of ceiling and in-rack sprinkler systems in protecting flammable liquid fires in rack storage configurations representing wholesale and retail occupancy scenarios,

(2) determining the storage heights and sprinkler design densities required to protect rack storage configurations representative of wholesale and retail occupancy scenarios under ceiling heights of 18 and 27 feet, and

(3) determining the effectiveness of ceiling sprinklers and a combination of ceiling and in-rack sprinklers in protecting uncartoned and case-cut display (hand-pick) configurations of flammable liquids representing wholesale and retail occupancy scenarios.

OBJECTIVE:

The objective of this fire test research investigation conducted by Underwriters Laboratories Inc (UL) under guidance of the National Fire Protection Research Foundation Research Team and the Technical Advisory Committee (TAC) was to develop fire test data regarding the performance of ceiling sprinklers and a combination of ceiling and in-rack sprinkler systems intended to protect rack storage configurations of flammable liquids simulating end use storage and potential ignition scenarios found in wholesale and retail occupancies.

TEST PLAN:

Three series of fire tests were planned to be conducted including ignition scenario, display (hand-pick) and mixed rack storage (with or without) display arrangement fire tests. These tests were planned to use heptane, a Class IB flammable liquid, stored in 1 quart and 1 gallon metal F-style and 5 gal metal tight-head containers. Testing of plastic container storage configurations of flammable liquids was not conducted under this project.

IGNITION SCENARIO TESTS

The ignition scenario tests were planned to be conducted using both an 18 and 27 ft high ceiling to determine the maximum size of a heptane spill fire that would not activate ceiling mounted sprinklers. In-rack sprinklers were also to be used in the tests under an 18 ft high ceiling.

The in-rack sprinklers were to be positioned 8 ft, 3 in. apart at a height of 5 ft above the floor. Both standard and quick response type sprinklers in the 155°F temperature rating were to be used. In addition, two standard response and two quick response pendent style sprinklers in the 286°F temperature rating were to be installed below the ceiling on a 10 by 10 ft spacing. Starting with a 1 gal spill of heptane, the size of the spill fire was to be increased in 1 gal increments until the minimum size of spill fire required to activate all of the test sprinklers was determined.

DISPLAY (HAND-PICK) FIRE TESTS

The display (hand-pick) fire tests were planned to be conducted under an 18 ft high ceiling using uncartoned or case-cut 1 gallon with or without 1 quart metal containers and 5 gallon metal containers of heptane. Three tests were to be conducted using a rack storage arrangement with 2 or 3 levels of shelving. One test was planned to use an enclosed solid metal shelving unit with enclosed top, sides and back.

MIXED RACK STORAGE/DISPLAY FIRE TESTS

A series of 13 mixed rack storage (with or without) display fire tests were planned to be conducted. The fire tests were planned to be of increasing fuel loading and storage heights under both 18 and 27 ft high ceilings. The maximum height of Class 1B rack storage with ceiling sprinklers only and with a combination of both ceiling and in-rack sprinklers was to be determined. Fire tests were to be conducted using both nominal 2 by 6 in. wood slat shelving spaced 2 in. apart and open 2 by 2 in. wire mesh shelving. Mixed rack storage (with or without) display tests were also planned to be conducted using full pallet loads of commodity positioned above a display (hand-pick) arrangement in storage racks. Enclosed solid metal shelving units are not typically used for rack storage in retail stores so no tests were to be conducted utilizing enclosed solid metal shelving.

2.0 SAMPLES, FACILITIES AND EQUIPMENT

FLAMMABLE LIQUIDS, CONTAINERS AND CARDBOARD COMMODITY:

FLAMMABLE LIQUID

The flammable liquid used in this investigation was heptane, a non-polar Class IB flammable liquid hydrocarbon, having a flash point of 25°F.

1 QUART METAL F-STYLE CONTAINER

The 1 quart metal F-style (oblong) containers measured 4-9/16 by 2-3/8 by 7-1/2 in. high. Each container was fitted with a single fill opening, approximately 7/8 in. in diameter, located in one corner of the top of the container. The metal fill opening (collar) was fitted with a metal screw cap with a plastic "child proof" type cover. Twelve metal F-style containers, filled with heptane, were placed in a case-cut corrugated cardboard carton having outside dimensions of 16 by 10 by 2 in. high. See Ills. 1 and 2.

1 GALLON METAL F-STYLE CONTAINERS

The 1 gallon metal F-style (oblong) containers measured 4-1/8 by 6-5/8 by 10-1/4 in. high. Each container was fitted with a single fill opening, approximately 7/8 in. in diameter, located in one corner of the top of the container. The metal fill opening (collar) was fitted with a metal screw cap having a plastic "child proof" type cover. A flat metal carrying handle was positioned at the top center of the container.

Four metal F-style containers, filled with heptane, were placed in either a case-cut corrugated carton measuring 8-1/2 by 13-1/2 by 2 in. high or a corrugated cardboard carton having outside dimensions of 8-1/2 by 13-1/2 by 11 in. high. Thirteen cartons were positioned on a 42 by 42 by 5 in. high wood pallet. This provided a fuel loading of 52 gallons per layer of cartons. The cartons were staggered on the pallet to increase stability. Full pallet loads consisted of three layers of cartons having a total height (including pallet) of 38 in.* and were stretch-wrapped in plastic to simulate normal handling procedures. Total fuel loading was 156 gallons per pallet.** See Ills. 1, 3 and 4.

* - or four layers of cartons having a total height (including Pallet) of 49 in.;

** - for the three layer stack and 208 gallons per pallet for the four layer stack.

5 GALLON METAL TIGHT-HEAD CONTAINERS

The 5 gallon metal tight-head containers measured 11 in. in diameter by 14 in. high. The top of the cylindrical container was fitted with a nominal 2-1/4 in. fill opening located near the outer edge and a metal carrying handle in the center. The fill opening was provided with a 1-1/4 in. in diameter polyethylene pour spout which was nested inside the container.

Twelve 5 gallon metal tight-head containers, filled with heptane, were positioned on a 42 by 42 by 5 in. high wood pallet. This provided a fuel loading of 60 gallons per layer of containers. The top of the containers are slightly tapered so that the bottom of the next layer of containers would fit over them. Full pallet loads consisted of two layers of containers having a total height* of 32 in. and were stretch-wrapped in plastic to simulate normal handling procedures. Total fuel loading was 120 gallons per pallet. See Ills. 1 and 4.

CARDBOARD COMMODITY

The cardboard commodity used in the display (hand-pick) and rack storage fire tests consisted of tri-wall corrugated cardboard cartons measuring 42 by 42 by 42 in. high. Each carton was fitted with metal crossbraces to prevent collapse and placed on a 42 by 42 by 5 in. high wooden pallet.

TEST BUILDING:

The fire tests were conducted at UL's test facilities located in Northbrook, IL. The test building measured 40 by 40 by 50 ft in height and was equipped with a 30,000 cfm regenerative incinerator for smoke abatement purposes. The unit was operated at an exhaust rate of approximately 5,000 cfm for these tests. A 32 by 32 ft flat, horizontal ceiling was suspended at heights of 18 or 27 ft level above the floor such that a clearance of approximately 4 ft between the suspended ceiling and the walls were provided at the perimeter of the ceiling. This ceiling arrangement, together with the smoke abatement equipment exhausting smoke above the ceiling simulated a larger ceiling area. See Ill. 5.

* (including Pallet)

CEILING SPRINKLER SYSTEM:

A wet pipe sprinkler system was installed below the movable ceiling to provide a design density of 0.30 to 0.50 gpm/ft^2 for the display fire tests and 0.50 to 0.60 gpm/ft^2 for the rack storage fire tests. For the display fire tests and the rack storage fire tests conducted at a 0.50 gpm/ft^2 design density, 16 large orifice pendent style sprinklers were installed on a 10 by 10 ft spacing. For the rack storage fire tests conducted at a design density of 0.60 gpm/ft^2, 16 extra large orifice pendent style sprinklers were installed on 10 by 10 ft spacing. The branch lines in the sprinkler system were a minimum 2 in. diameter and the system piping was looped to minimize losses in pressure due to friction. See Ills. 6 and 7.

IN-RACK SPRINKLER SYSTEM:

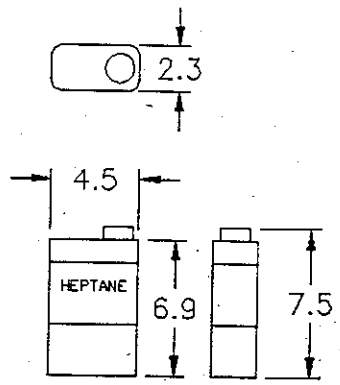
A separate wet pipe in-rack sprinkler system was installed in the 6 in. flue space between the double row racks. Large orifice sprinklers, designed to discharge at a flow rate of 30 gpm, were installed on a 8 ft, 3 in. spacing. The branch lines(s) were 1-1/2 in. in diameter and when 2 branch lines were installed, the branch lines were looped to minimize losses due to friction. See Ill. 8.

INSTRUMENTATION:

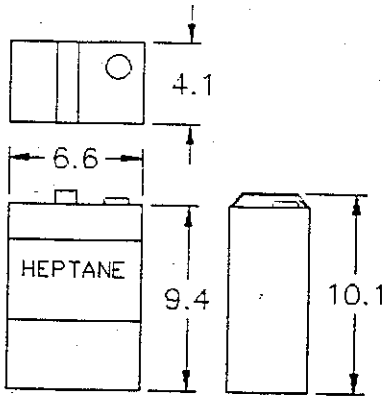
To record ceiling temperatures, 16 thermocouples were positioned 6 in. below the ceiling adjacent to each sprinkler. Twelve additional thermocouples were positioned 12 in. above the ceiling in the perimeter flue spaces. See Ill. 7.

DRAINAGE:

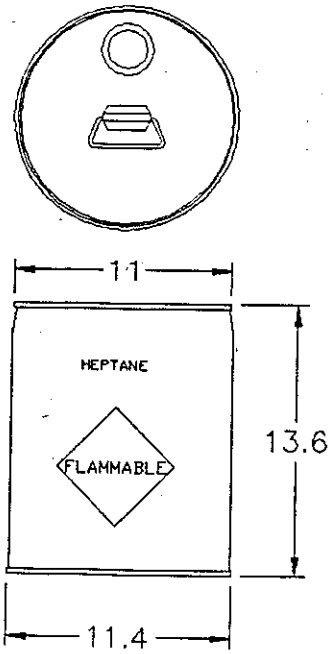
A 2 by 2 ft drain opening was located in each of the four corners of the test building. The positioning of these drains assisted in simulating a larger open floor area by permitting any spilled fuel to spread across the floor area toward the corners of the test building.



ONE QUART CAN



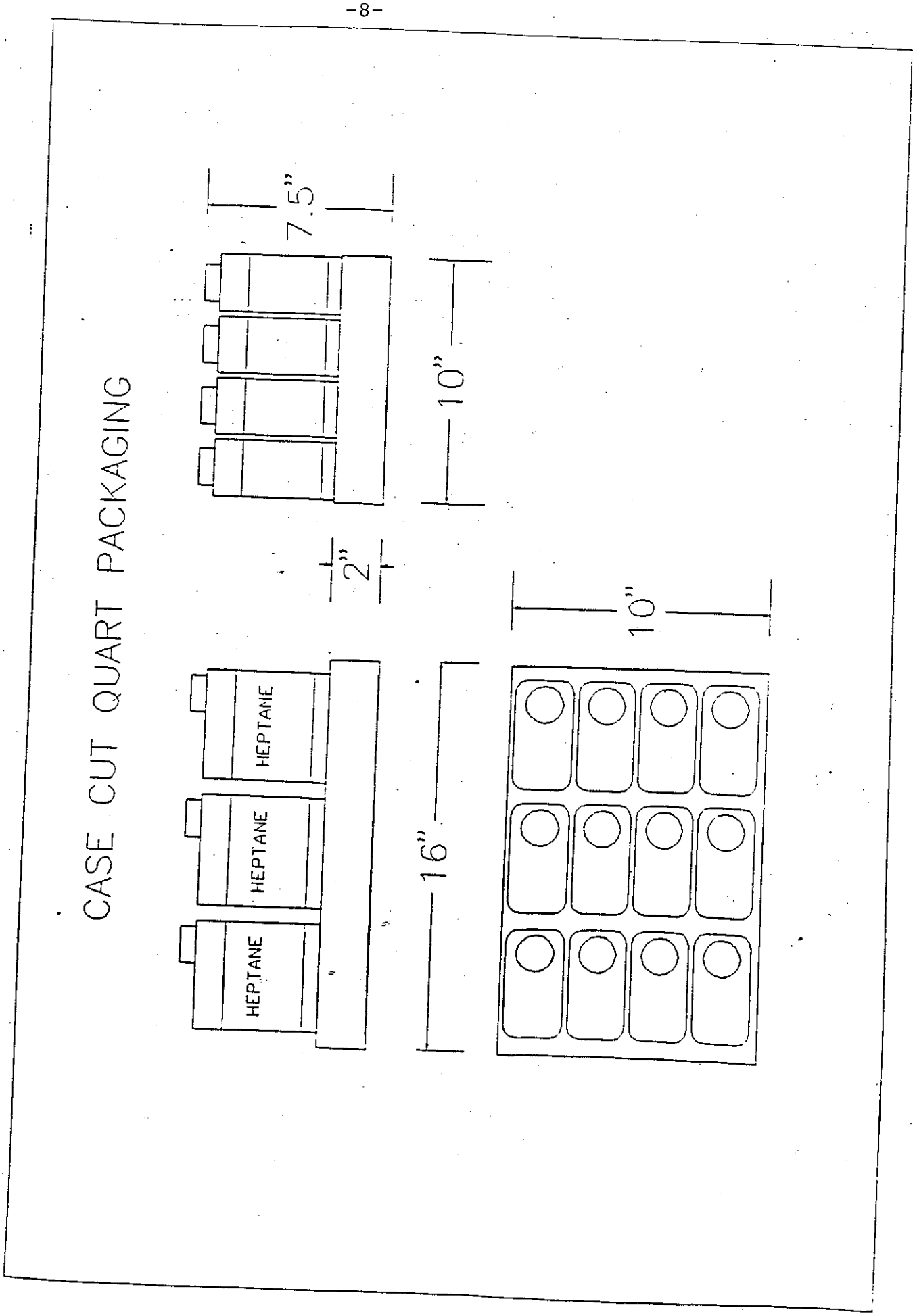
ONE GALLON CAN



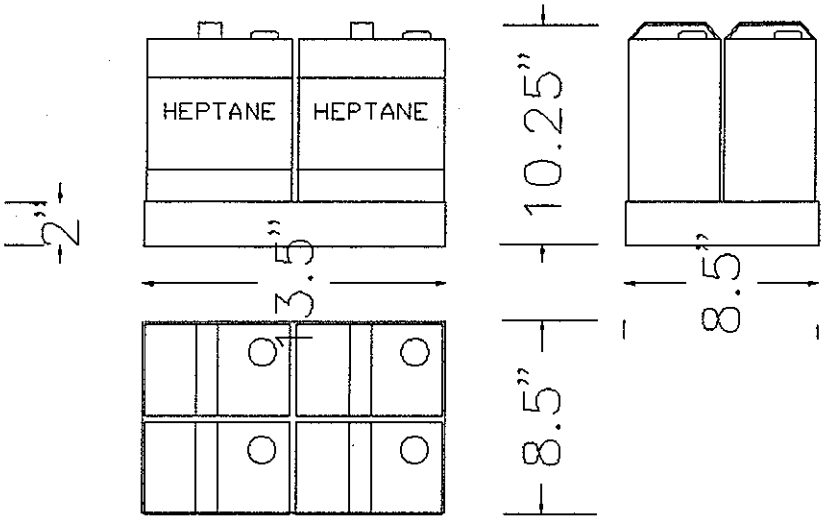
FIVE GALLON CAN

CONTAINER DETAILS

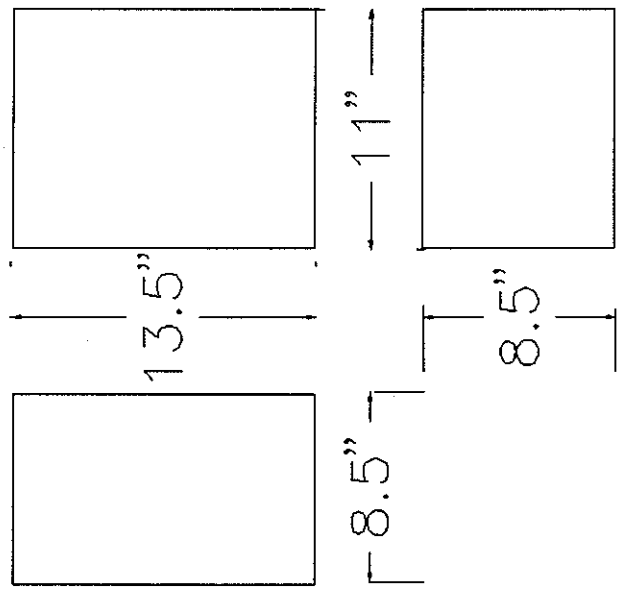
ILL. 1


CASE CUT QUART PACKAGING
7.5"
10"
2"
10"
16"
HEPTANE
HEPTANE
HEPTANE

ILL. 2

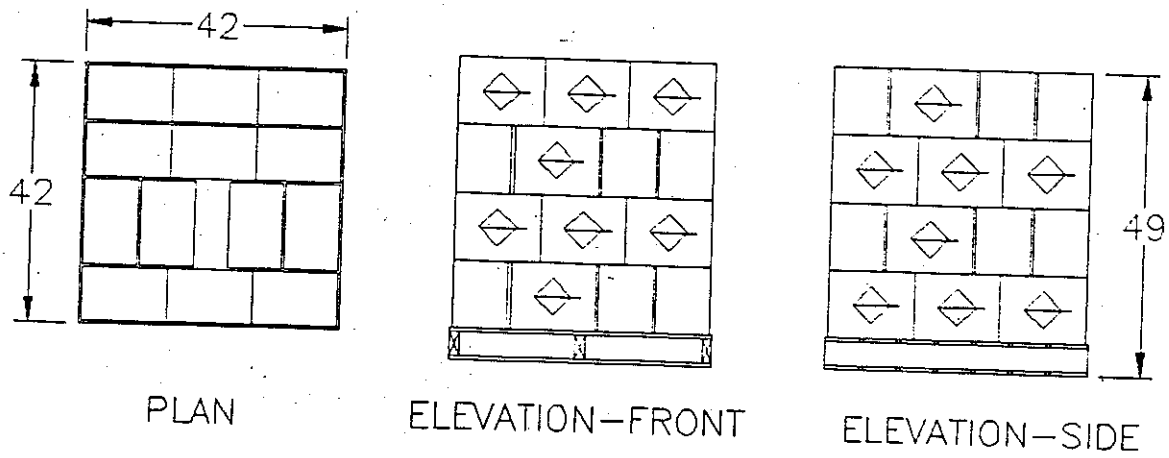


CASE CUT GALLON PACKAGING

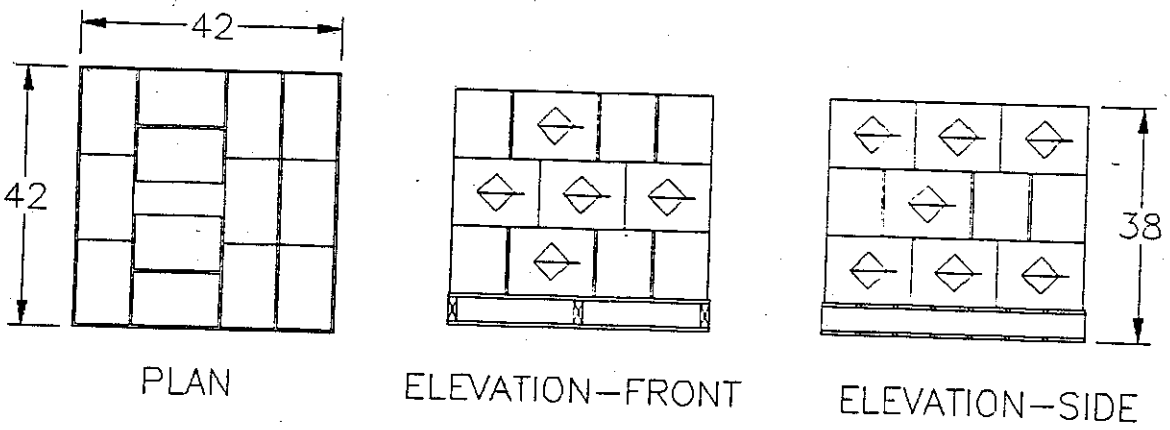


CASE GALLON PACKAGING

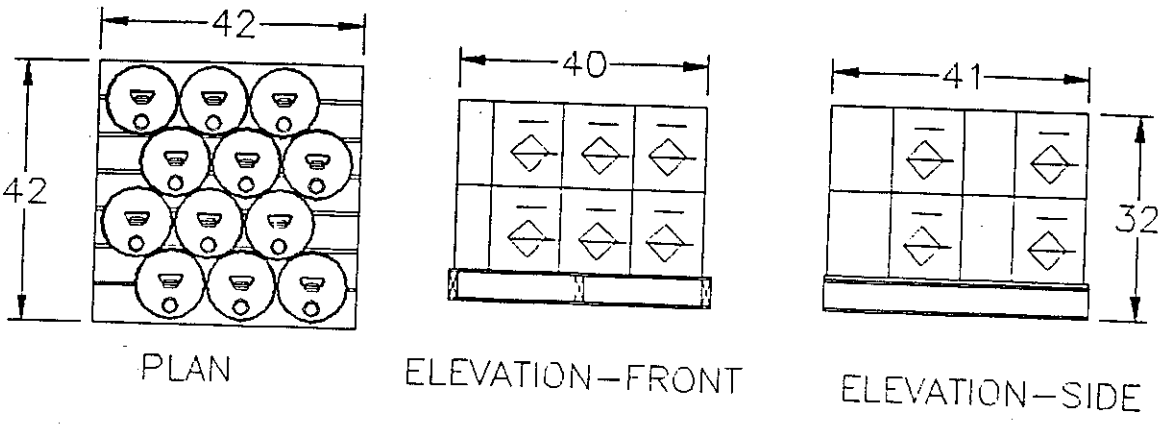
ILL. 3



FOUR–HIGH PALLETS – GALLON CANS



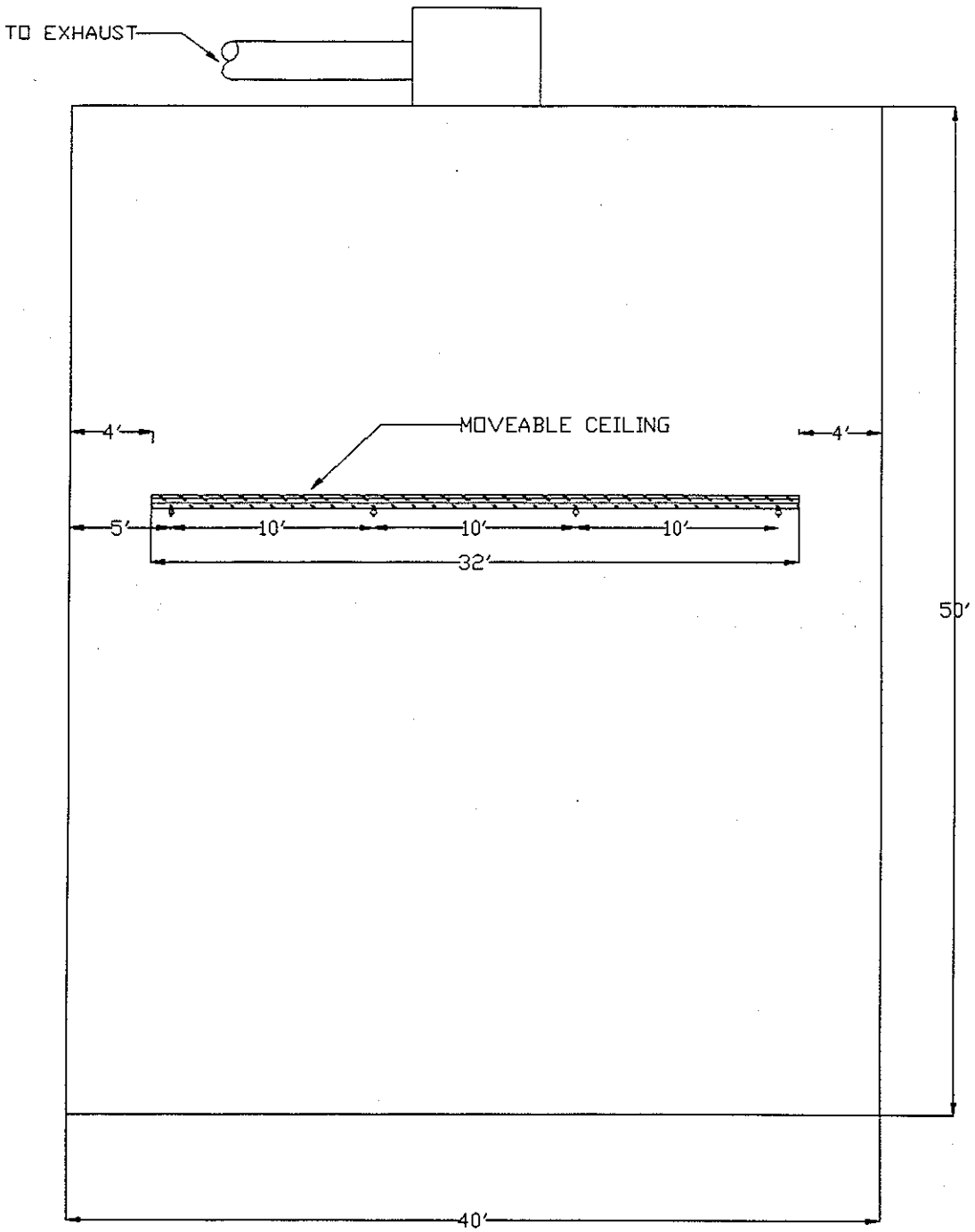
THREE–HIGH PALLETS – GALLON CANS



TWO–HIGH PALLETS – 5 GALLON CANS

PALLET DETAILS

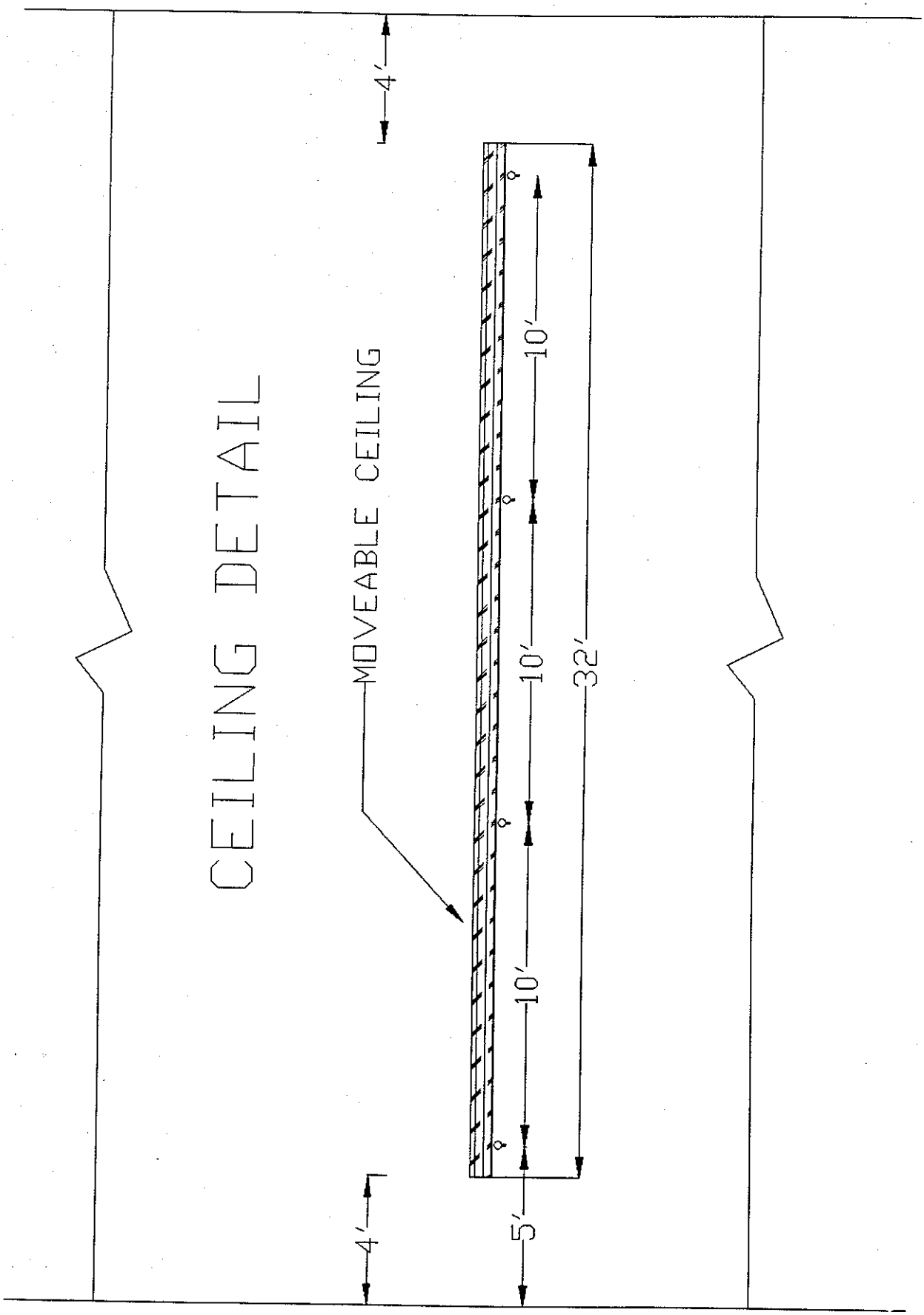
ILL. 4



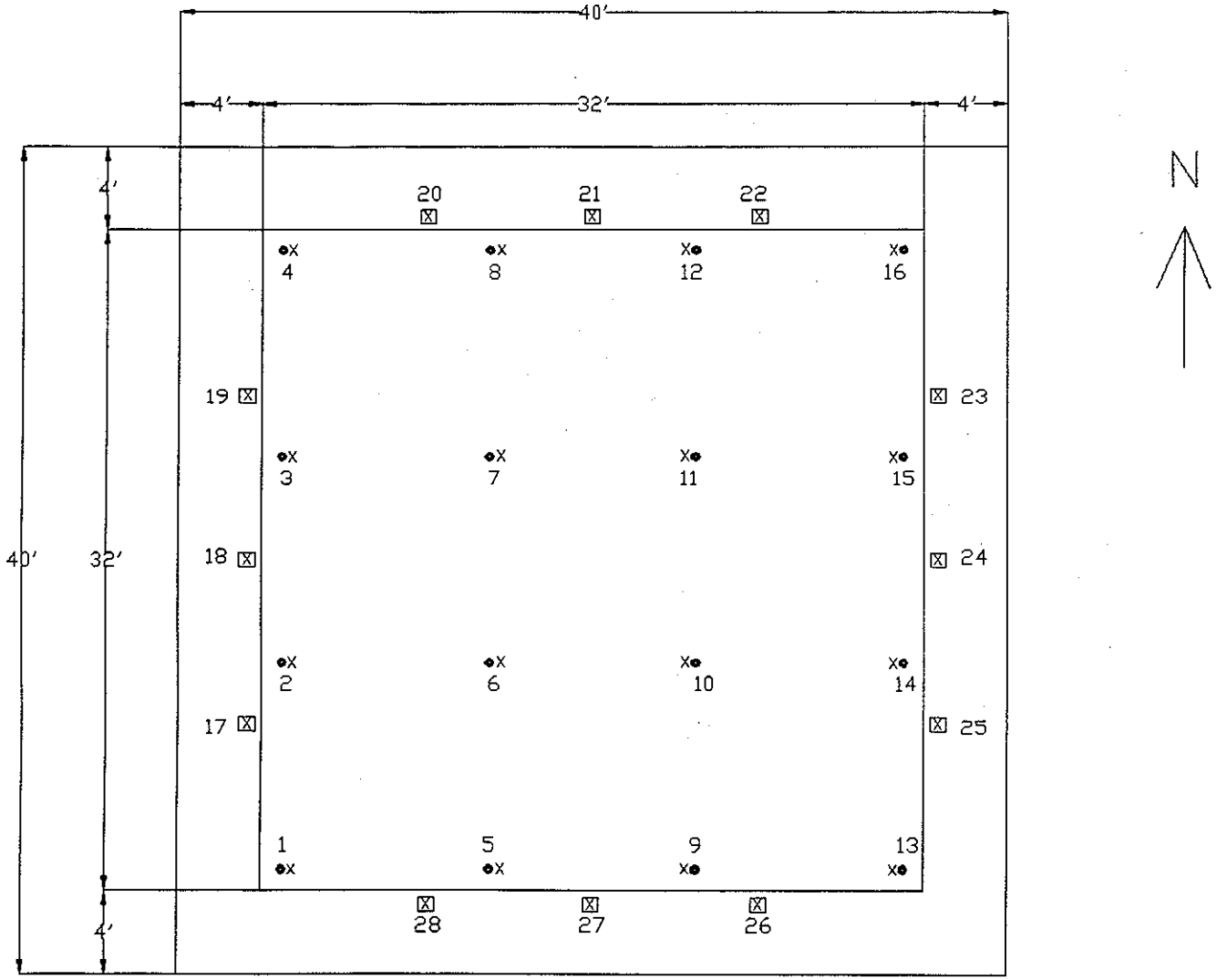
UL'S HIGHRISE TEST BUILDING

40' X 40' X 50' HIGH

ILL. 5



ILL. 6



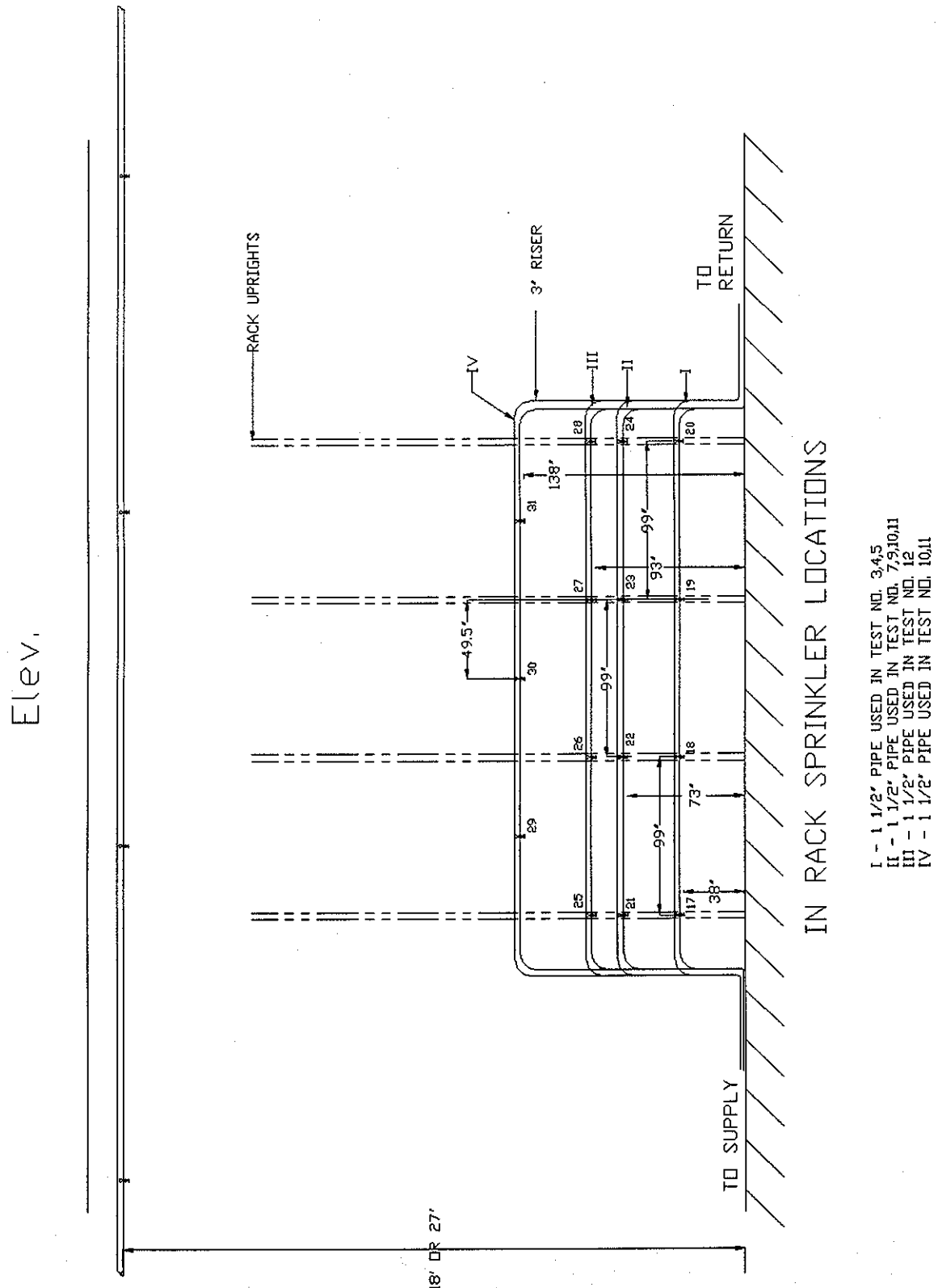
● – PENDANT STYLE SPRINKLER ON 10' X 10' SPACING

x – THERMOCOUPLE POSITIONED 6" BELOW CEILING

⊠– THERMOCOUPLE POSITIONED 12" ABOVE CEILING

SPRINKLER AND THERMOCOUPLE LOCATIONS PLAN VIEW

ILL. 7


Elev.
RACK UPRIGHTS
3" RISER
TO RETURN
TO SUPPLY
18' OR 27'
IV
III
II
I
138'
99'
93'
49.5'
99'
73'
99'
38'
IN RACK SPRINKLER LOCATIONS
I - 1 1/2" PIPE USED IN TEST NO. 3,4,5
II - 1 1/2" PIPE USED IN TEST NO. 7,9,10,11
III - 1 1/2" PIPE USED IN TEST NO. 12
IV - 1 1/2" PIPE USED IN TEST NO. 10,11

Ill. 8

3.0 FIRE TESTS

IGNITION SCENARIO TESTS:

TEST PROCEDURE

A series of freeburn fire tests were conducted using a heptane spill fire to determine the maximum quantity of fuel which would not activate both standard and quick response 286°F temperature rated sprinklers installed under an 18 and 27 ft high ceiling. Under the 18 ft high ceiling, both standard and quick response 155°F temperature rated in-rack sprinklers were installed to record their operating times.

Two pairs of pendent style large orifice sprinklers were installed in a branch line at a 8 ft, 3 in. spacing. The sprinkler deflector to floor distance was 60 in. Each sample pair, identified as NE and NW or SE and SW, consisted of a standard response and a quick response sprinkler in the 155°F temperature rating. In addition, two standard response and two quick response sprinklers in the 286°F temperature rating were installed on a 10 by 10 ft spacing below the ceiling. The standard response and quick response sprinklers were positioned diagonally opposite each other. Event recorders to record the operating time of each sprinkler and thermocouples to measure the air temperature were positioned near each pair of in-rack sprinklers and each ceiling sprinkler.

Plastic bags, each containing one gallon of heptane, were positioned on the floor and centered below both the in-rack and ceiling sprinklers. Starting with one gallon of heptane and increasing in one gallon increments, the maximum quantity of a heptane spill fire that would not activate the ceiling sprinklers at heights of 18 and 27 ft was determined.

RESULTS

The results of the ignition scenario fire tests are contained in Table 1. The air temperatures adjacent to each sprinkler or pair of sprinklers for the tests under an 18 ft high ceiling are shown in Appendix A.

TABLE 1 - IGNITION SCENARIO FIRE TEST RESULTS

Test Number	Ceiling Height, ft	Quantity of Heptane Fuel,Gal	Ceiling Sprinklers				In-Rack Sprinklers			
			286°F		286°F QR		155°F		155°F QR	
			Sprinkler Location+	Operating Time,s	Sprinkler Location+	Operating Time,s	Sprinkler Location	Operating Time,s	Sprinkler Location	Operating Time,s
1	18	1	7	-	6	-	SW	-	SE	-
			10	-	11	-	NE	24	NW	24
2	18	2	7	-	6	-	SW	74	SE	30
			10	-	11	-	NE	74	NW	30
3	18	3	7	-	6	46	SW	-	SE	66
			10	-	11	46	NE	40	NW	34
4	18	4	7	63	6	42	SW	60	SE	54
			10	63	11	42	NE	60	NW	42
5	27	3	7	-	6	55	-	-	-	-
			10	-	11	42				
6	27	4	7	65	6	41	-	-	-	-
			10	65	11	41				

+ See ILL. 7 for sprinkler layout.

IGNITION SOURCE:

Each of the display (hand-pick) and mixed rack storage (with or without) display fire tests was ignited using a 2 gal spill of heptane. Two plastic bags, each filled with 1 gal of heptane, were positioned in the transverse flue space formed between the double row racks except for Display (Hand-Pick) Fire Test No. 4 and Mixed Rack Storage Fire Test No. 8 where the 2 bags of heptane were positioned in the aisle. A wick of heptane was poured over the two plastic bags to achieve simultaneous ignition of both bags of heptane.

MEASUREMENTS AND OBSERVATIONS:

The following measurements and observations were made during each test:

1. The operating time of each sprinkler.
2. Air temperatures adjacent to each sprinkler and along the perimeter of the ceiling.
3. Total water flow.
4. Damage assessment.
5. Weather conditions.

DISPLAY (HAND-PICK) FIRE TESTS:

TEST PROCEDURE

A series of display (hand-pick) fire tests were conducted to evaluate the suppression characteristics of sprinkler systems installed to protect fires involving flammable liquid arranged in displays representing typical wholesale and retail sales areas. Three of the fire tests were conducted using a double row rack storage arrangement with a 6 in. flue space. One test involved the use of a solid metal shelving unit with an enclosed back, sides and top.

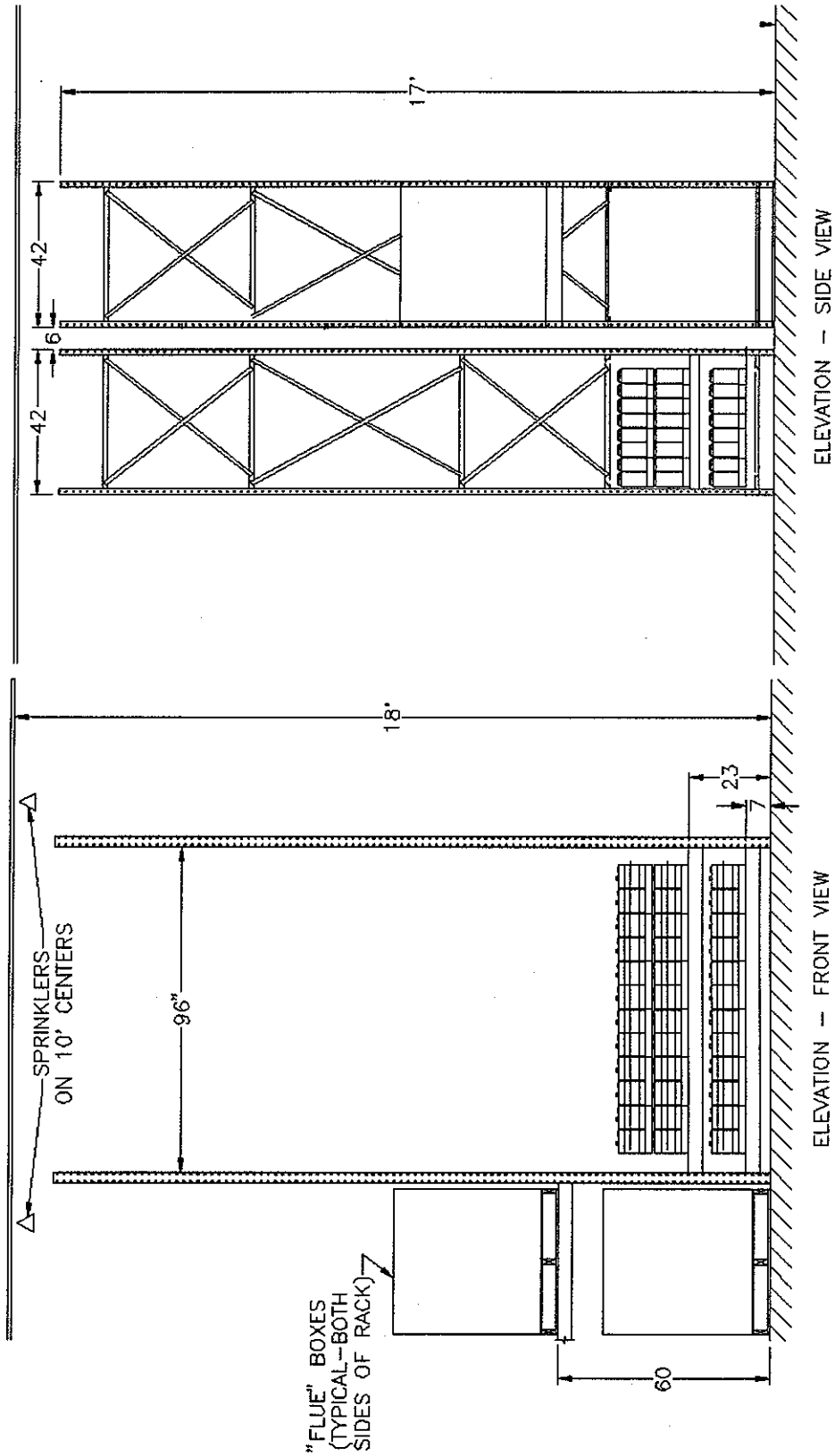
The test parameters are summarized in Table 2. For Display Fire Tests 1 through 3, an 8 ft wide display (hand-pick) arrangement of flammable liquids with cardboard commodity positioned on the back side of the double row rack was used. See Ills. 9-11. Except for Fire Test 4, two 1 gallon bags of heptane were centered in the flue space between the cardboard and display commodities. For Fire Test 4, a 7 ft wide solid metal shelf unit having enclosed sides, back and top was used and the two bags of heptane were positioned in the aisle. The shelving unit also had a solid vertical metal divider located 3 ft in from one side. See ILL. 12. Open 2 by 2 in. wire mesh shelving was used in Fire Tests 2 and 3, nominal 2 by 6 in. wood slats positioned 2 in. apart on the cross beams in Fire Test 1, and solid metal shelving in Fire Test 4. One gallon metal F-style containers of heptane were used in Fire Tests 1 and 2, one quart and one gallon metal F-style containers of heptane in Fire Test 3, one quart and one gallon metal F-style containers and five gallon metal tight-head containers of heptane in Fire Test 4.

For Fire Tests 1 through 3, water was supplied to the four open large orifice pendent style ceiling sprinklers located directly over the test array in positions 6, 7, 9 and 10 to provide a design density of 0.30 gpm/ft^2, 2 min into the test. For Fire Test 4, sixteen 286°F temperature rated large orifice sprinklers were installed below the ceiling at a design density of 0.30 gpm/ft^2.

The heptane spill fire was ignited and observations were made to determine the sprinkler system suppression/control characteristics provided for the various display arrangements.

TABLE 2 - DISPLAY (HAND-PICK) FIRE TEST PARAMETERS

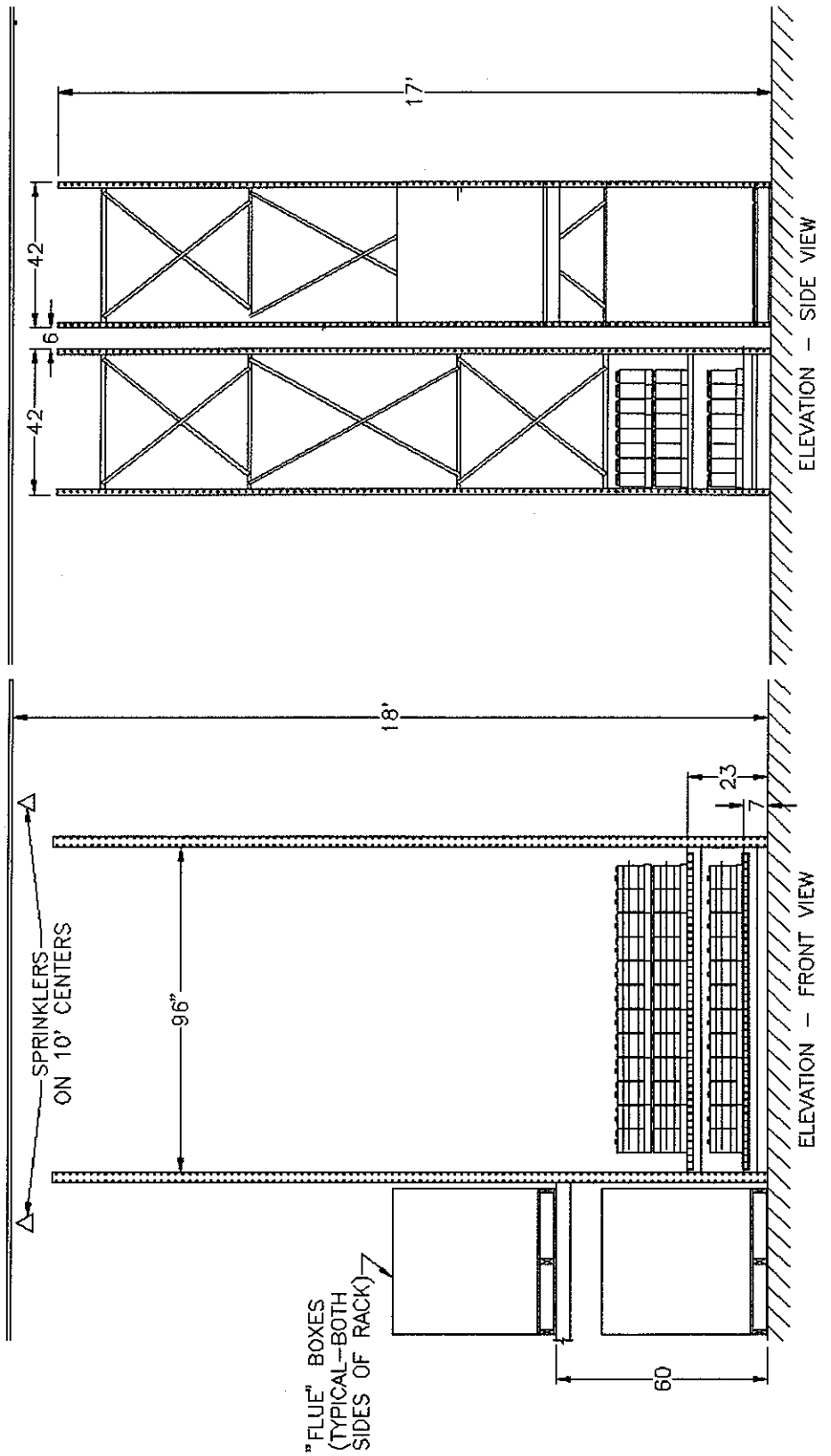
Test No.	Ignition Location	ILL. No.	Ceiling Height, Ft	Total Storage Height, In.	Design Density GPM/ft²	Ceiling Sprinkler Type	Shelf Type	Shelf Heights, in.	Heptane Containers, Storage Per Shelf		
									Qts	1 Gal	5 Gal
1	Flue	9	18	44.5	0.30	Open	2 x 6	7	-	112	-
						LO	Wood	23	-	224	-
							Slat				
							Spaced 2 in.				
							Apart				
2	Flue	10	18	44.5	0.30	Open	Open 2 by 2 in.	7	-	112	-
						LO	Wire Mesh	23	-	224	-
3	Flue	11	18	67	0.30	Open	Open 2 by 2 in.	7	-	112	-
						LO	Wire Mesh	23	-	224	-
								49	324	-	-
4	Aisle	12	18	88	0.30	286°F	Enclosed Top,	11.5	-	-	14
						LO	Back and	35	-	48	-
							Sides Steel	51.25	-	48	-
							Shelving	68	68	-	-
							Unit	80.25	68	-	-



NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

HAND–PICK TEST NO. 1

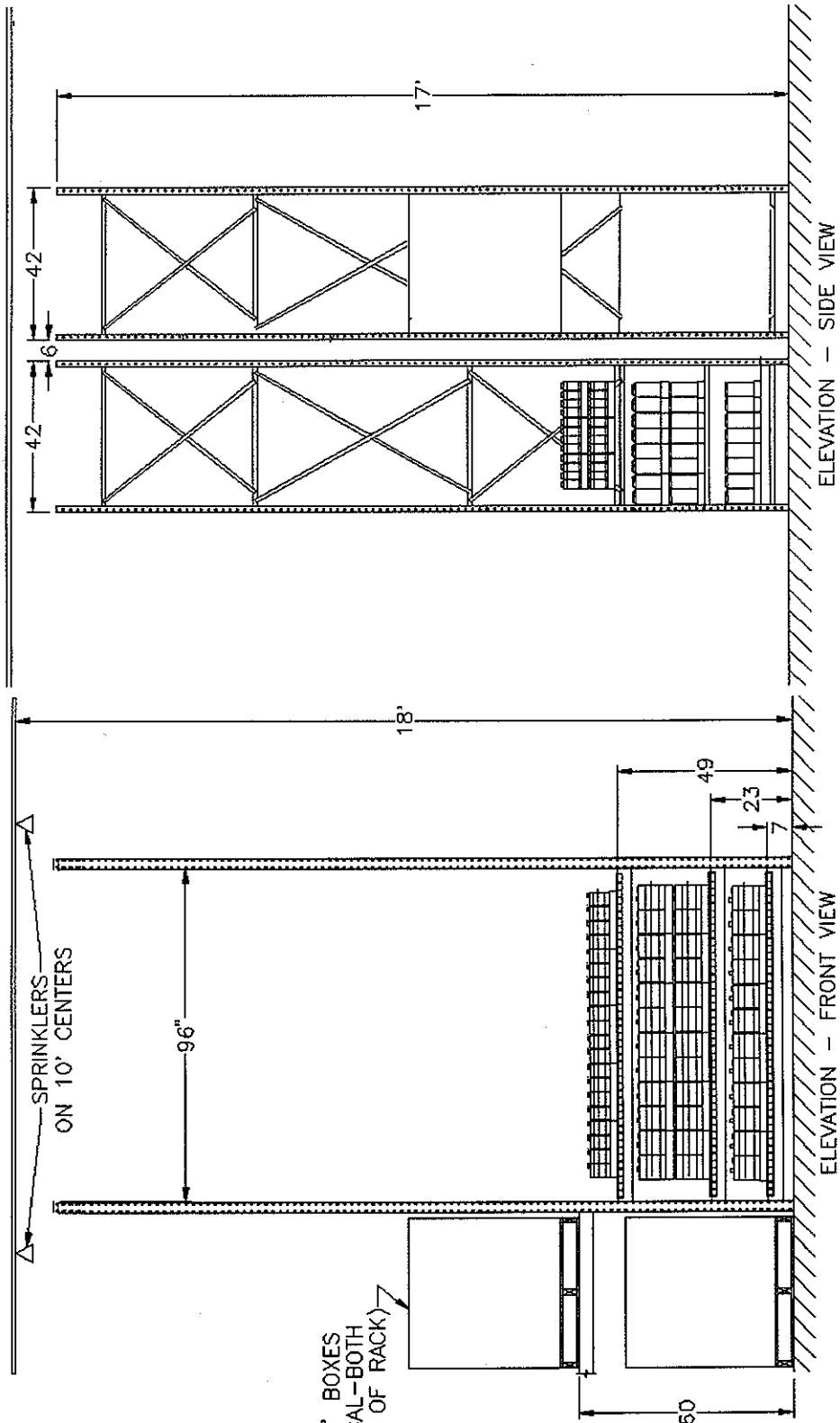
ILL. 9



NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

HAND–PICK TEST NO. 2

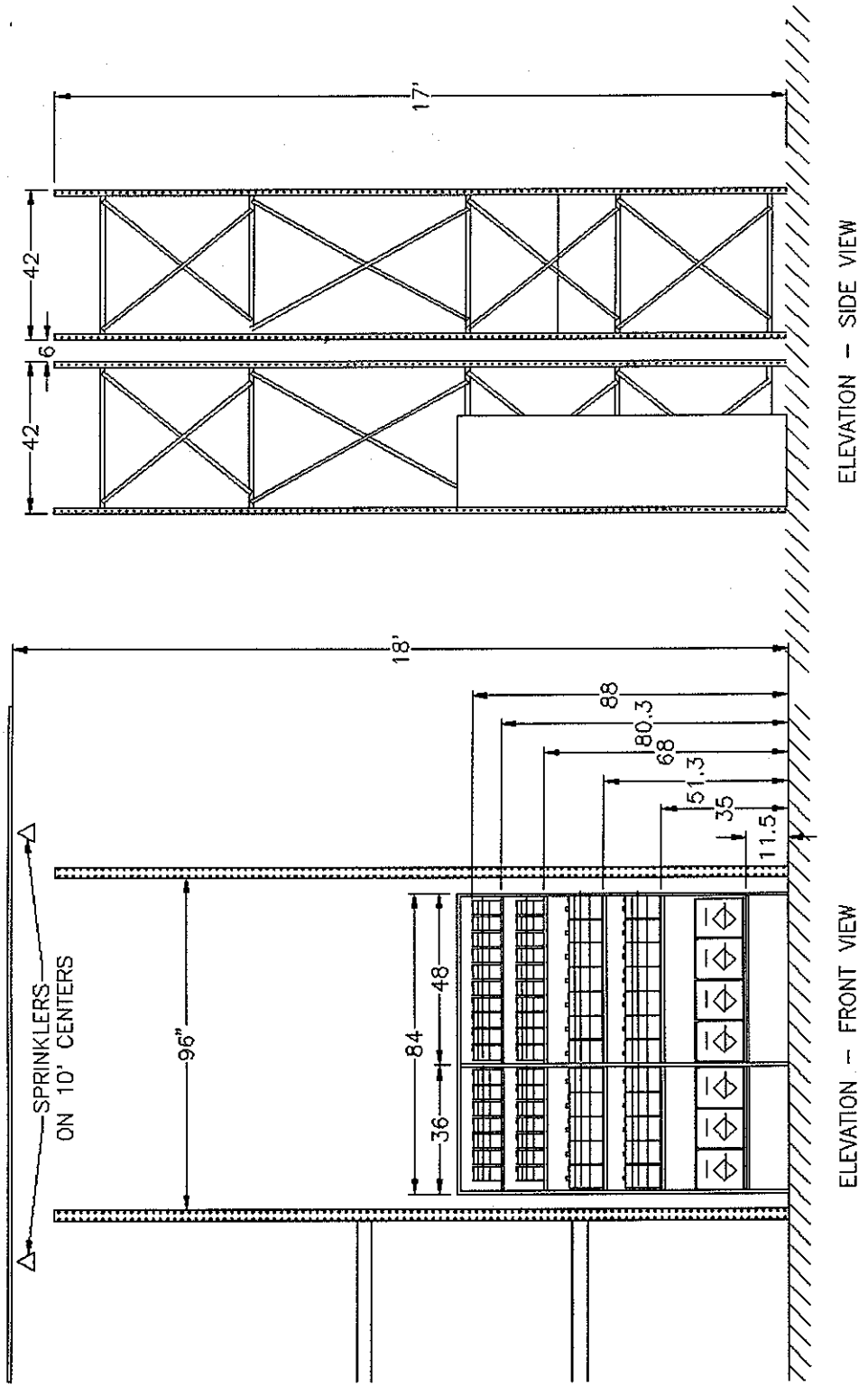
ILL.10



NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

HAND–PICK TEST NO. 3

ILL. 11



NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

HAND–PICK TEST NO. 4

ILL.12

RESULTS

The test results are summarized in Table 3.

The results of Fire Tests 1 through 3 were determined to provide fire control as evidenced by the fact that there was no rupturing of metal containers of heptane and damage was limited to a small area near the ignition source. See Figs. 1-3.

In Fire Test 4, several 1 quart metal F-style containers of heptane ruptured a few seconds after the first ceiling sprinkler operated. This caused a total of 12 ceiling sprinklers, all but numbers 1, 5, 9 and 13, to operate over an 18 s period. The rupture of the one quart containers dislocated the top of the shelving enclosure and caused 29 quart containers to fall onto the floor. See Fig. 4.

TABLE 3 - DISPLAY (HAND-PICK) FIRE TEST RESULTS

Test No.	ILL. No.	Ceiling Height, Ft	Storage Height, In.	Ceiling Sprinklers		Total Flow Rate, GPM	Fire Controlled	Damage Assessment
				No.	Operating Time,s			
1	9	18	44.5	4+	93	120	Yes	Caps separated on numerous 1 gal containers. Twelve 1 gal containers leaked. Bottom shelf fell due to beam expansion.
2	10	18	44.5	4+	120	120	Yes	Caps separated on numerous 1 gal containers.
3	11	18	67	4+	120	120	Yes	Caps separated on numerous 1 gal containers.
4++	12	18	88	12+++	Between 167 and 185	360	No	Pour spouts vented on all 5 gal containers. Rupture of several quart containers caused the top shelf to move out of place. Twenty-nine quart containers on the floor. Damage to shelving unit from rupturing of quart containers.

\+ Nos. 6, 7, 10 and 11.
++ Aisle ignition.
+++ All but Nos. 1, 5, 9 and 13.

MIXED RACK STORAGE WITH DISPLAY FIRE TESTS:

TEST PROCEDURE

A series of Mixed Rack Storage (with or without) Display Fire Tests were conducted involving the storage of heptane in 1 quart and 1 gallon metal F-style and 5 gallon metal tight-head containers. Eight fire tests were conducted under an 18 ft high ceiling and five fire tests under a 27 ft high ceiling. Four fire tests involved the use of ceiling sprinklers only; seven fire tests employed ceiling and one level of in-rack sprinklers and two fire tests employed ceiling and two levels of in-rack sprinklers. Five fire tests were conducted with large orifice ceiling sprinklers discharging at a design density of 0.50 gpm/ft^2 and eight fire tests with extra large orifice pendent style ceiling sprinklers discharging at a design density of 0.60 gpm/ft^2. Seven fire tests employed nominal 2 by 6 in. wood slats spaced 2 in. apart and the remaining fire tests utilized open 2 by 2 in. wire mesh shelving. A summary of the rack storage fire test parameters is presented in Table 4.

The flammable liquid commodity was placed in a 7.5 ft wide double-row rack and the cardboard commodity was placed in the rack on both adjacent sides and across a 7.5 ft aisle. A 2 gal heptane spill fire was positioned in the flue space for all of the fire tests except Fire Test No. 8 which used an aisle ignition.

The heptane spill fire was ignited and observations were made to determine the sprinkler systems suppression characteristics for the various fuel packages.

TABLE 4 - MIXED RACK STORAGE (WITH OR WITHOUT) DISPLAY FIRE TEST PARAMETERS

Test No.	Ignition Location	Ill. No.	Ceiling Height, Ft	Total Storage Height Ft: In.	Ceiling Sprinklers Design Density, Gpm/Ft²	Ceiling Sprinklers Type	In-Rack Sprinklers Height, In.	In-Rack Sprinklers Type	Shelf Type	Shelf Heights, In.	Number Of Heptane Container Storage Per Shelf Qts	1 Gal	5 Gal	Cardboard Commodity Shelf Heights, Ft	Target Aisle, Ft
1	Flue	13	18	10: 8	0.50	286°F LO	-	-	2 x 6 in. Wood Slats	0 42 90	- - -	- 624 624	96 - -	0 5 10	7.5
2	Flue	14	18	6: 8	0.50	286°F LO	-	-	Open 2 by 2 in. Wire Mesh	0 42	- -	- 624	96 -	0 5 10	7.5
3	Flue	15	18	6: 8	0.50	286°F LO	38	155°F LO	2 x 6 in. Wood Slats	0 42	- -	- 624	96 -	0 5 10	7.5
4	Flue	16	18	6: 8	0.50	155°F LO	38	155°F LO	2 x 6 in. Wood Slats	0 42	- -	- 624	96 -	0 5 10	7.5
5	Flue	17	18	6: 8	0.50	155°F LO	38	155°F QR LO+	2 x 6 in. Wood Slats	0 42	- -	- 624	96 -	0 5 10	7.5
6	Flue	18	18	12:0	0.60	286°F ELO	-	-	Open 2 by 2 in. Wire Mesh	7 36 54 77 95	- - 360 - -	192 96 - 96 416	- - - - -	0 5 10	7.5

(table cont'd)

Test No.	Ignition Location	Ill. No.	Ceiling Height, Ft	Total Storage Height Ft: In.	Ceiling Sprinklers Design Density, Gpm/Ft²	Ceiling Sprinklers Type	In-Rack Sprinklers Height, In.	In-Rack Sprinklers Type	Shelf Type	Shelf Heights, In.	Number Of Heptane Container Storage Per Shelf Qts	1 Gal	5 Gal	Cardboard Commodity Shelf Heights, Ft	Target Aisle, Ft
7	Flue	19	18	12:0	0.60	286°F ELO	73	155°F QR LO+	Open	7	-	192	-		
									2 by 2 in.	36	-	96	-	0	7.5
									Wire	54	360	-	-	5	
									Mesh	79	-	96	-	10	
										97	-	416	-		
8	Aisle	20	18	12:0	0.60	286°F ELO	-	-	Open	7	-	192	-		
									2 by 2 in.	36	-	96	-	0	7.5
									Wire	54	360	-	-	5	
									Mesh	79	-	96	-	10	
										97	-	416	-		
9	Flue	21	27	12:0	0.60	286°F ELO	73	155°F QR LO+	Open	7	-	192	-	0.5	
									2 by 2 in.	36	-	96	-	5	7.5
									Wire	54	360	-	-	10	
									Mesh	79	-	96	-		
										97	-	416	-		
10	Flue	22	27	16:0	0.60	286°F ELO	73 and 138	155°F QR LO+	Open	7	-	192	-	0.5	
									2 by 2 in.	36	-	96	-	5	
									Wire	54	360	-	-	10	
									Mesh	79	-	96	-		
										95	-	312	-		
										144	-	416	-		

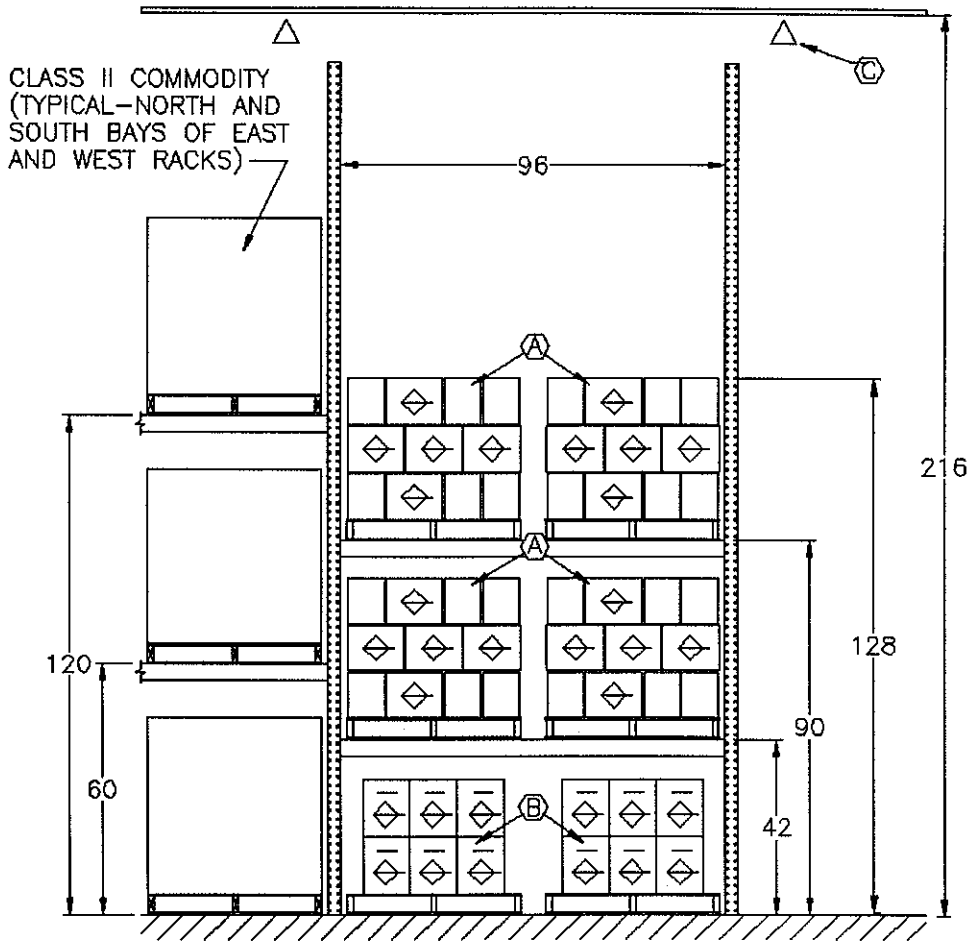
(table cont'd)

Test No.	Ignition Location	Ill. No.	Ceiling Height, Ft	Total Storage Height, Ft: In.	Ceiling Sprinklers Design Density, Gpm/Ft²	Ceiling Sprinklers Type	In-Rack Sprinklers Height, In.	In-Rack Sprinklers Type	Shelf Type	Shelf Heights, In.	Number Of Heptane Container Storage Per Shelf Qts	Number Of Heptane Container Storage Per Shelf Gals	Cardboard Commodity Shelf Heights, Ft	Target Aisle, Ft
11	Flue	23	27	19: 8	0.60	286°F ELO	73 and 138	155°F QR LO+	2 x 6 in. Wood Slats And Open 2 by 2 in. Wire Mesh On Top Shelf Only.	7 36 54 79 95 144 188++	- - 360 - - - -	192 96 - 96 312 312 -	- - - - - - -	0.5 5 10 15	7.5
12	Flue	24	27	16: 0	0.60	286°F ELO	93	155°F QR LO+	2 x 6 in. Wood Slats And Open 2 by 2 in. Wire Mesh On Top Shelf Only.	7 36 54 79 95 144	- - 360 - - -	192 96 - 96 312 416	- - - - - -	0.5 5 10	7.5
16	Flue	25	27	16: 0	0.60	286°F QR ELO+	93	155°F QR LO++	2 x 6 in. Wood Slats And Open 2 by 2 in. Wire Mesh On Top Shelf Only.	7 36 54 79 95 144	- - 360 - - -	192 96 - 96 312 416	- - - - - -	0.5 5 10	7.5

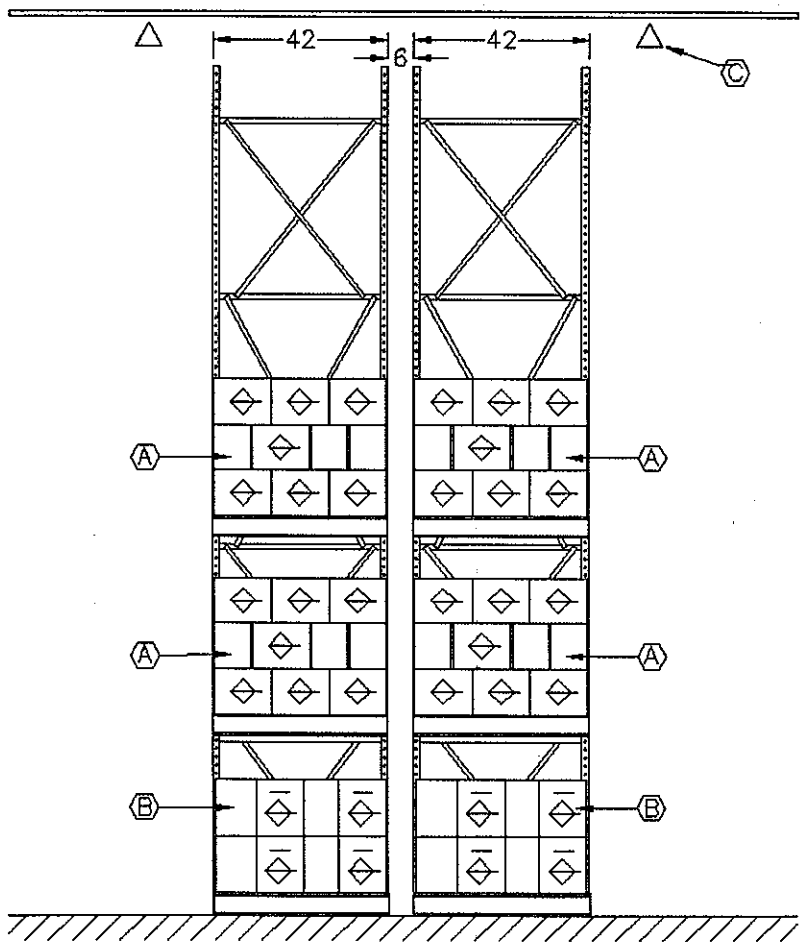
+ - Sprinkler frame positioned perpendicular to branchline.

++ - Cardboard Commodity also positioned above heptane commodity.

+++ - Extra large orifice, nominal 5/8 in. diameter, pendent style quick response sprinklers.



ELEVATION–FRONT VIEW

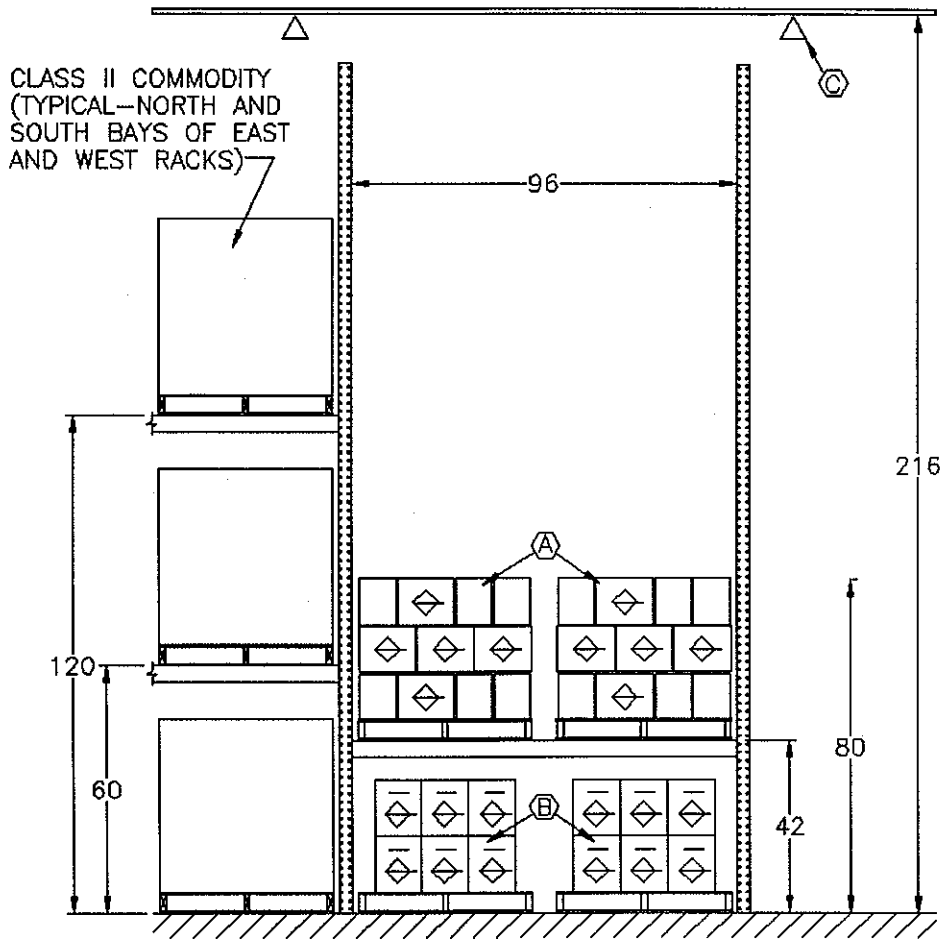


ELEVATION–SIDE VIEW

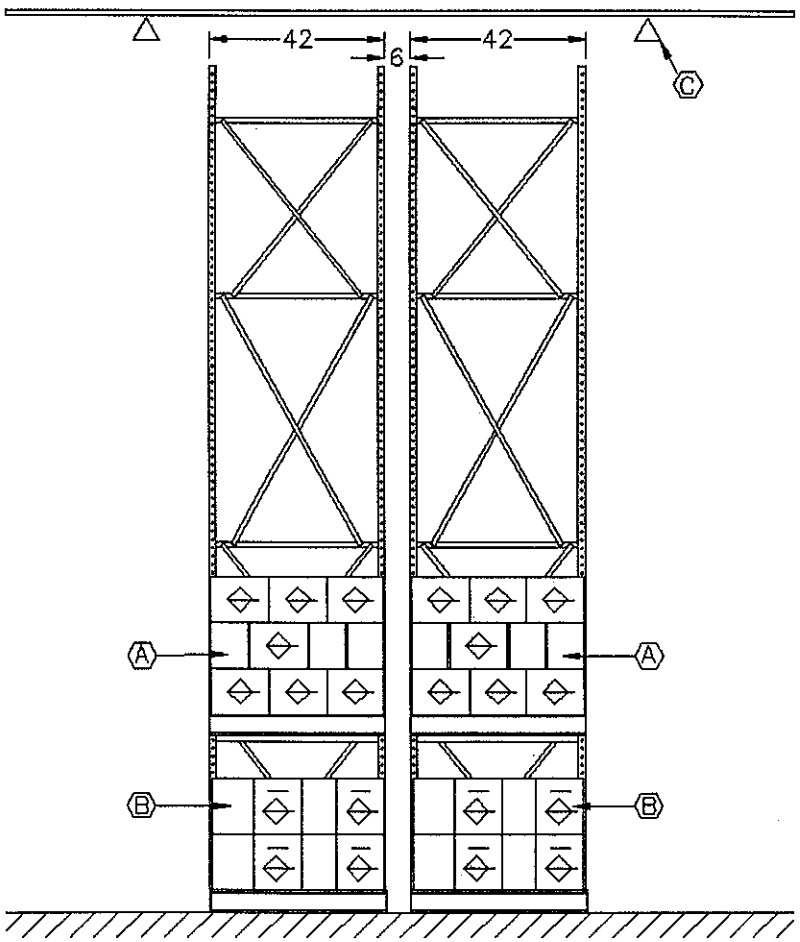
Ⓐ PALLETIZED 1 GAL "F" STYLE – 156 GAL/PALLET
Ⓑ PALLETIZED 5 GAL "TIGHT HEAD" – 120 GAL/PALLET
Ⓒ 286 F LARGE ORIFICE SPRINKLERS ON 10 FT CENTERS

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

RACK CONFIGURATION–TEST NO. 1



ELEVATION—FRONT VIEW

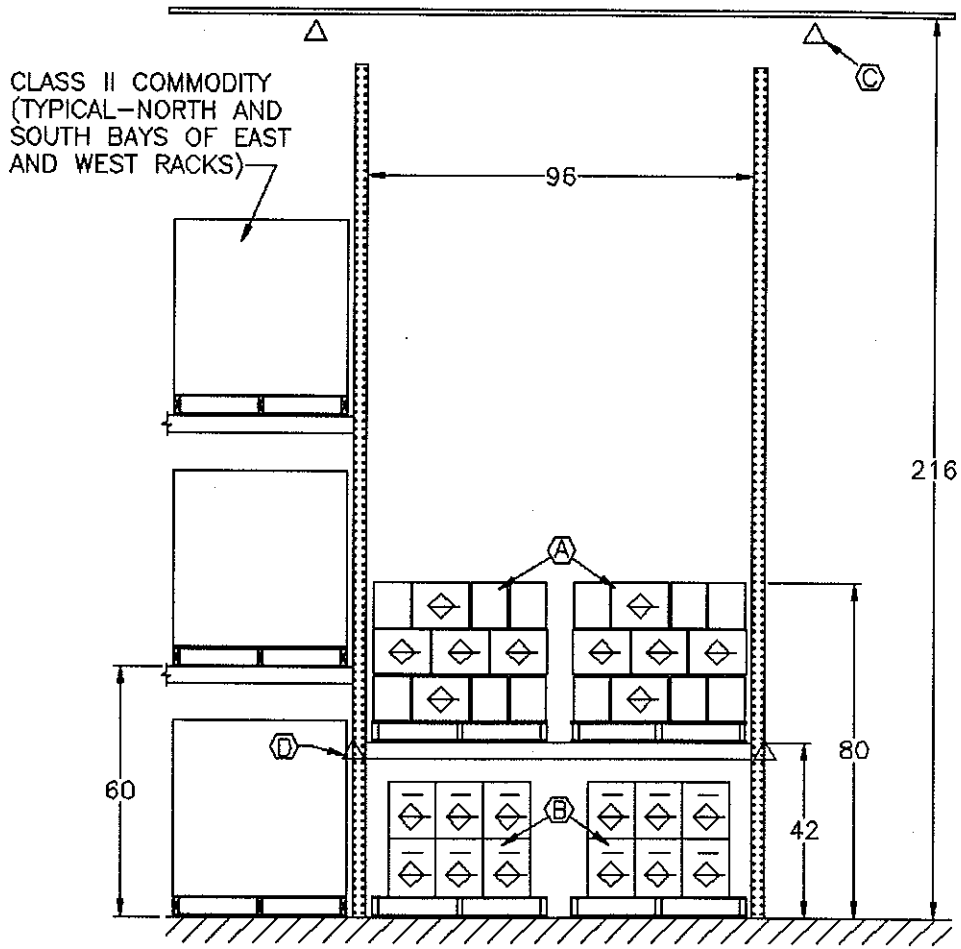


ELEVATION—SIDE VIEW

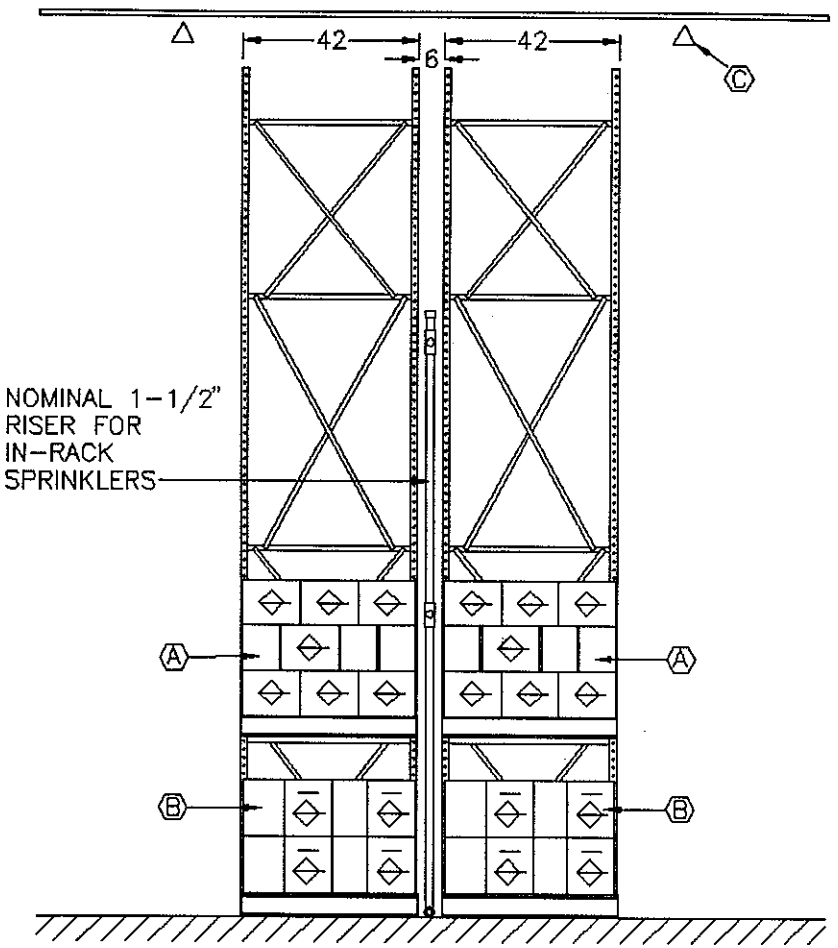
Ⓐ PALLETIZED 1 GAL "F" STYLE – 156 GAL/PALLET
Ⓑ PALLETIZED 5 GAL "TIGHT HEAD" – 120 GAL/PALLET
Ⓒ 286 F LARGE ORIFICE SPRINKLERS ON 10 FT CENTERS

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

RACK CONFIGURATION—TEST NO. 2



ELEVATION–FRONT VIEW

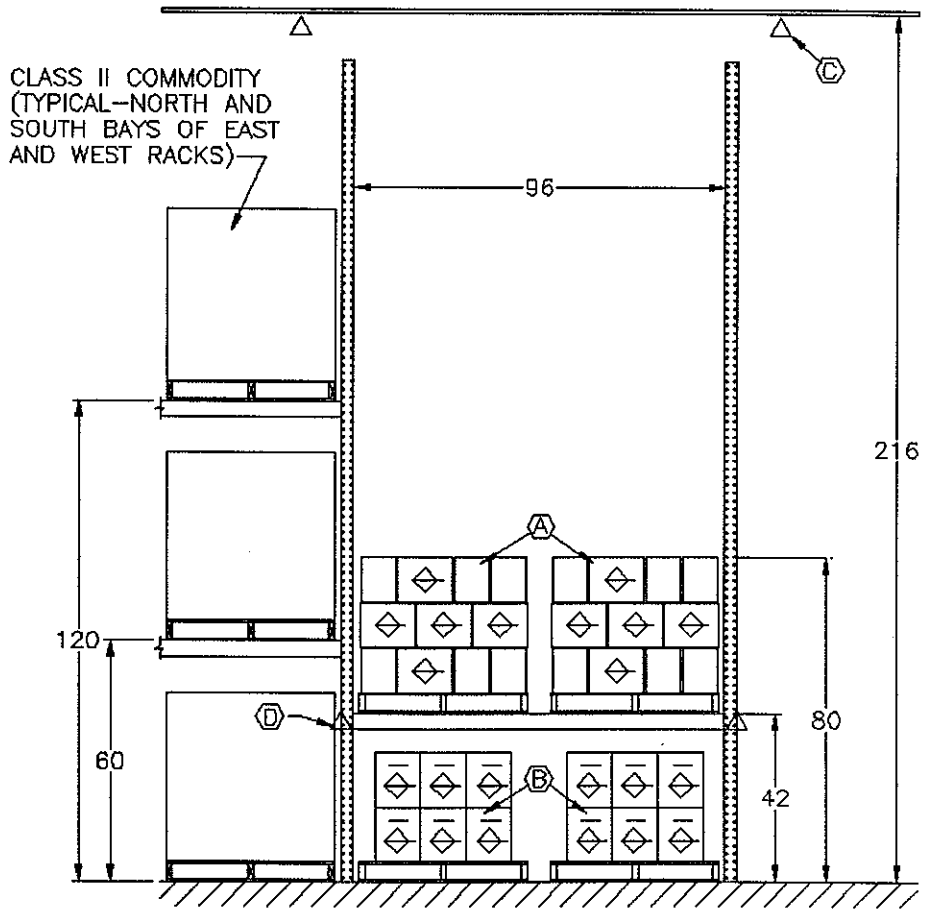


ELEVATION–SIDE VIEW

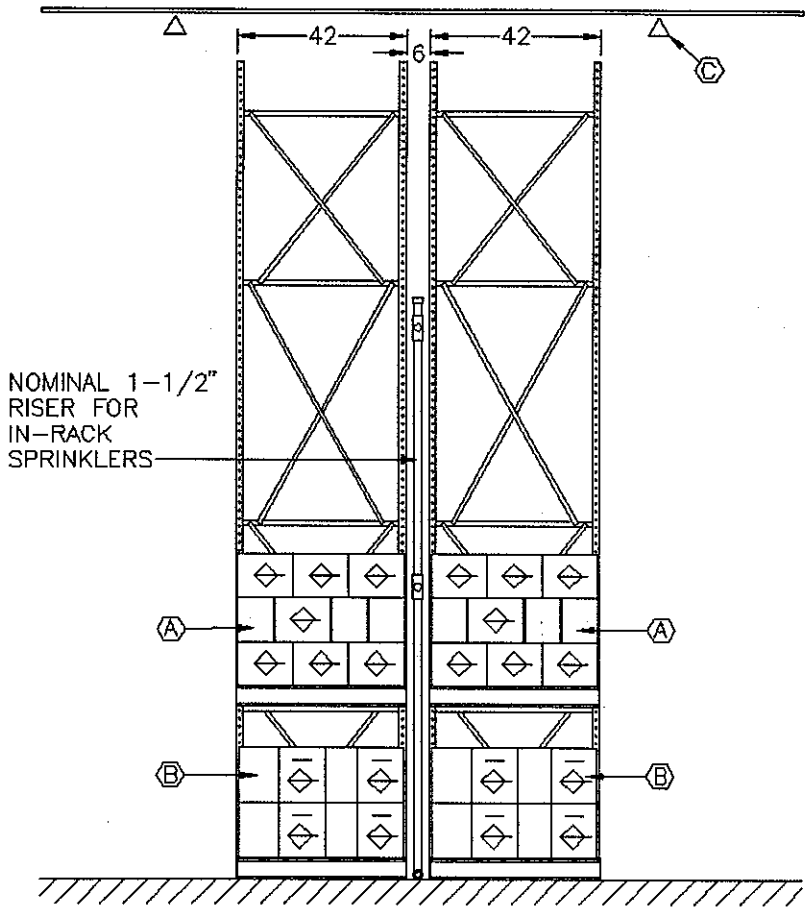
Ⓐ PALLETIZED 1 GAL "F" STYLE – 156 GAL/PALLET
Ⓑ PALLETIZED 5 GAL "TIGHT HEAD" – 120 GAL/PALLET
Ⓒ 286 F LARGE ORIFICE SPRINKLERS ON 10 FT CENTERS
Ⓓ 155 F SPRINKLERS ON 8 FT 3 IN CENTERS PARRALLEL ORIENTATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

RACK CONFIGURATION–TEST NO. 3



ELEVATION–FRONT VIEW

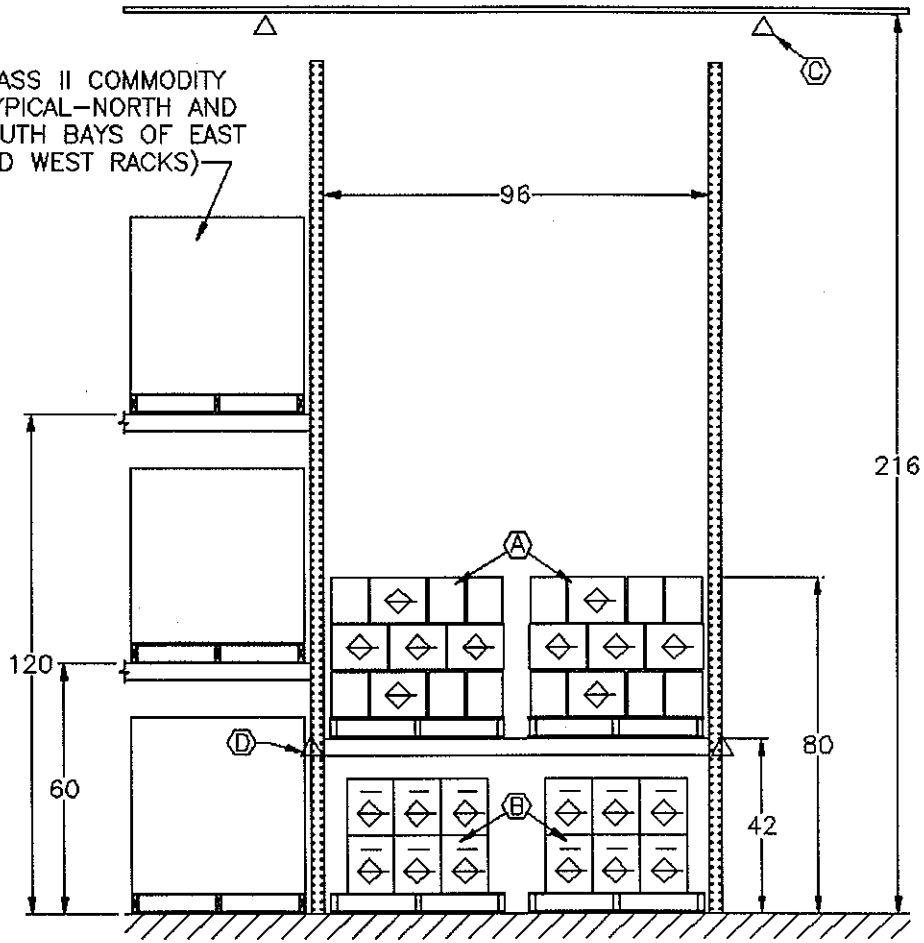


ELEVATION–SIDE VIEW

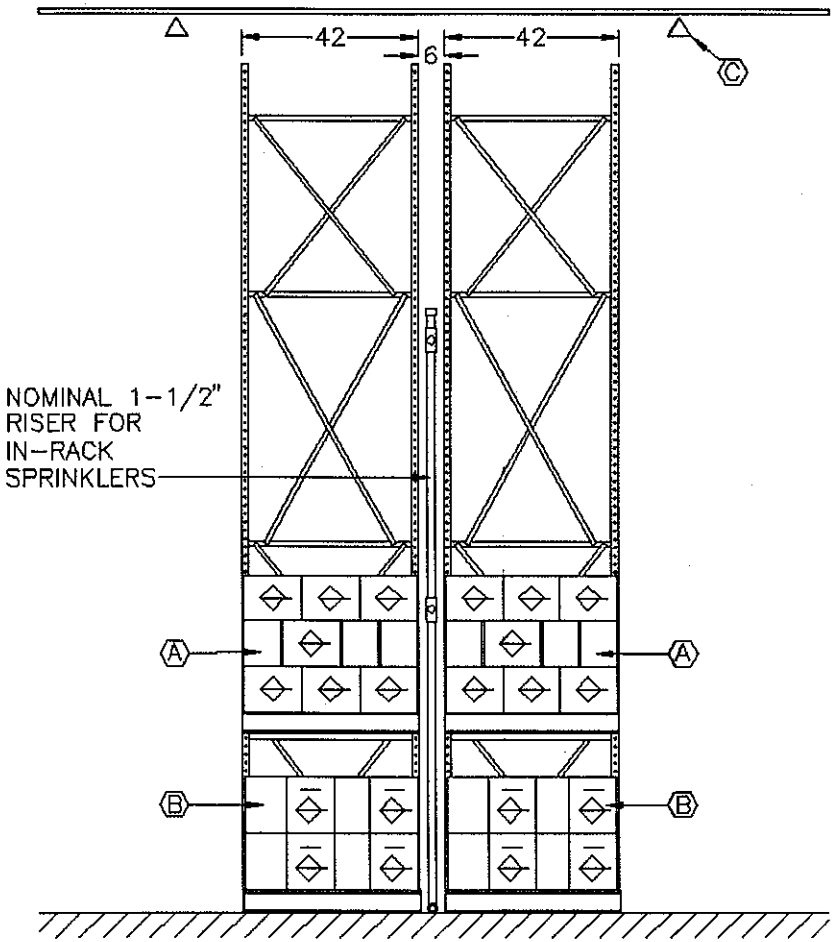
Ⓐ PALLETIZED 1 GAL "F" STYLE – 156 GAL/PALLET
Ⓑ PALLETIZED 5 GAL "TIGHT HEAD" – 120 GAL/PALLET
Ⓒ 155 F LARGE ORIFICE SPRINKLERS ON 10 FT CENTERS
Ⓓ 155 F QR LARGE ORIFICE SPRINKLERS ON 8 FT 3 IN CENTERS PARRALLEL ORIENTATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

RACK CONFIGURATION–TEST NO. 4



ELEVATION–FRONT VIEW

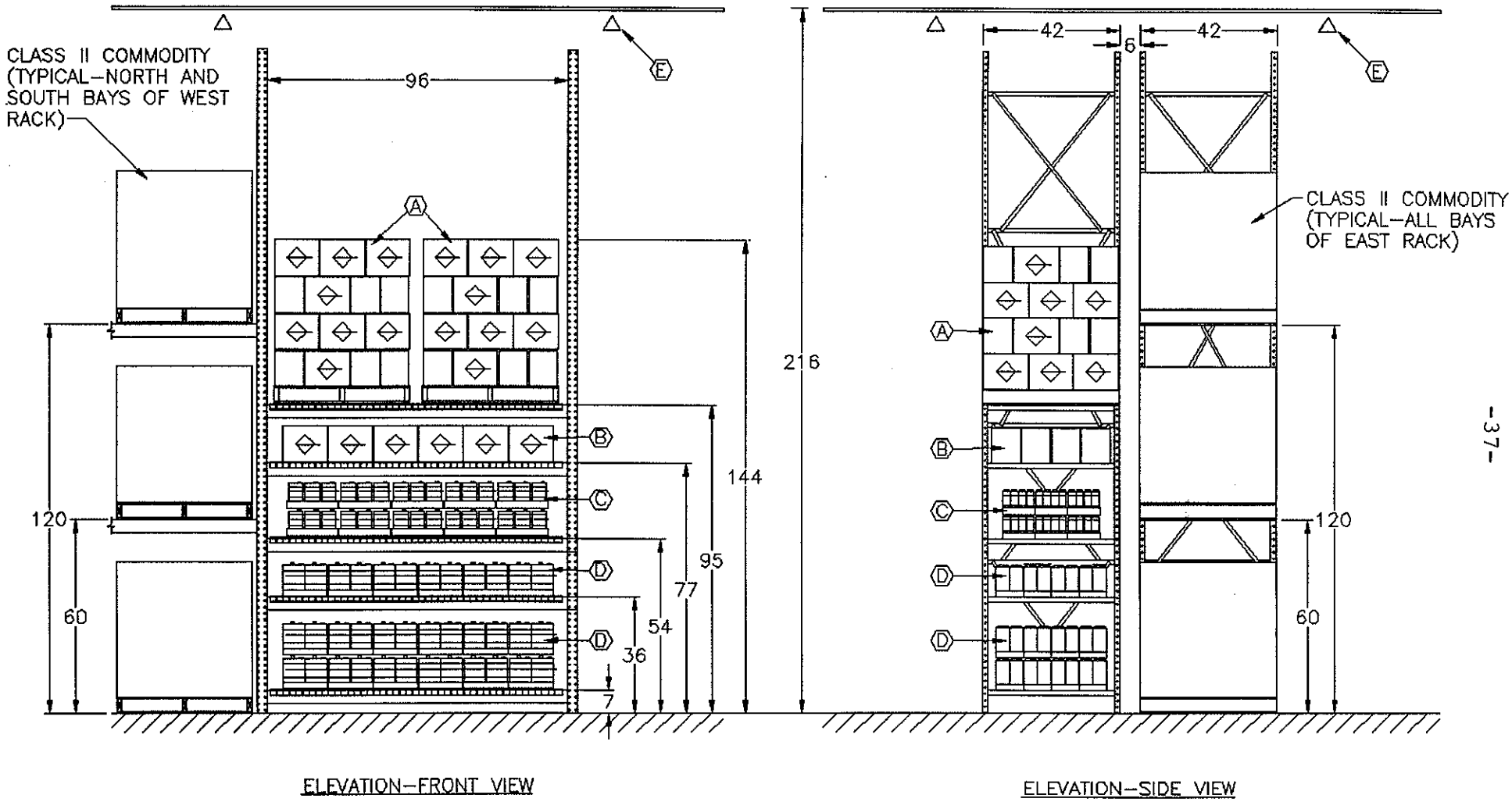


ELEVATION–SIDE VIEW

Ⓐ PALLETIZED 1 GAL "F" STYLE – 156 GAL/PALLET
Ⓑ PALLETIZED 5 GAL "TIGHT HEAD" – 120 GAL/PALLET
Ⓒ 155 F LARGE ORIFICE SPRINKLERS ON 10 FT CENTERS
Ⓓ 155 F QR LARGE ORIFICE SPRINKLERS ON 8 FT 3 IN CENTERS PERPENDICULAR ORIENTATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

RACK CONFIGURATION–TEST NO. 5



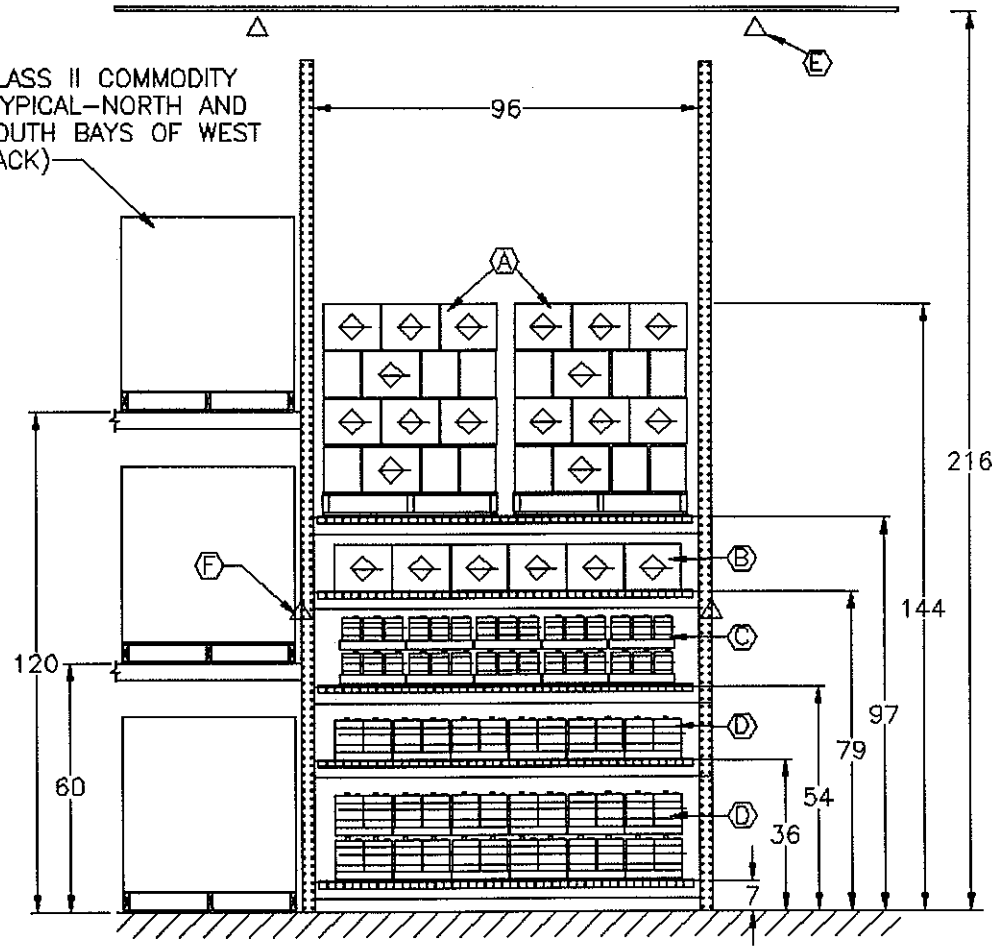
ELEVATION–FRONT VIEW

ELEVATION–SIDE VIEW

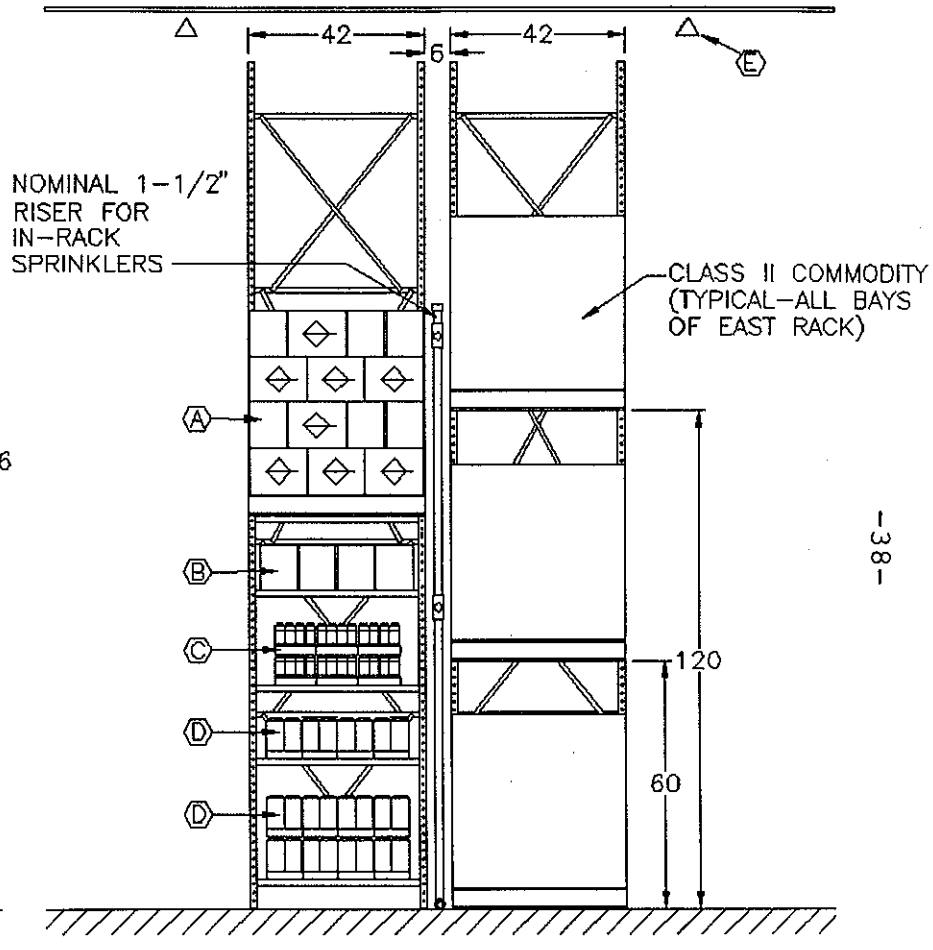
Ⓐ PALLETIZED 1 GAL "F" STYLE – 208 GAL/PALLET
Ⓑ CARTONED 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓒ CASE CUT 1 QT "F" STYLE – 12 QT/CARTON
Ⓓ CASE CUT 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓔ 286 F EXTRA LARGE ORIFICE SPRINKLERS ON 10 FT CENTERS

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

RACK CONFIGURATION–TEST NO. 6



ELEVATION–FRONT VIEW

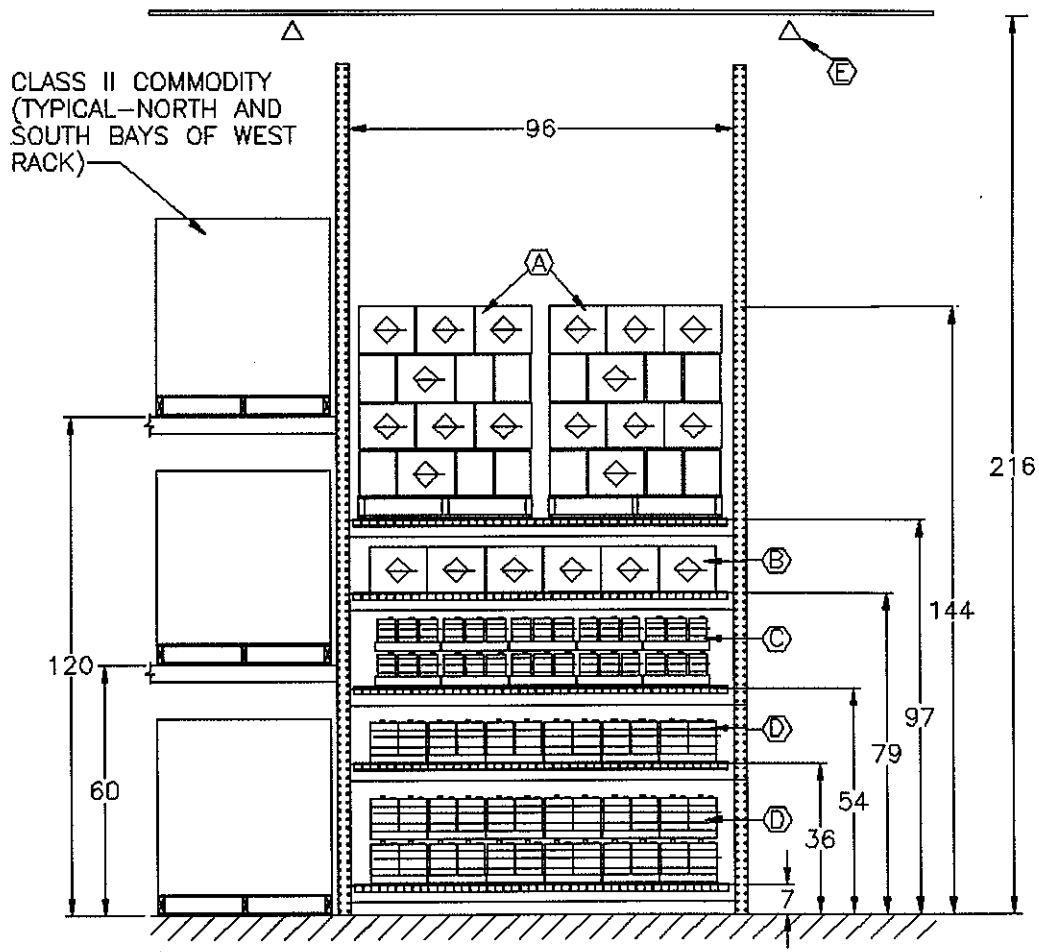


ELEVATION–SIDE VIEW

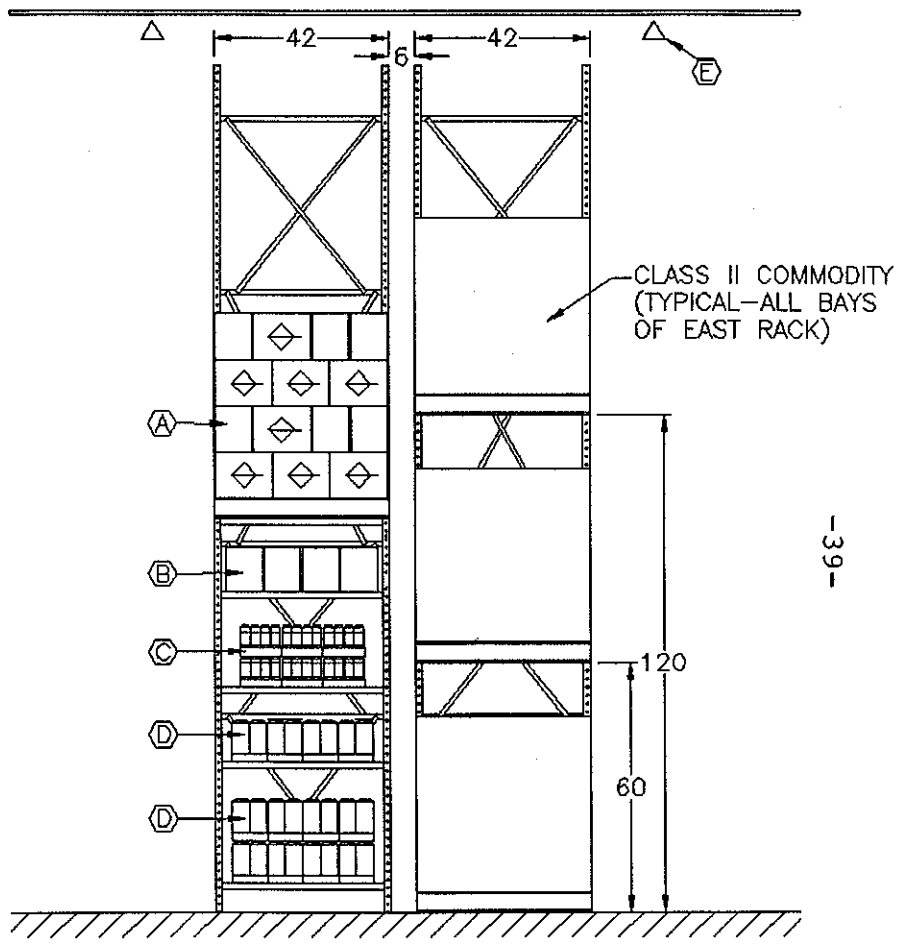
Ⓐ PALLETIZED 1 GAL "F" STYLE – 208 GAL/PALLET
Ⓑ CARTONED 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓒ CASE CUT 1 QT "F" STYLE – 12 QT/CARTON
Ⓓ CASE CUT 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓔ 286 F EXTRA LARGE ORIFICE SPRINKLERS ON 10 FT CENTERS
Ⓕ 155 F QR LARGE ORIFICE SPRINKLERS ON 8 FT 3 IN CENTERS PERPENDICULAR ORIENTATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

RACK CONFIGURATION–TEST NO. 7



ELEVATION–FRONT VIEW

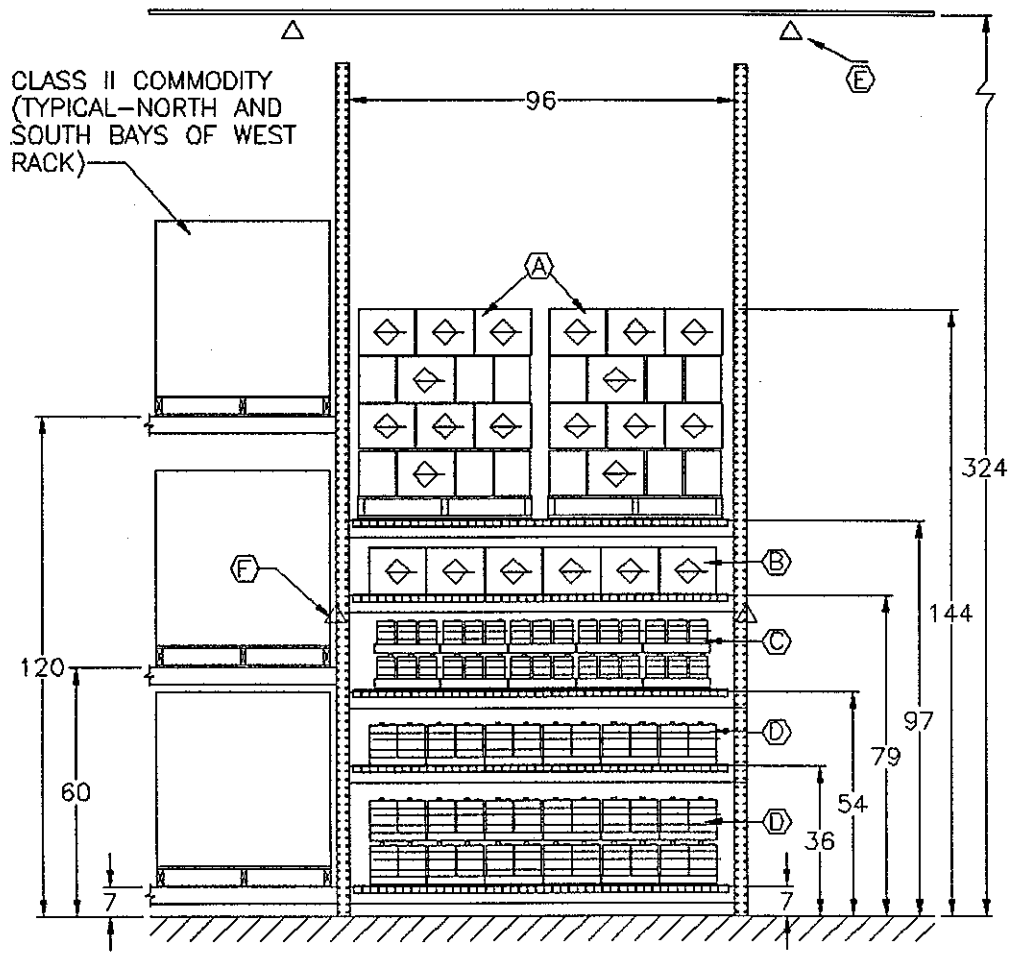


ELEVATION–SIDE VIEW

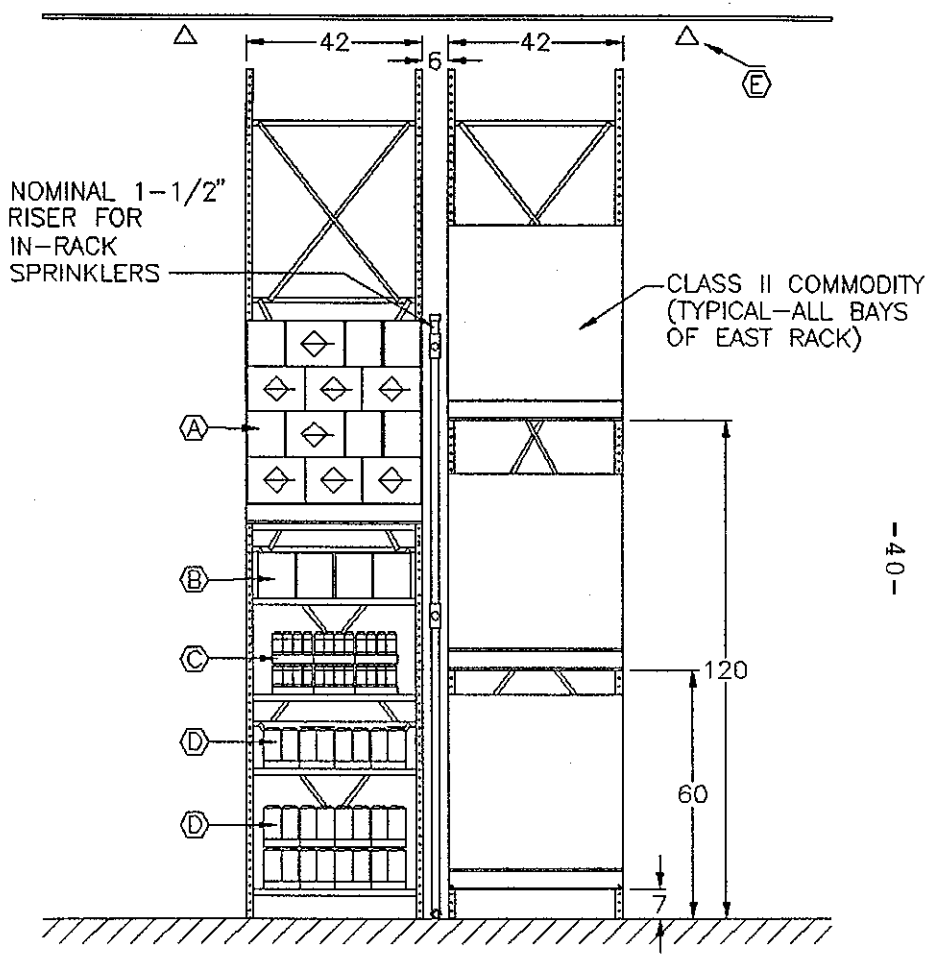
Ⓐ PALLETIZED 1 GAL "F" STYLE – 208 GAL/PALLET
Ⓑ CARTONED 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓒ CASE CUT 1 QT "F" STYLE – 12 QT/CARTON
Ⓓ CASE CUT 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓔ 286 F EXTRA LARGE ORIFICE SPRINKLERS ON 10 FT CENTERS

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

RACK CONFIGURATION–TEST NO. 8



ELEVATION–FRONT VIEW

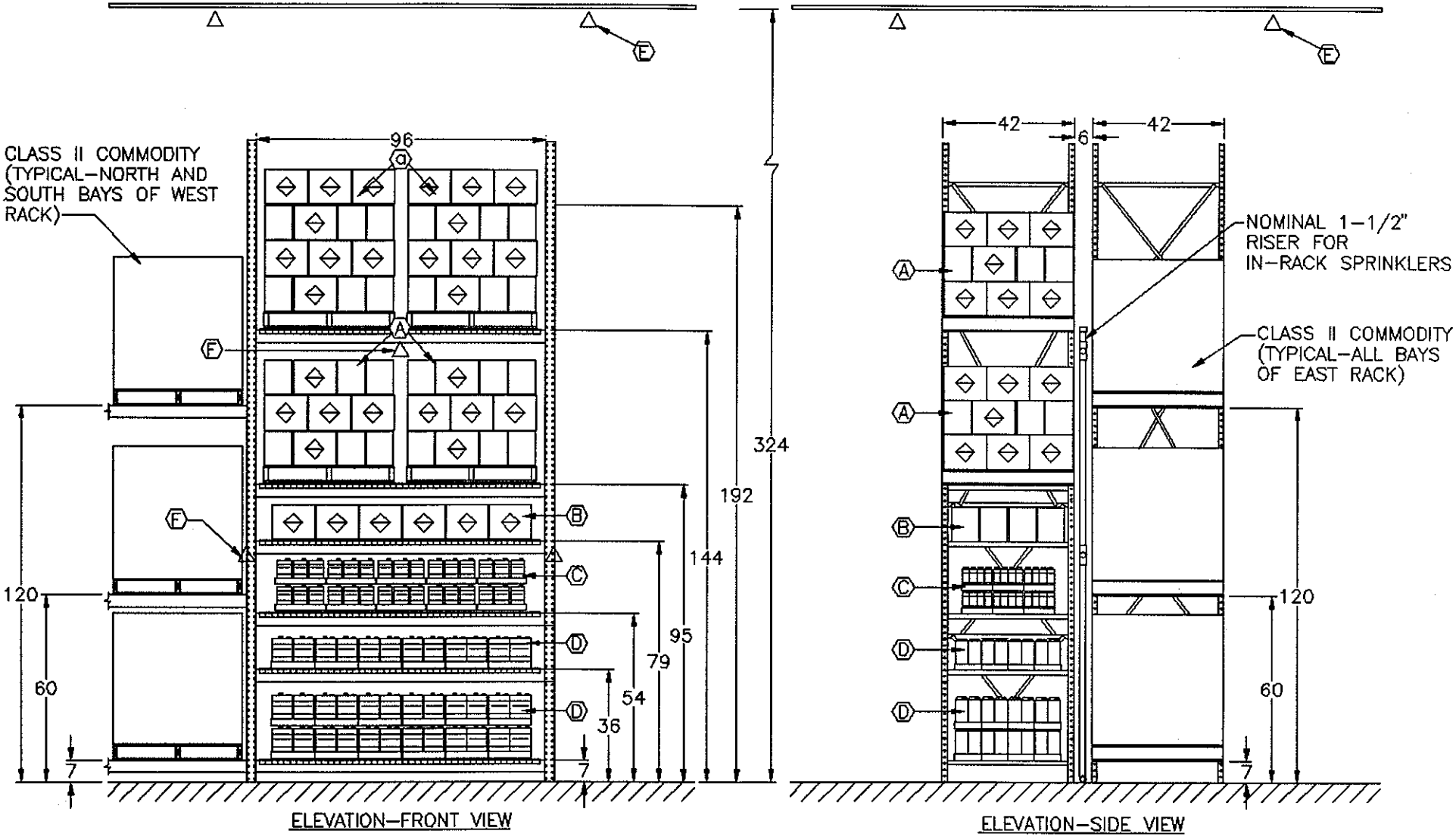


ELEVATION–SIDE VIEW

Ⓐ PALLETIZED 1 GAL "F" STYLE – 208 GAL/PALLET
Ⓑ CARTONED 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓒ CASE CUT 1 QT "F" STYLE – 12 QT/CARTON
Ⓓ CASE CUT 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓔ 286 F EXTRA LARGE ORIFICE SPRINKLERS ON 10 FT CENTERS
Ⓕ 155 F QR LARGE ORIFICE SPRINKLERS ON 8 FT 3 IN CENTERS PERPENDICULAR ORIENTATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

RACK CONFIGURATION–TEST NO. 9

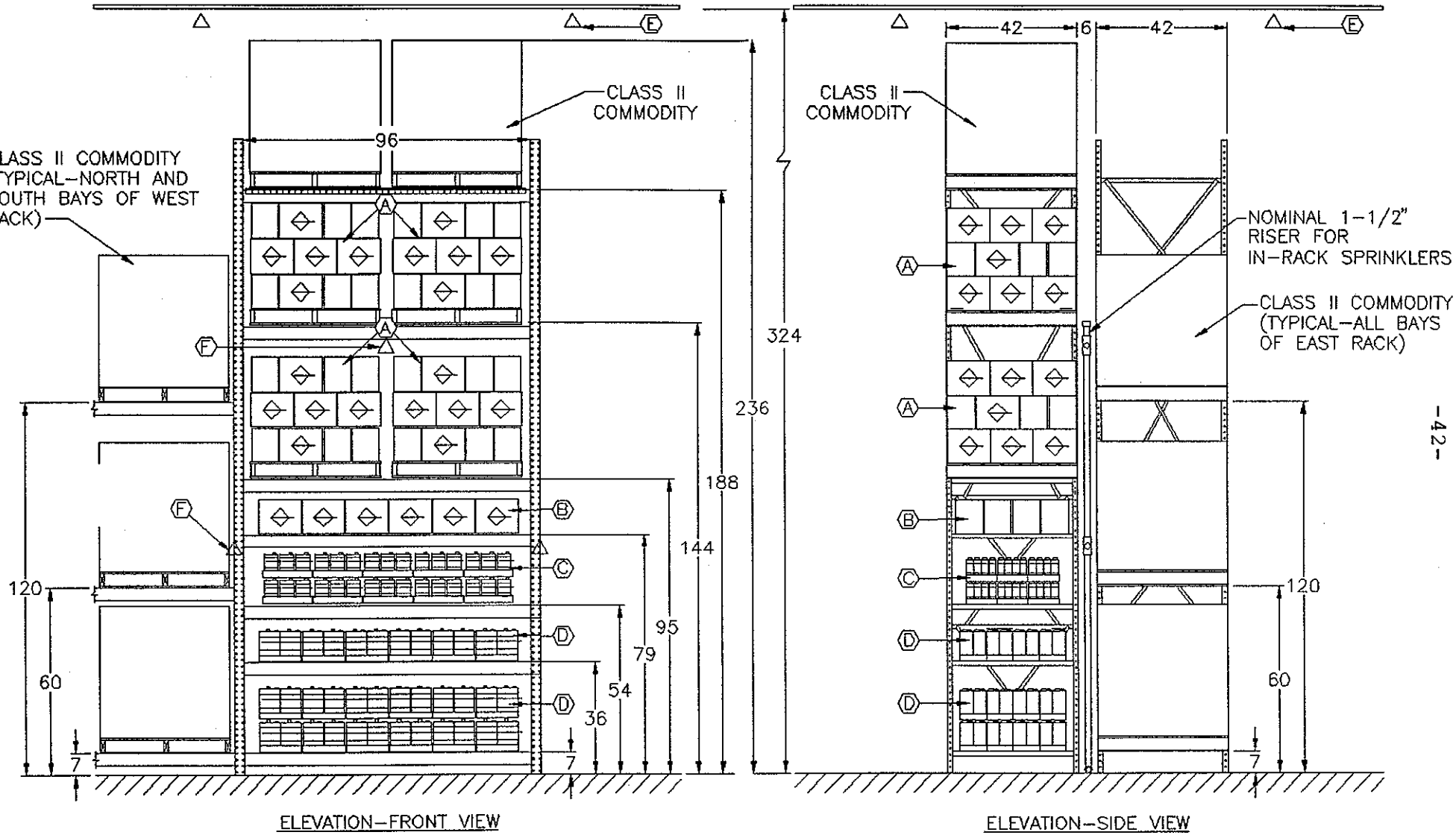


Ⓐ PALLETIZED 1 GAL "F" STYLE–156 GAL/PALLET
ⓐ PALLETIZED 1 GAL "F" STYLE–208 GAL/PALLET
Ⓑ CARTONED 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓒ CASE CUT 1 QT "F" STYLE – 12 QT/CARTON
Ⓓ CASE CUT 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓔ 286 F EXTRA LARGE ORIFICE SPRINKLERS ON 10 FT CENTERS
Ⓕ 155 F QR LARGE ORIFICE SPRINKLERS ON 8 FT 3 IN CENTERS PERPENDICULAR ORIENTATION

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

RACK CONFIGURATION–TEST NO. 10

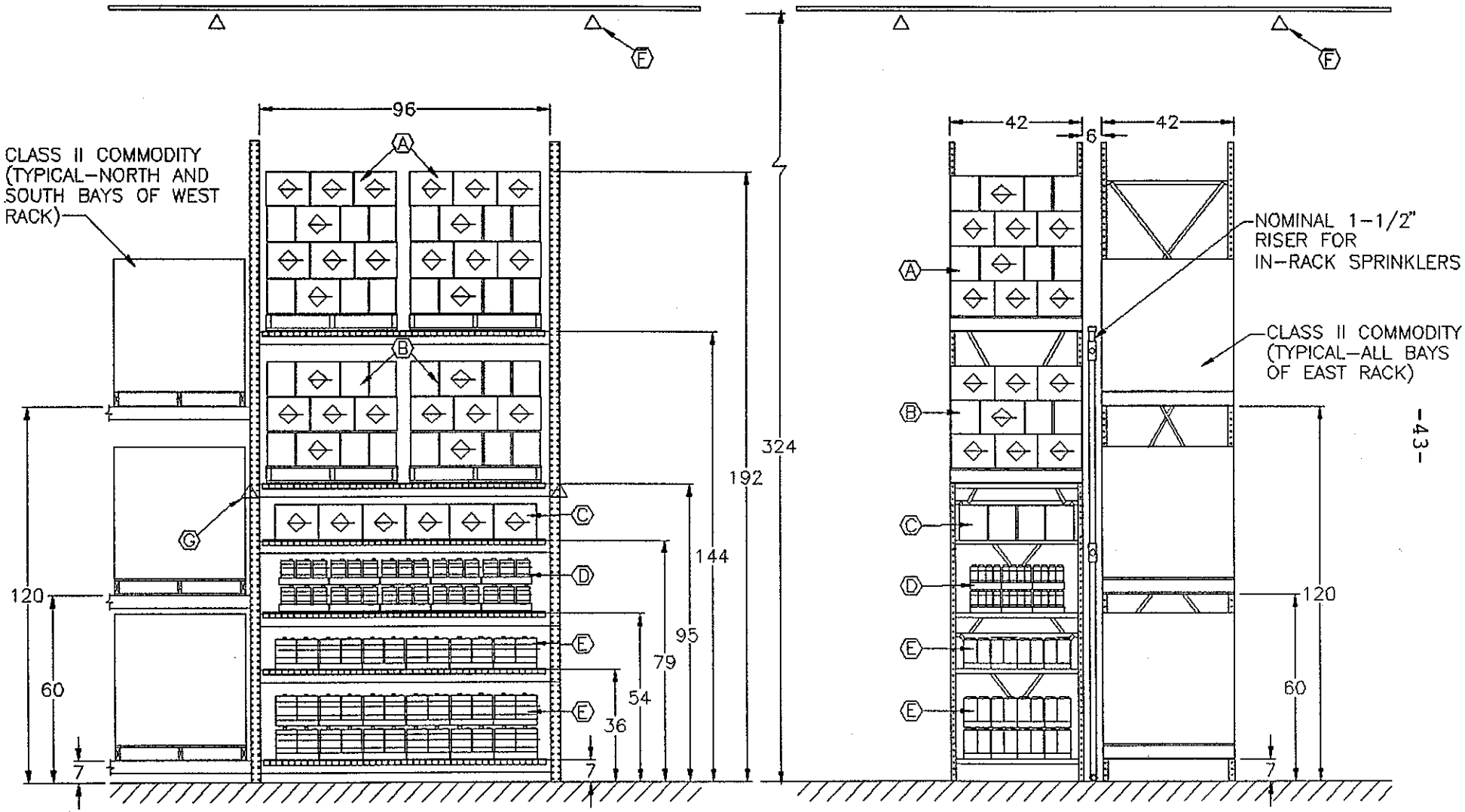
ILL. 22



Ⓐ PALLETIZED 1 GAL "F" STYLE–156 GAL/PALLET
Ⓑ CARTONED 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓒ CASE CUT 1 QT "F" STYLE – 12 QT/CARTON
Ⓓ CASE CUT 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓔ 286 F EXTRA LARGE ORIFICE SPRINKLERS ON 10 FT CENTERS
Ⓕ 155 F QR LARGE ORIFICE SPRINKLERS ON 8 FT 3 IN CENTERS

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

RACK CONFIGURATION–TEST NO. 11



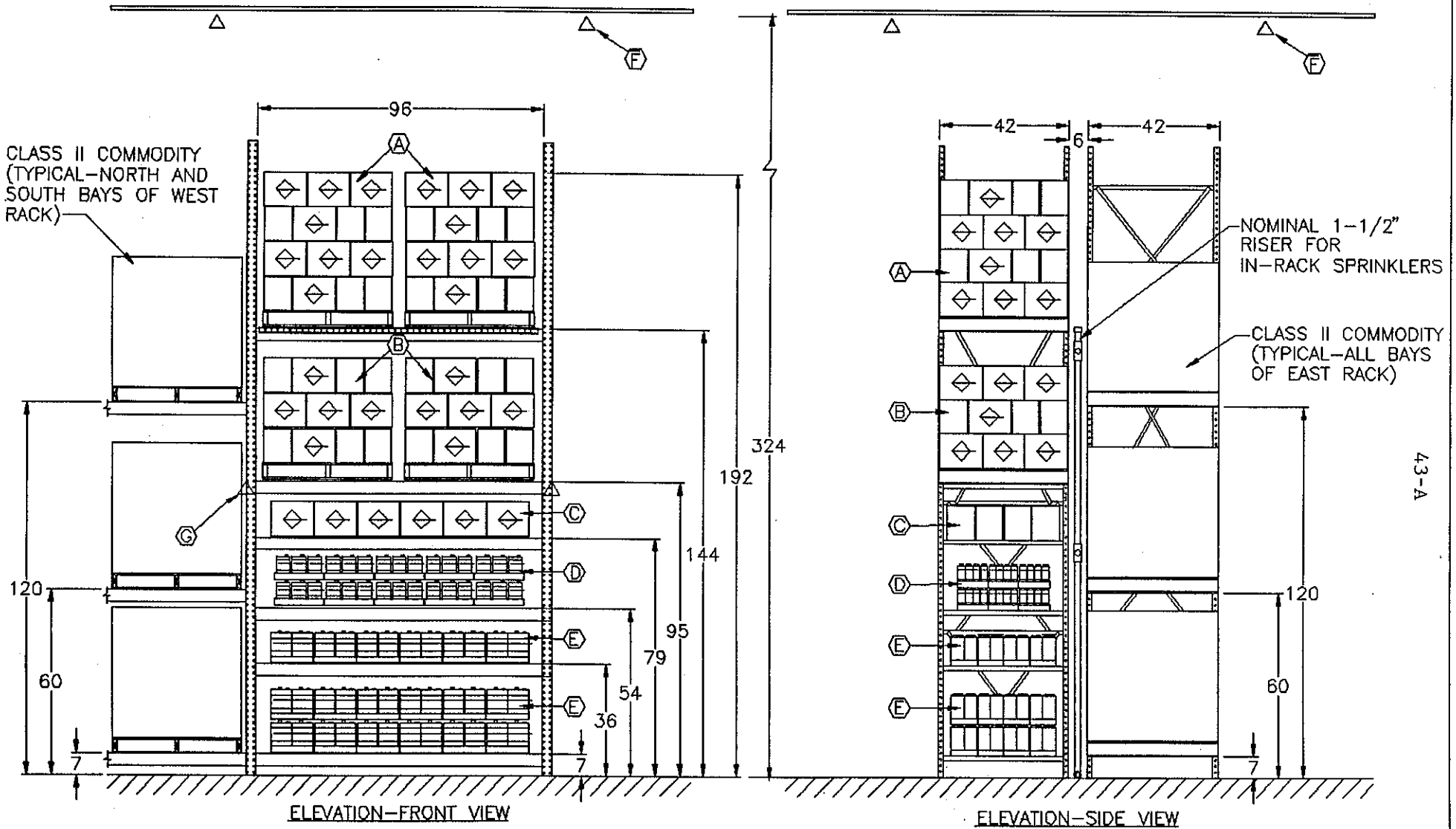
ELEVATION–FRONT VIEW

ELEVATION–SIDE VIEW

Ⓐ PALLETIZED 1 GAL "F" STYLE–208 GAL/PALLET
Ⓑ PALLETIZED 1 GAL "F" STYLE–156 GAL/PALLET
Ⓒ CARTONED 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓓ CASE CUT 1 QT "F" STYLE – 12 QT/CARTON
Ⓔ CASE CUT 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓕ 286 F EXTRA LARGE ORIFICE SPRINKLER ON 10 FT CENTERS
Ⓖ 155 F QR LARGE ORIFICE SPRINKLERS ON 8 FT 3 IN CENTERS

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

RACK CONFIGURATION–TEST NO. 12



Ⓐ PALLETIZED 1 GAL "F" STYLE–208 GAL/PALLET
Ⓑ PALLETIZED 1 GAL "F" STYLE–156 GAL/PALLET
Ⓒ CARTONED 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓓ CASE CUT 1 QT "F" STYLE – 12 QT/CARTON
Ⓔ CASE CUT 1 GAL "F" STYLE – 4 GAL/CARTON
Ⓕ 286 F QR EXTRA LARGE ORIFICE SPRINKLER ON 10 FT CENTERS
Ⓖ 155 F QR LARGE ORIFICE SPRINKLERS ON 8 FT 3 IN CENTERS

NOTE: ALL DIMENSIONS IN INCHES UNLESS OTHERWISE NOTED

RACK CONFIGURATION–TEST NO. 16

ILL. 25

43-A

RESULTS

The results of the Mixed Rack Storage With (with or without) Display Fire Tests are summarized in Table 5. Ceiling and perimeter temperatures are presented in Ills. B-1 thru B-96 in App. B.

The results of Tests Nos. 1 and 2, conducted under an 18 ft high ceiling, indicated that ceiling only, large orifice 286°F temperature rated sprinklers discharging water at a design density of 0.50 gpm/ft^2 were able to maintain relatively low ceiling temperatures and prevented the operation of sprinklers outside of the fire area. However, the ceiling only sprinklers could not prevent the rupturing of 1 gal metal containers when both 1 and 5 gal metal containers of heptane were used. See Figs. 5-6.

The results of Test No. 3, which involved the protection of a 6 ft, 8 in. high rack storage configuration of 1 and 5 gal metal containers of heptane indicated that large orifice ceiling and one level of in-rack large orifice sprinklers were able to maintain relatively low ceiling temperature and prevent the operation of additional sprinklers outside of the fire area. However, the combination of sprinkler systems could not prevent the venting of several 5 gal containers of heptane located in the racks which resulted in the subsequent burning of flammable liquid at an increasing intensity. See Fig. 7.

To achieve faster response of the ceiling sprinklers in Test No. 4, the temperature rating of the ceiling sprinklers was reduced from 286°F to 155°F. The results of this test indicated that the combination of 155°F standard response ceiling and in-rack sprinklers were unable to suppress the heptane spill fire without venting of the top layer of 5 gal "tight-head" containers. Subsequent burning of flammable liquids was at an increasing intensity and the test was terminated at 7 min. See Fig. 8.

In an attempt to achieve faster response and enhanced performance of the large orifice in-rack sprinklers, Test No. 5 was conducted using large orifice quick-response type in-rack sprinklers in the 155°F temperature rating with their frame arms oriented perpendicular to the branch line piping. Four 5 gal containers vented and fire suppression was achieved at 4 min, 20 s. See Fig. 9.

In Test No. 6, the (1) storage height was increased to 12 ft, (2) ceiling sprinkler orifice size was increased from large orifice to extra large orifice, (3) ceiling sprinkler design density was increased from 0.50 to 0.60 gpm/ft^2 and (4) in-rack sprinklers were removed. Three to four 1 qt containers ruptured and the test was terminated. See Fig. 10.

A 12 ft high storage arrangement was also used for Test No. 7. The combination of extra large orifice 286°F ceiling sprinklers discharging water at a design density of 0.60 gpm/ft^2 and one level of 155°F temperature rated quick-response large orifice sprinklers resulted in the fire being suppressed at 5 min. See Fig. 11.

Test No. 8 was a repeat of Fire Test No. 6, with the location of the 2 gal heptane spill moved from the flue space into the aisle. Only one ceiling sprinkler operated and the fire was suppressed at 7 min, 12 s. See Fig. 12.

For Tests Nos. 9 through 12, the height of the ceiling was increased from 18 to 27 ft. Fire Test No. 9 was a repeat of Fire Test 7 with 12 ft high storage and one level of in-rack quick-response sprinklers. At approximately 13 min into the test, the ceiling temperatures began to rise causing a 1 gal container of heptane to rupture approximately 5 min later. The rupturing of the container operated a second ceiling sprinkler and controlled the fire in the top layer of the north end of the test array. The test was terminated at 25 min. See Fig. 13.

For Test No. 10, a second level of in-rack sprinklers was included and the storage height was increased from 12 to 16 ft. The fire was suppressed at 5 min except for limited burning in one of the cardboard cartons. See Fig. 14.

In Test No. 11, the storage height was increased from 16 ft to 19 ft, 8 in. and fire suppression was obtained by 2 min, 30 s. See Fig. 15.

In Test No. 12, the storage height was reduced to 16 ft with a single level of in-rack sprinklers. Due to relatively low ceiling temperatures, only 2 ceiling sprinklers operated. A 1 gal container of heptane ruptured at approximately 10 min, 40 s. See Fig. 16.

For Test No. 16, to achieve quicker response of the ceiling sprinklers, 286°F quick response extra large orifice sprinklers were installed and Test No. 12 was repeated. No additional changes were made to the remaining test parameters.

TABLE 5 - MIXED RACK STORAGE (WITH OR WITHOUT) DISPLAY FIRE TEST RESULTS

Test No.	Ceiling Height, Ft	Total Storage Height, Ft: In.	Ceiling Sprinklers		In-Rack Sprinklers		Total Flow Rate, Gpm	Test Duration min:s	Fire Controlled	Damage Assessment
			No. Operating	Operating Time, s	Level	Number and Operating Time, s				
1	18	10: 8	6	No. 10@ 86 No. 7@ 131 No. 3@ 284 No. 6@ 293 No. 16@ 677 No. 15@ 716	-	-	300	7:50	No	Pour spouts vented on 10-12 five gal containers. Rupture of several 1 gal containers
2	18	6: 8	2	No. 6@ 117 No. 10@ 123	-	-	100	4:50	No	Pour spouts vented on 10-12 five gal containers. Venting of several 1 gal containers.
3	18	6: 8	4	No. 6@ 264 No. 10@ 264 No. 7@ 315 No. 11@ 315	First	No. 18@ 61	230	5:40	No	Pour spouts vented on 10-12 five gal containers.
4	18	6: 8	4	No. 6@ 96 No. 7@ 106 No. 11@ 119 No. 10@ 122	First	No. 18@ 115	230	7:00	No	Pour spouts vented on 6-8 five gal containers. Caps separated on several 1 gal containers.
5	18	6: 8	1	No. 6@ 114	First	No. 18@ 55 No. 19@ 67	110	4:20	Yes	Pour spouts vented on 4 five gal containers. Fire was suppressed by 4 min, 20 sec.
6	18	12:0	3	No. 6@ 52 No. 10@ 68 No. 11@ 72	-	-	180	3:15	No	Rupture of 3-4 qt containers. Caps separated on several quart containers.

(table cont'd)

Test No.	Ceiling Height, Ft	Total Storage Height, Ft: In.	Ceiling Sprinklers		In-Rack Sprinklers		Total Flow Rate, Gpm	Test Duration min:s	Fire Controlled	Damage Assessment
			No. Operating	Operating Time, s	Level	Number and Operating Time, s				
7	18	12	2	No. 11 @ 1:15 No. 10 @ 1:33	First	No. 22 @ 1:03 No. 23 @ 1:08	180	5:00	Yes	No ruptures. Fire was suppressed within 5 min except for slight burning inside of one of the cardboard commodity cartons.
8	18	12	1	No. 7 @ 1:12	-	-	60	7:12	Yes	No ruptures. Fire was suppressed within 7 min, 12 s.
9	27	12	2	No. 7 @ 2:42 No. 11 @ 19:06	First	No. 22 @ 0:36 No. 23 @ 0:36	180	25:00	Yes	Insufficient heat to operate second ceiling sprinkler prior to rupture of a 1 gallon Container of heptane.
10	27	16	None	-	First Second	No. 23 @ 0:45 No. 23 @ 1:15 No. 30 @ 0:13	90	5:00	Yes	No ruptures and fire was suppressed within 5 min.
11	27	19: 8	None	-	First Second	No. 22 @ 0:06 No. 23 @ 0:08 No. 30 @ 0:12	90	2:30	Yes	No ruptures and fire was suppressed within 2 min, 30 s.
12	27	16	2	No. 6 @ 1:21 No. 7 @ 8:18	First	No. 26 @ 0:48 No. 27 @ 0:48 No. 25 @ 10:40	210	10:40	No	Insufficient heat to operate more than two ceiling

(table cont'd)

Test No.	Ceiling Height, Ft	Total Storage Height, Ft: In.	Ceiling Sprinklers		In-Rack Sprinklers		Total Flow Rate, Gpm	Test Duration min:s	Fire Controlled	Damage Assessment
			No. Operating	Operating Time, s	Level	Number and Operating Time, s				
16	27	16	3	No. 6 @ 1:18 No. 10 @ 1:18 No. 11 @ 1:18	First	No. 26 @ 1:20 No. 27 @ 1:20	240	30:00	Yes	Three 1 quart containers ruptured. Shelf located at the 36 and 54 in. heights fell permitting heptane to spill and burn in aisle. Several 1 quart and 1 gallon containers were leaking through collar soldered joint. No burning or charring of cardboard commodity adjacent to main storage array was observed. Fire did not jump aisle to target arrays.

WEATHER CONDITIONS:

All fire tests were conducted inside the test building and the outside weather conditions were recorded at noon on each test day a rack storage fire test was conducted. The wind direction, wind velocity, temperature and barometric pressure were recorded. The readings were as follow:

Rack Storage Fire Test No.	Date	Temperature, °F	Wind Direction	Wind Velocity, mph	Barometric Pressure, In-Hg
1	4-03-92	47	SW	11	29.975
2	4-10-92	50	E	12	29.245
3	4-14-92	42	E	11	29.580
4	4-15-92	50	S	9	29.415
5	4-17-92	42	NE	11	29.405
6	4-20-92	68	SE	14	28.945
7,8	4-24-92	48	NW	9	29.285
9	4-28-92	55	S	7	29.480
10	4-29-92	58	SW	15	29.120
11	4-30-92	52	NE	7	29.305
12	6-11-92	80	SW	6	29.415
16	11-13-92	32	W	18	29.940

4.0 DISCUSSION AND RECOMMENDATIONS

DISCUSSION:

GENERAL

The data developed during the series of fire tests described in this Report demonstrated the ability of a combination of ceiling and one or two levels of in-rack sprinklers to protect the mixed rack storage (with or without) display arrangements of flammable liquids (palletized storage above with hand-pick below) at storage heights up to 12 ft under an 18 ft high ceiling and up to 19 ft, 8 in. under a 27 ft high ceiling. Storage configurations included the use of wood slat and open 2 by 2 in. wire mesh shelving with full pallet, full carton, case-cut cartons and individual containers of heptane, a Class IB flammable liquid, arranged to simulate wholesale and retail showrooms, display and sales areas.

IGNITION SCENARIO

The results of the ignition scenario fire tests indicated that a 1 gal heptane spill fire did not generate sufficient heat to activate standard response 155°F temperature rated in-rack sprinklers positioned 5 ft above the floor on an 8 ft, 3 in. spacing. Two and three gallon heptane spill fires would not activate 286°F temperature rated sprinklers installed below an 18 and 27 ft high ceiling, respectively. Therefore, a 2 gal heptane spill was used as the ignition source for all of the display (hand-pick) and mixed rack storage (with or without) display fire tests because it would require involvement of commodity other than the heptane spill to activate the ceiling sprinklers.

Two of the fire tests were conducted with the heptane spill positioned in the aisle rather than the flue space. In a direct comparison of ignition location, Mixed Rack Storage (With or Without) Display Fire Test No. 6, with the ignition in the flue space, activated 3 ceiling sprinklers whereas the aisle ignition in Mixed Rack Storage (with or without) Display Fire Test No. 8 operated only 1 ceiling sprinkler.

DISPLAY (HAND-PICK) FIRE TESTS

The display (hand-pick) fire tests were conducted with sprinkler systems intended to protect typical display area found in warehouse style wholesale and retail stores. The storage arrays included 1 qt, 1 gal and 5 gal metal containers of heptane. Both nominal 2 by 6 in. wood slats spaced 2 in. apart and open 2 by 2 in. wire mesh shelving was used.

Results of these tests demonstrated the ability of ceiling sprinklers to control or suppress a 2 gallon spill scenario involving the storage of 1 gallon or less metal containers of heptane on 2 x 6 in. wood slats spaced 2 in. apart or open 2 x 2 in. wire mesh shelving. Control was not obtained in the display (hand-pick) fire test involving a 92 in. high solid metal shelving unit with enclosed top, sides and back, storing 1 quart and 1 gallon F-style containers and 5 gal metal tight-head containers of heptane.

MIXED RACK STORAGE (WITH OR WITHOUT) DISPLAY FIRE TESTS

The results of the mixed rack storage (with or without) display fire tests demonstrated the ability of 286°F standard response extra large orifice ceiling sprinklers and one level of quick response 155°F large orifice in-rack sprinklers to control or suppress double row rack storage of Class IB flammable liquids in one gallon or less metal containers up to 12 ft in height under both an 18 and 27 ft high ceiling; also, double row rack storage or display of flamable liquids in 5 gallon metal containers with ordinary temperature rated quick-response in-rack sprinklers at each level operating at a flow of 30 gpm and a ceiling sprinkler density of 0.50 gpm/ft^2 under an 18 ft high ceiling. The use of quick response, 286°F extra large orifice ceiling sprinklers and one level of quick response 155°F large orifice in-rack sprinklers were able to control or suppress double row rack storage of Class IB flammable liquids up to 16 ft in height under a 27 ft high ceiling. Extra large orifice standard response 286°F ceiling sprinklers and two levels of in-rack quick response 155°F large orifice sprinklers demonstrated their ability to control and suppress double row rack storage of Class IB flammable liquids in 1 gallon or less metal containers up to 19 ft, 8 in. in height under a 27 ft high ceiling.

Ceiling only sprinklers were unable to prevent the rupture of metal F-style containers fitted with metal nozzles (collars) and metal caps at a storage height of 6 ft, 8 in. under an 18 ft high ceiling but the fire was contained to a limited area. A combination of sprinkler systems incorporating extra large orifice ceiling sprinklers in the 286°F temperature rating and one level of in-rack large orifice quick response sprinklers in the 155°F temperature rating were able to control or suppress 12 ft high storage of flammable liquids in 1 gallon or less metal containers under both an 18 and 27 ft high ceiling.

RECOMMENDATIONS:

The results of the display (hand-pick) fire tests involving the 92 in. high, enclosed solid metal shelving unit and a 2 gallon heptane spill aisle ignition suggest that additional research is needed to achieve a condition whereby fire control of the commodity is obtained:

(a) prior to rupture of the containers, or

(b) by utilizing packaging systems equipped with relief devices.

A variety of schemes could be investigated including, but not limited to:

(1) the use of quick response type ceiling sprinklers,

(2) the use of in-rack sprinklers installed on the access side of the racks,

(3) container collars, caps or spouts which would vent prior to rupture or

(4) the storage or display of 5 gallon metal tight-head containers with plastic pour spouts under open ceilings (no storage above).

It is recommended that additional fire tests be conducted involving:

(1) rack storage of other commodities and mixes of commodities commonly found in wholesale and retail display and storage areas,

(2) the use of ceiling only 286°F temperature rated quick-response extra large orifice sprinklers,

(3) the use of quick response 286°F extra large orifice ceiling sprinklers and one level of in-rack sprinklers for protecting nominal 20 ft high rack storage of flammable liquids, and

(4) packaging modifications.

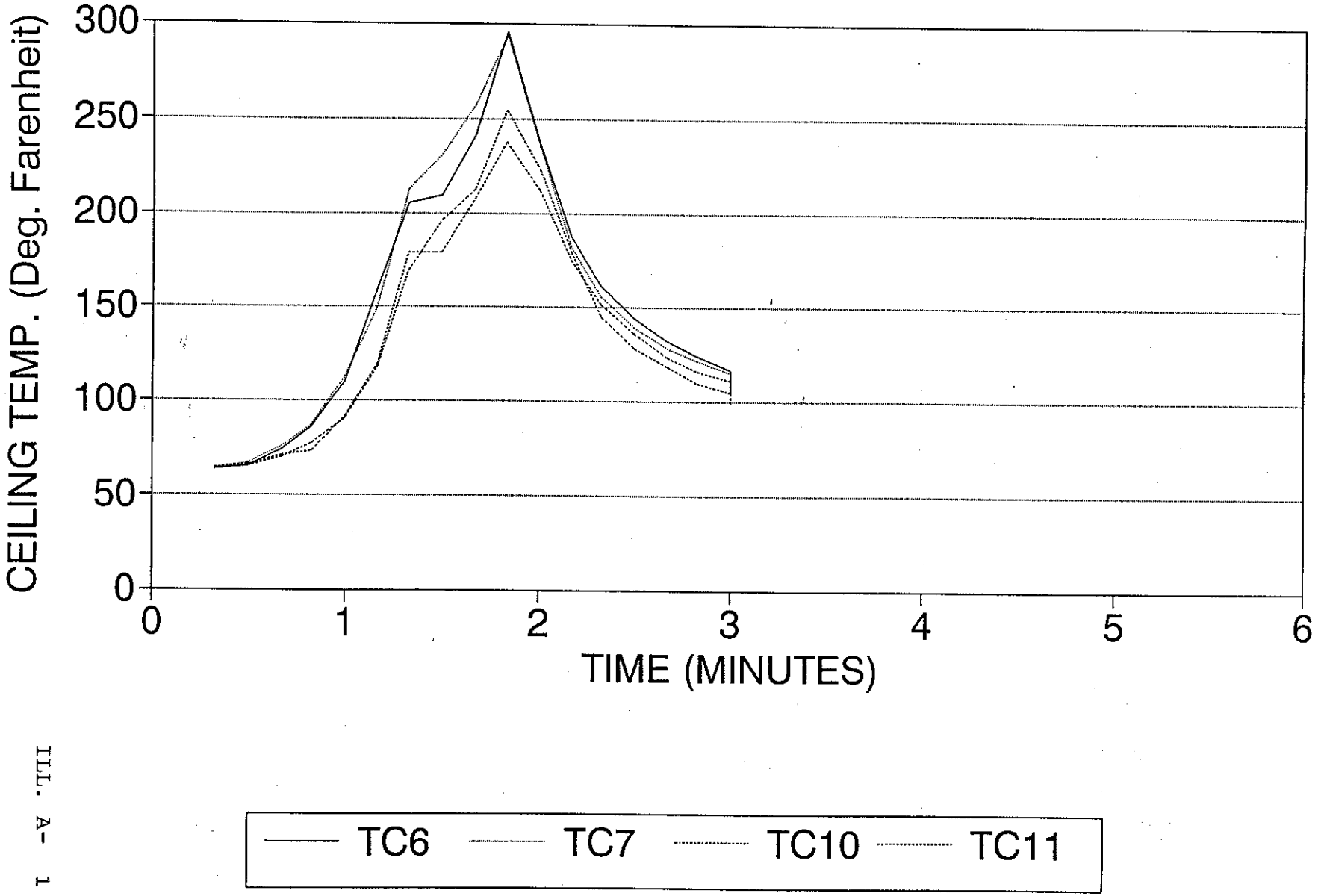
A P P E N D I X A

CEILING AND PERIMETER TEMPERATURE MEASUREMENTS

Description	Ill. No.
Ignition Scenario - 1 Gal Heptane Spill Fire	A1
Ignition Scenario - 2 Gal Heptane Spill Fire	A2
Ignition Scenario - 3 Gal Heptane Spill Fire	A3
Ignition Scenario - 4 Gal Heptane Spill Fire	A4

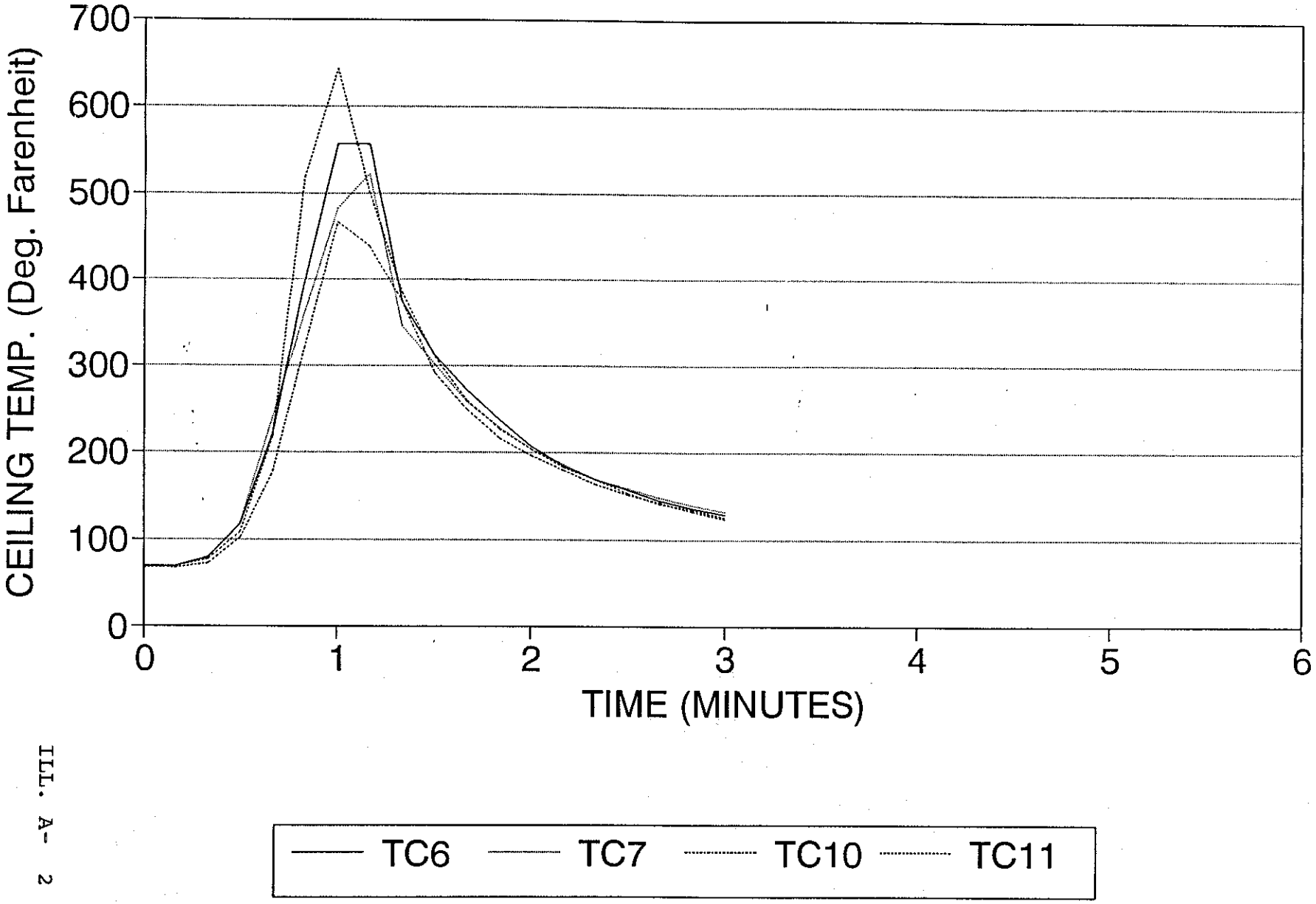
NFPRF IGNITION TESTS

1 GALLON HEPTANE, 18FT CEILING



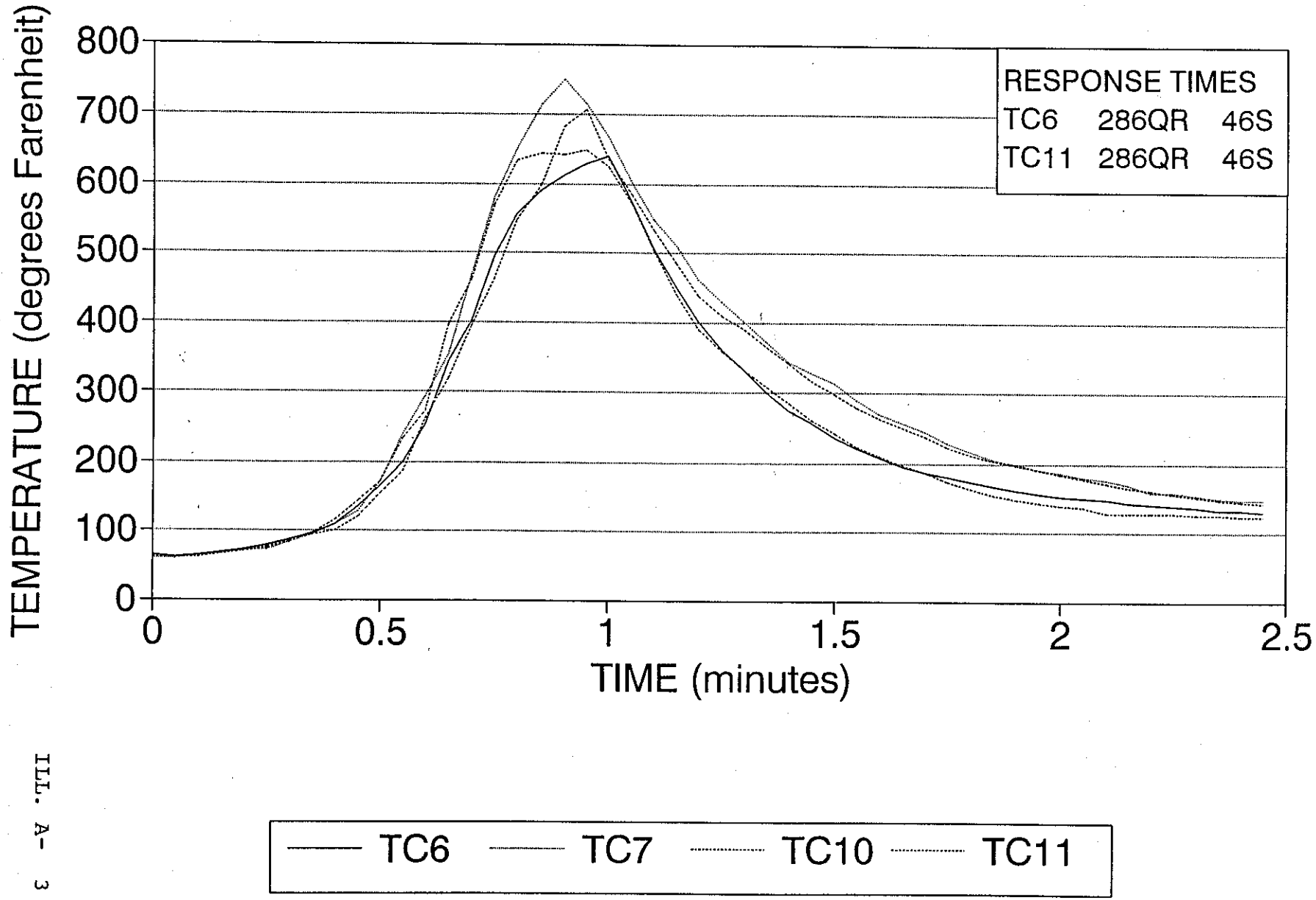
NFPRF IGNITION TESTS

2 GALLON HEPTANE, 18FT CEILING



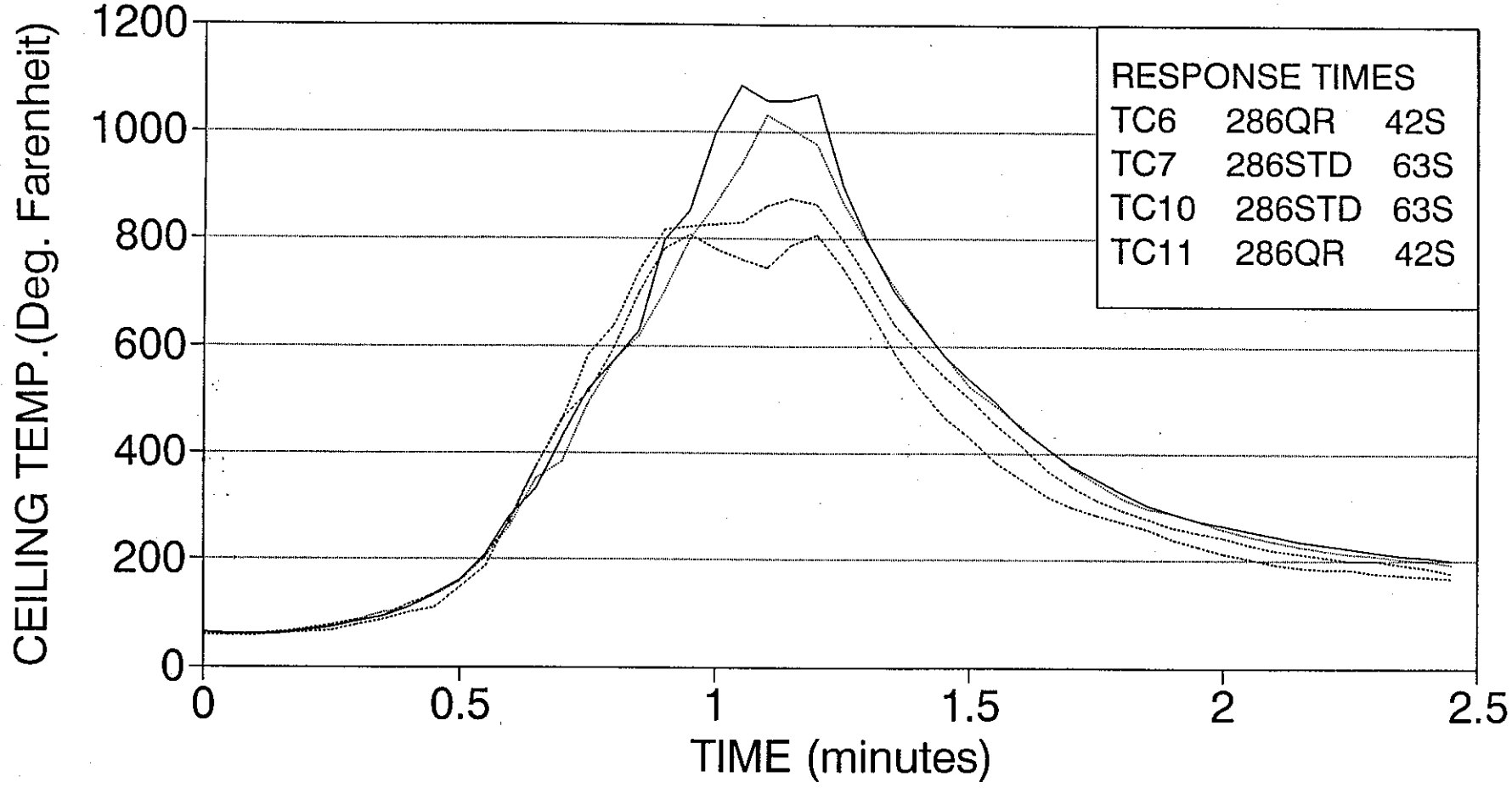
NFPRF IGNITION TESTS

3 GALLON HEPTANE, 18FT CEILING



NFPRF IGNITION TESTS

4 GALLON HEPTANE, 18FT CEILING



TC 6 TC 7 TC 10 TC 11

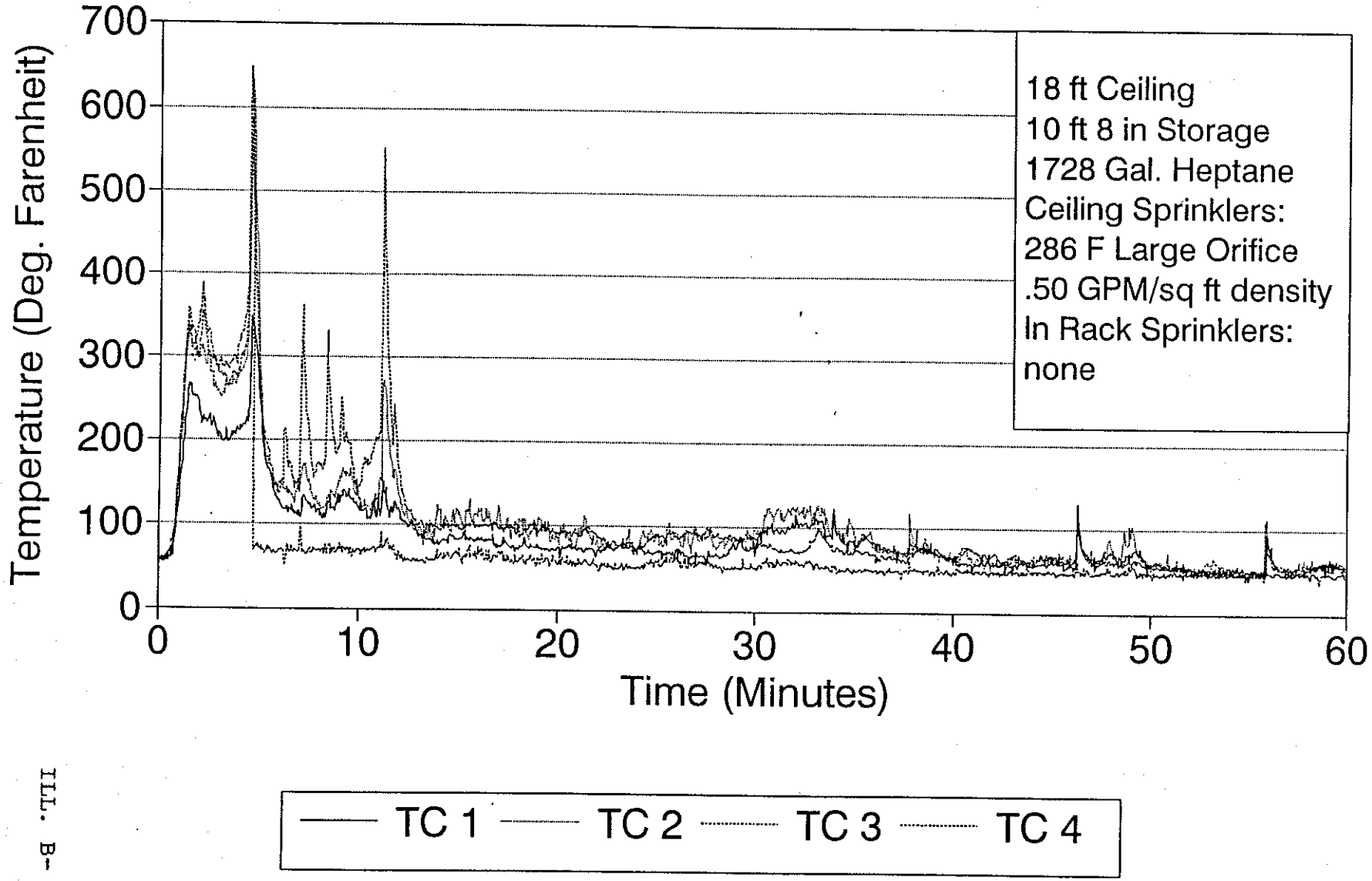
A P P E N D I X B

CEILING AND PERIMETER TEMPERATURE MEASUREMENTS

Description	ILL. No.
Rack Test 1 Ceiling Temperature	B1-B4
Rack Test 1 Perimeter Temperature	B5-B8
Rack Test 2 Ceiling Temperature	B9-B12
Rack Test 2 Perimeter Temperature	B13-B16
Rack Test 3 Ceiling Temperature	B17-B20
Rack Test 3 Perimeter Temperature	B21-B24
Rack Test 4 Ceiling Temperature	B25-B28
Rack Test 4 Perimeter Temperature	B29-B32
Rack Test 5 Ceiling Temperature	B33-B36
Rack Test 5 Perimeter Temperature	B37-B40
Rack Test 6 Ceiling Temperature	B41-B44
Rack Test 6 Perimeter Temperature	B45-B48
Rack Test 7 Ceiling Temperature	B49-B52
Rack Test 7 Perimeter Temperature	B53-B56
Rack Test 8 Ceiling Temperature	B57-B60
Rack Test 8 Perimeter Temperature	B61-B64
Rack Test 9 Ceiling Temperature	B65-B68
Rack Test 9 Perimeter Temperature	B69-B72
Rack Test 10 Ceiling Temperature	B73-B76
Rack Test 10 Perimeter Temperature	B77-B80
Rack Test 11 Ceiling Temperature	B81-B84
Rack Test 11 Perimeter Temperature	B85-B88
Rack Test 12 Ceiling Temperature	B89-B92
Rack Test 12 Perimeter Temperature	B93-B96
Rack Test 16 Ceiling Temperature	**B97-B100**

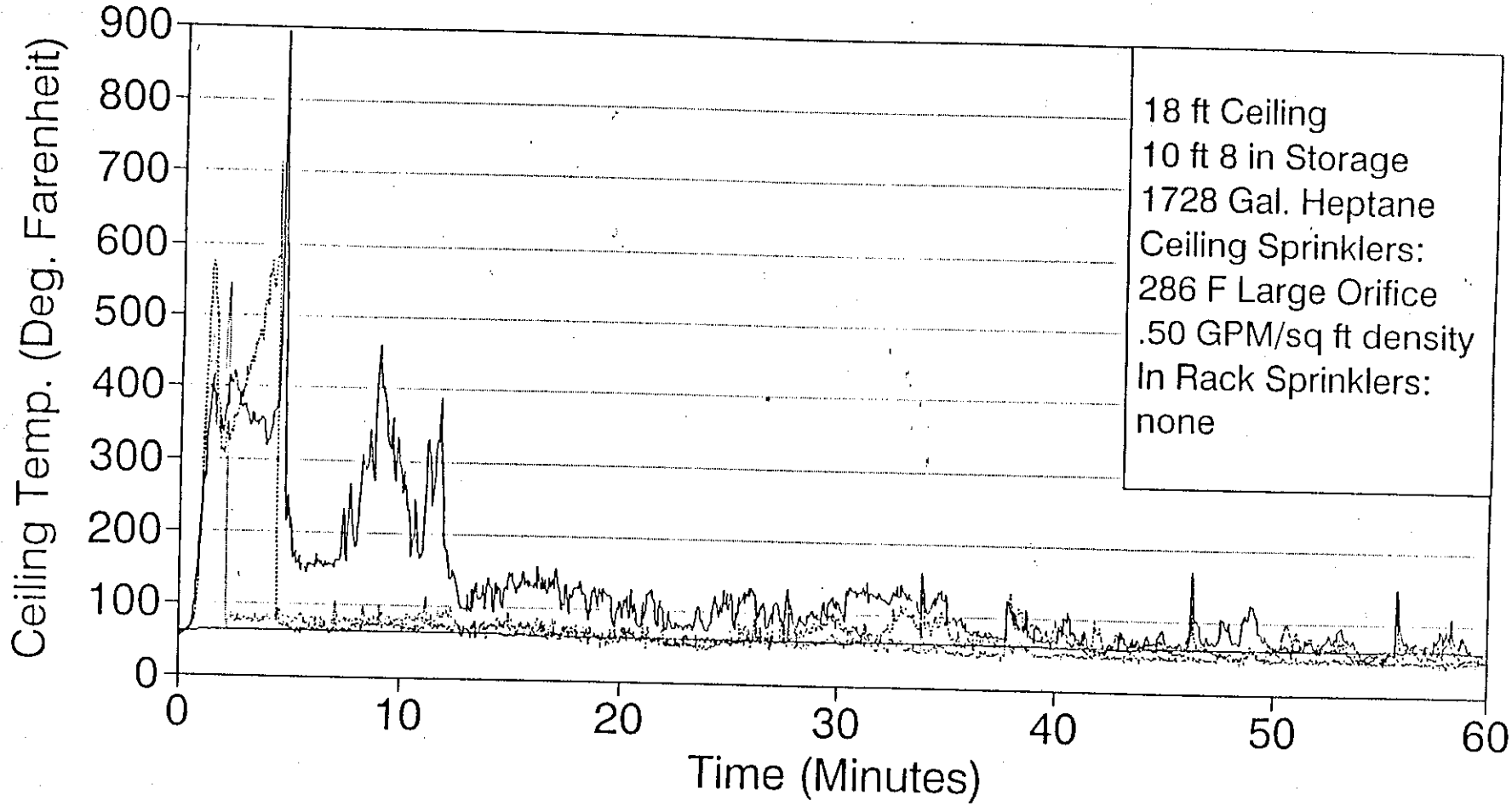
NFPRF RACK FIRE TEST NO. 1

Ceiling Temperatures



NFPRF RACK FIRE TEST NO. 1

Rack Fire Wood Sticker Shelving



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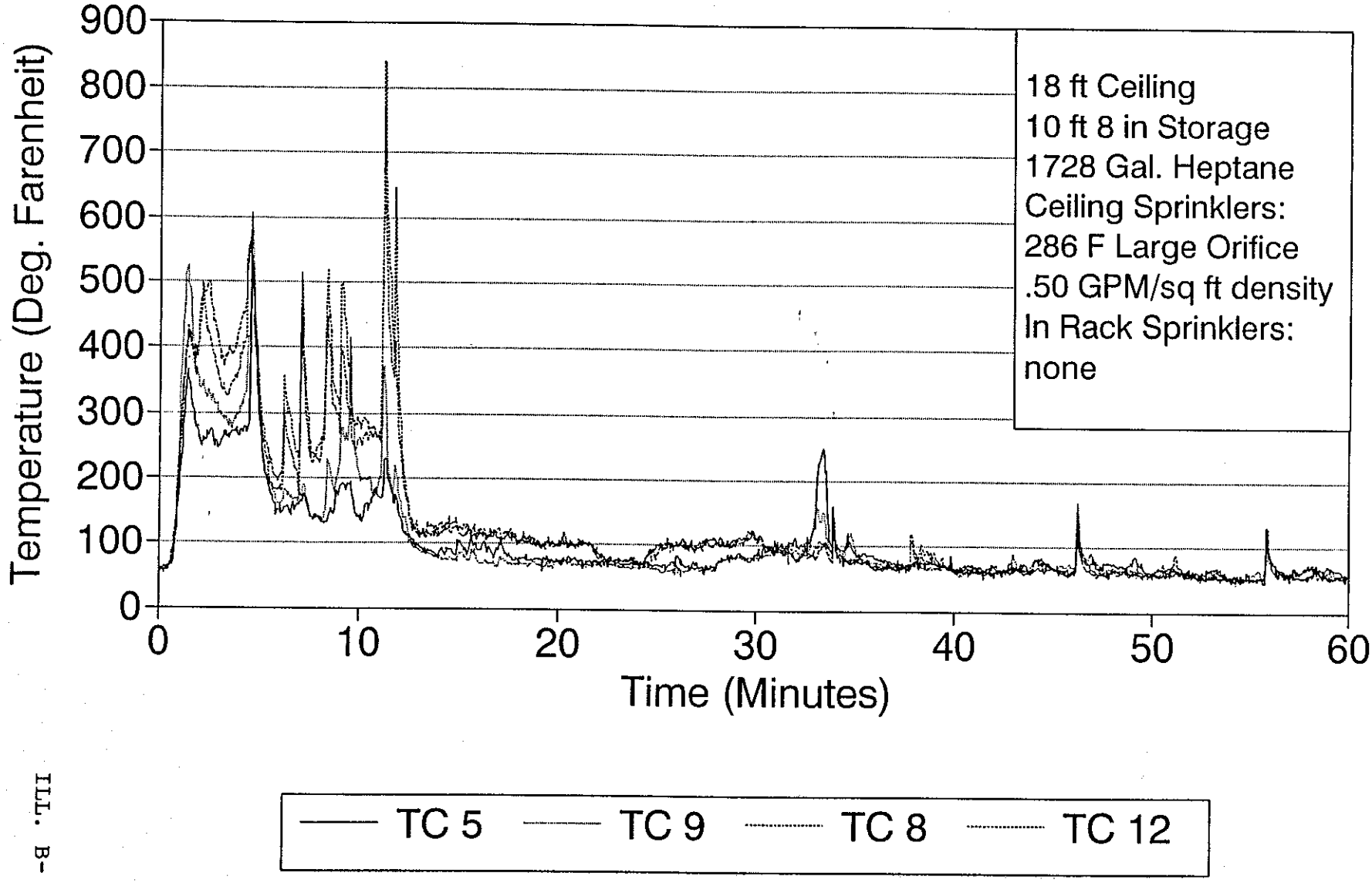
Ceiling Temperatures



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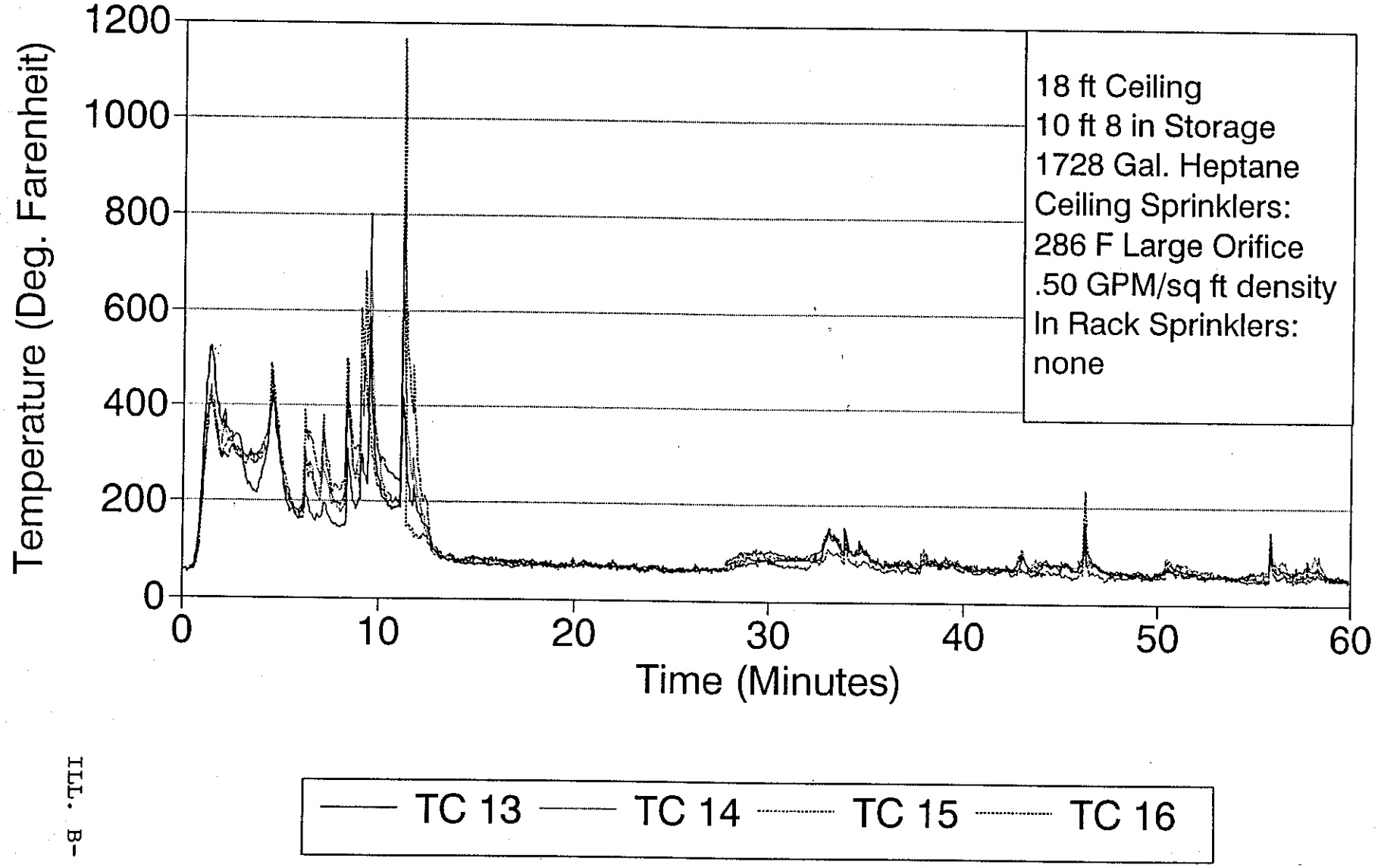
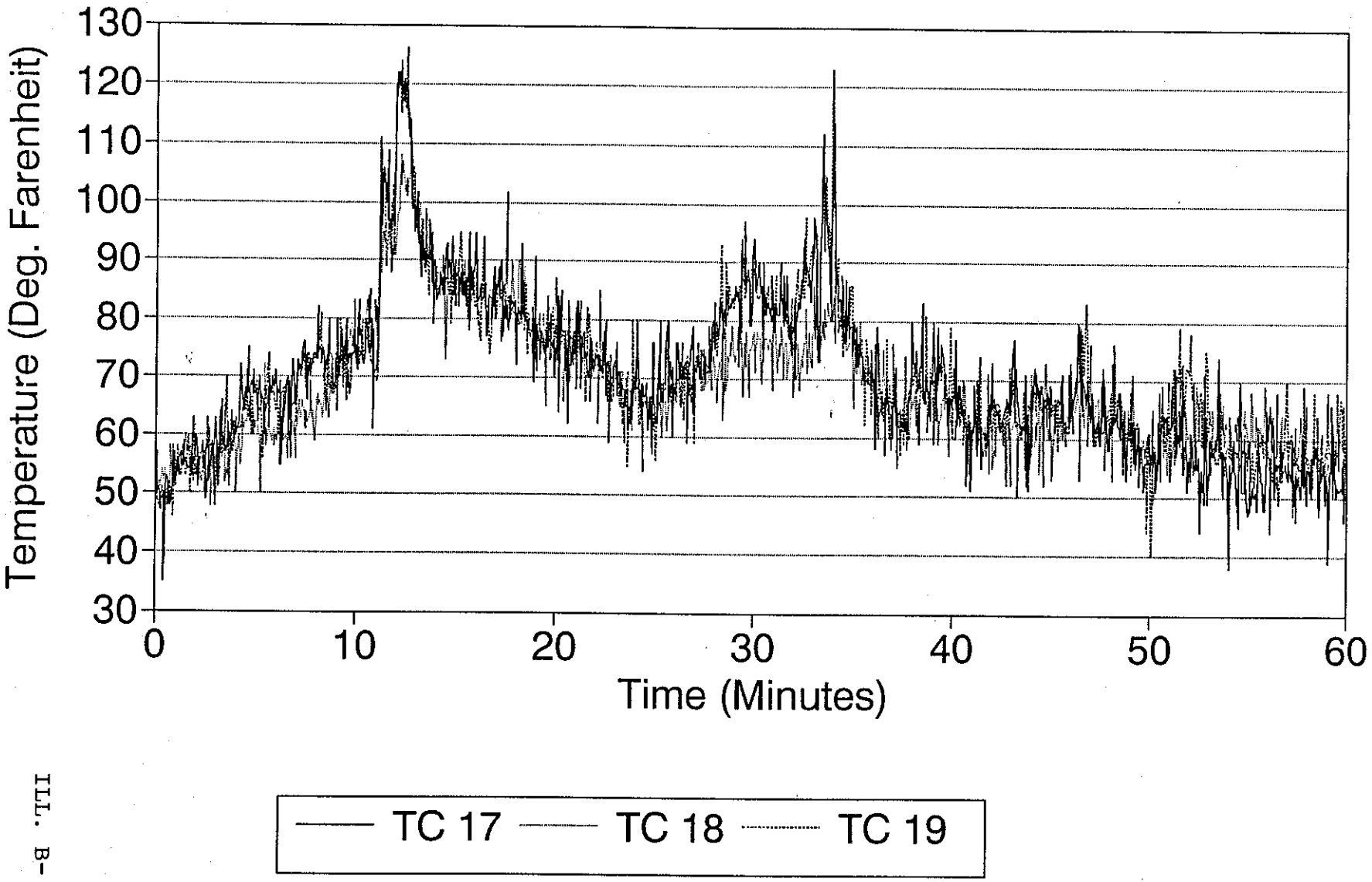
Ceiling Temperatures



NFPRF RACK FIRE TEST NO. 1

Perimeter Temperatures



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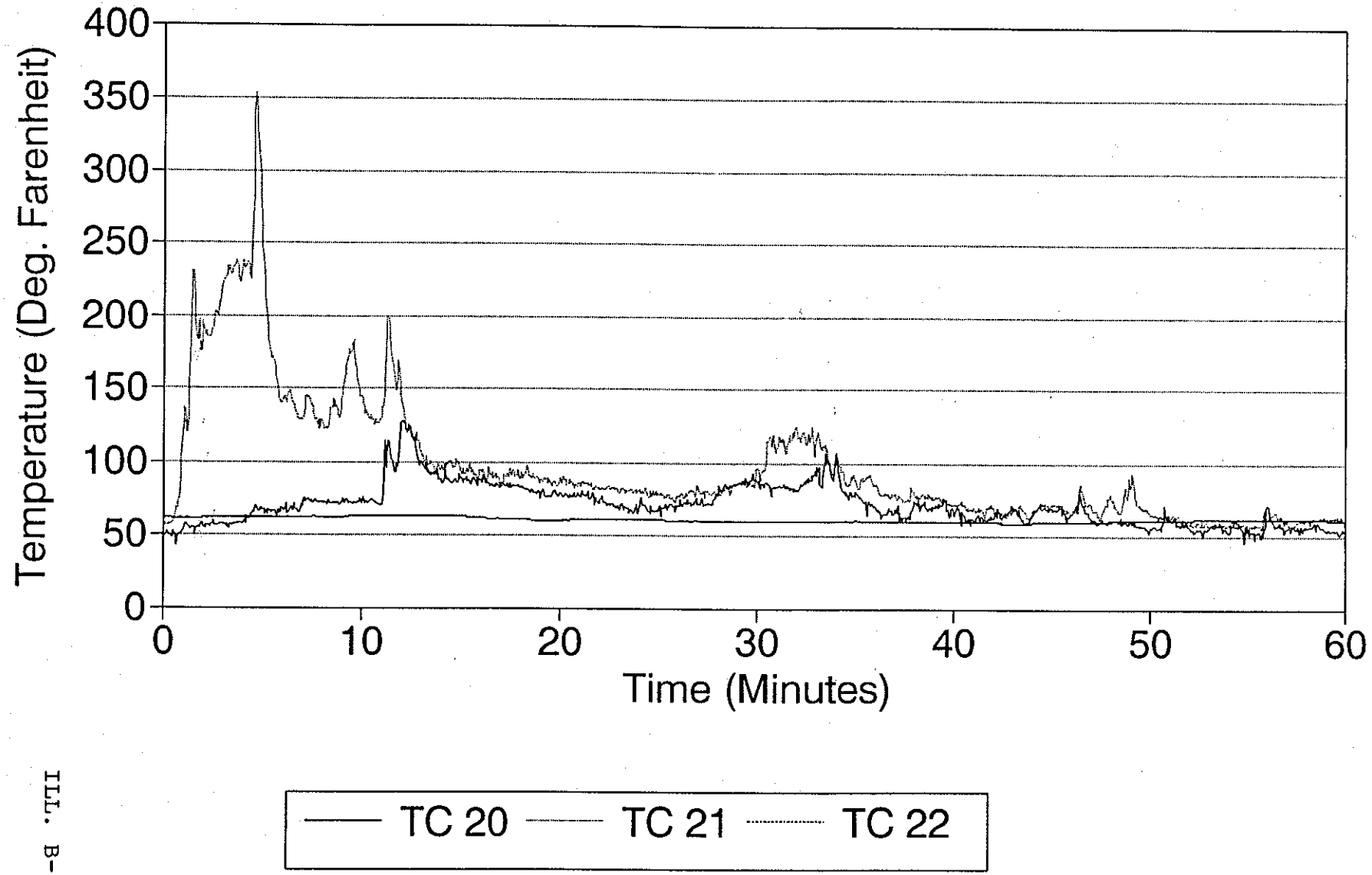
Perimeter Temperatures



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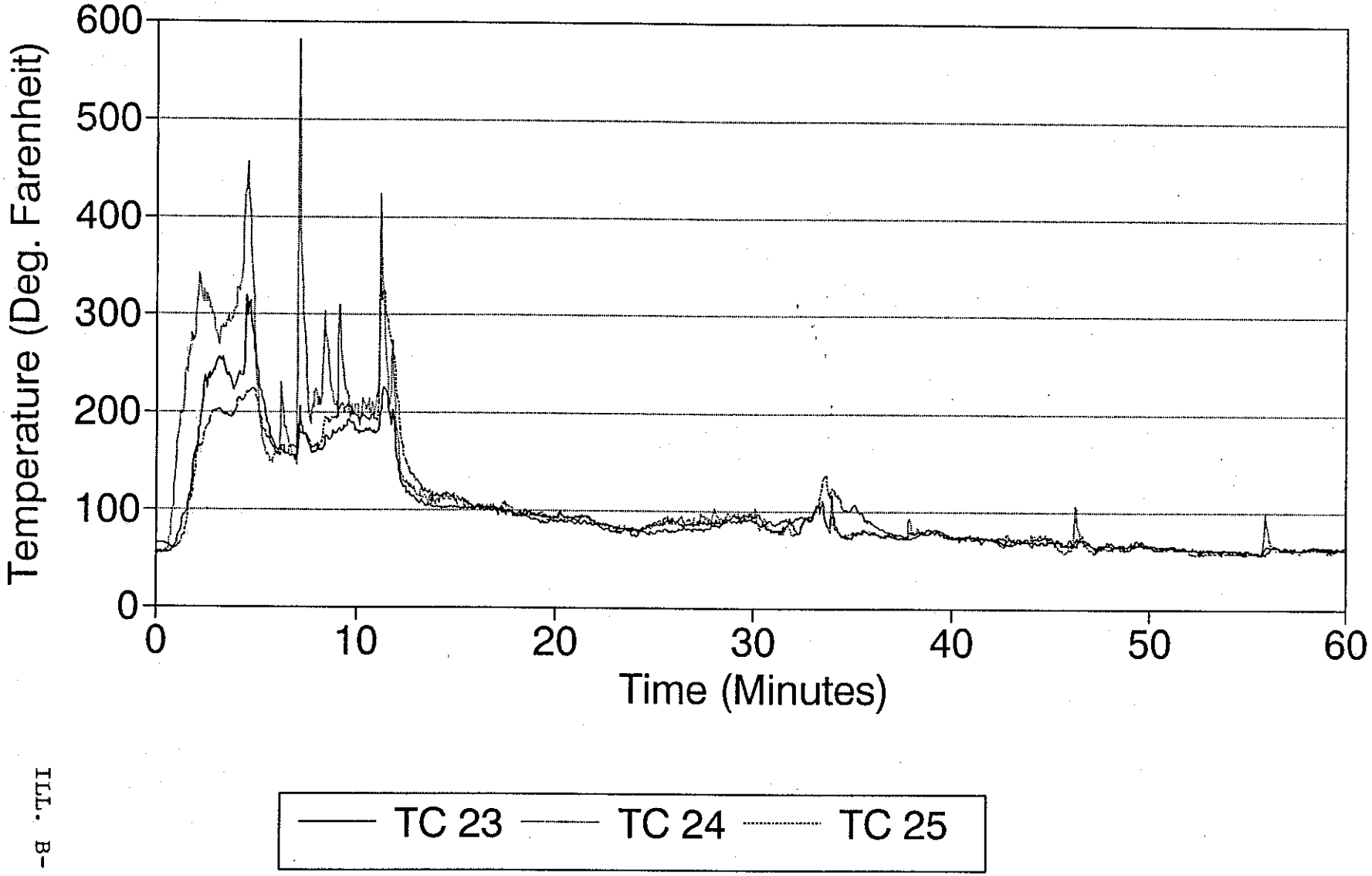

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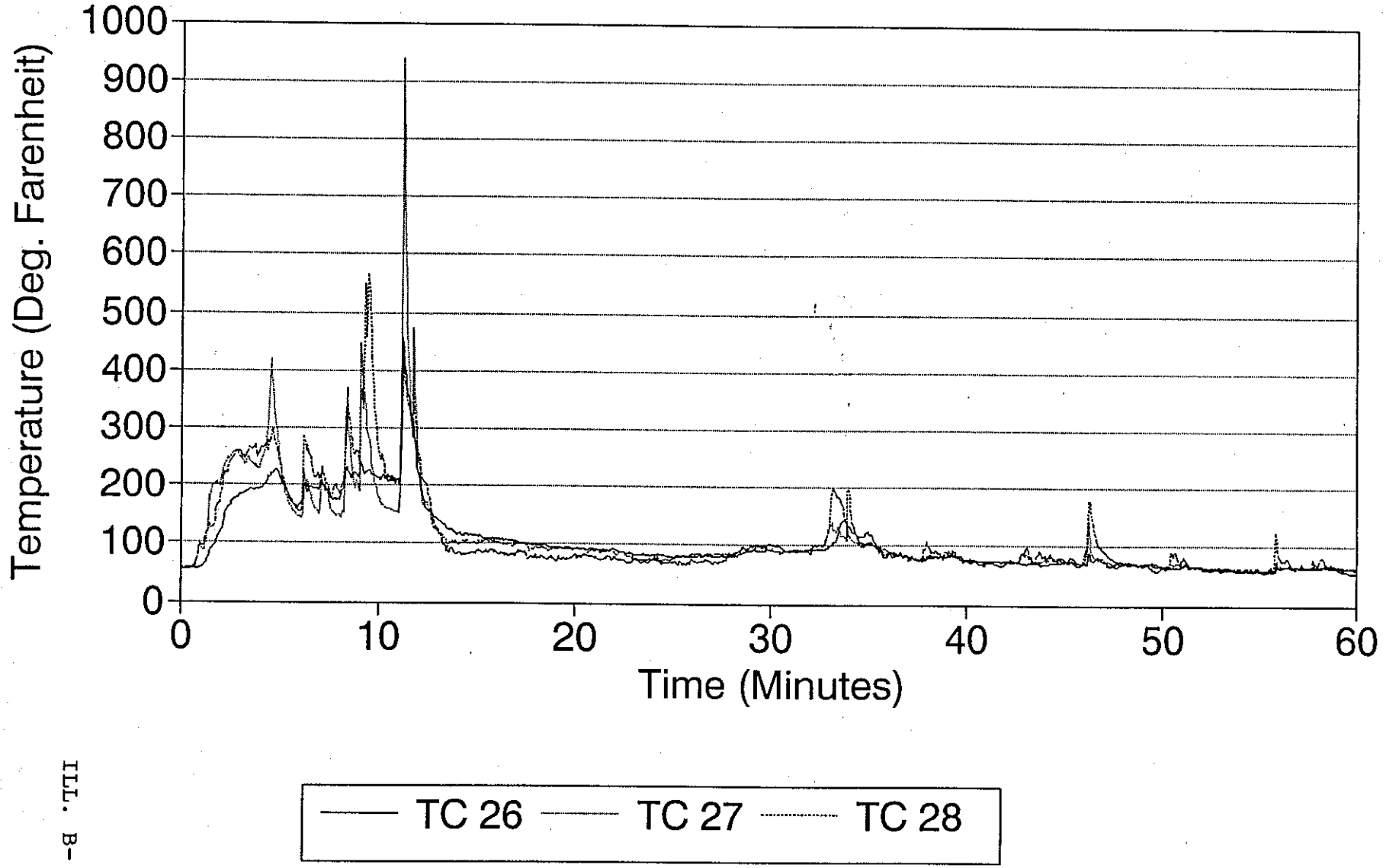
Perimeter Temperatures



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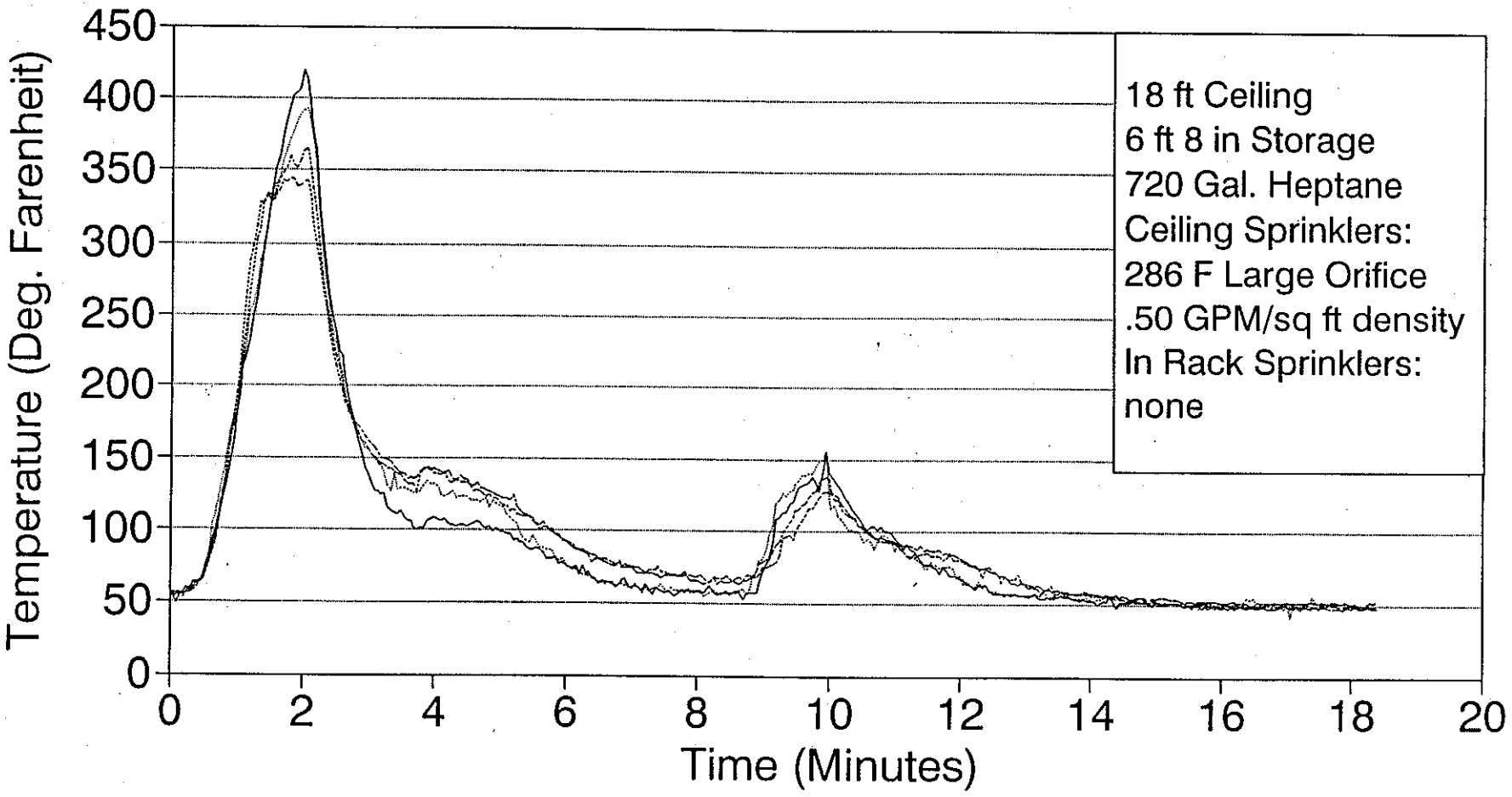
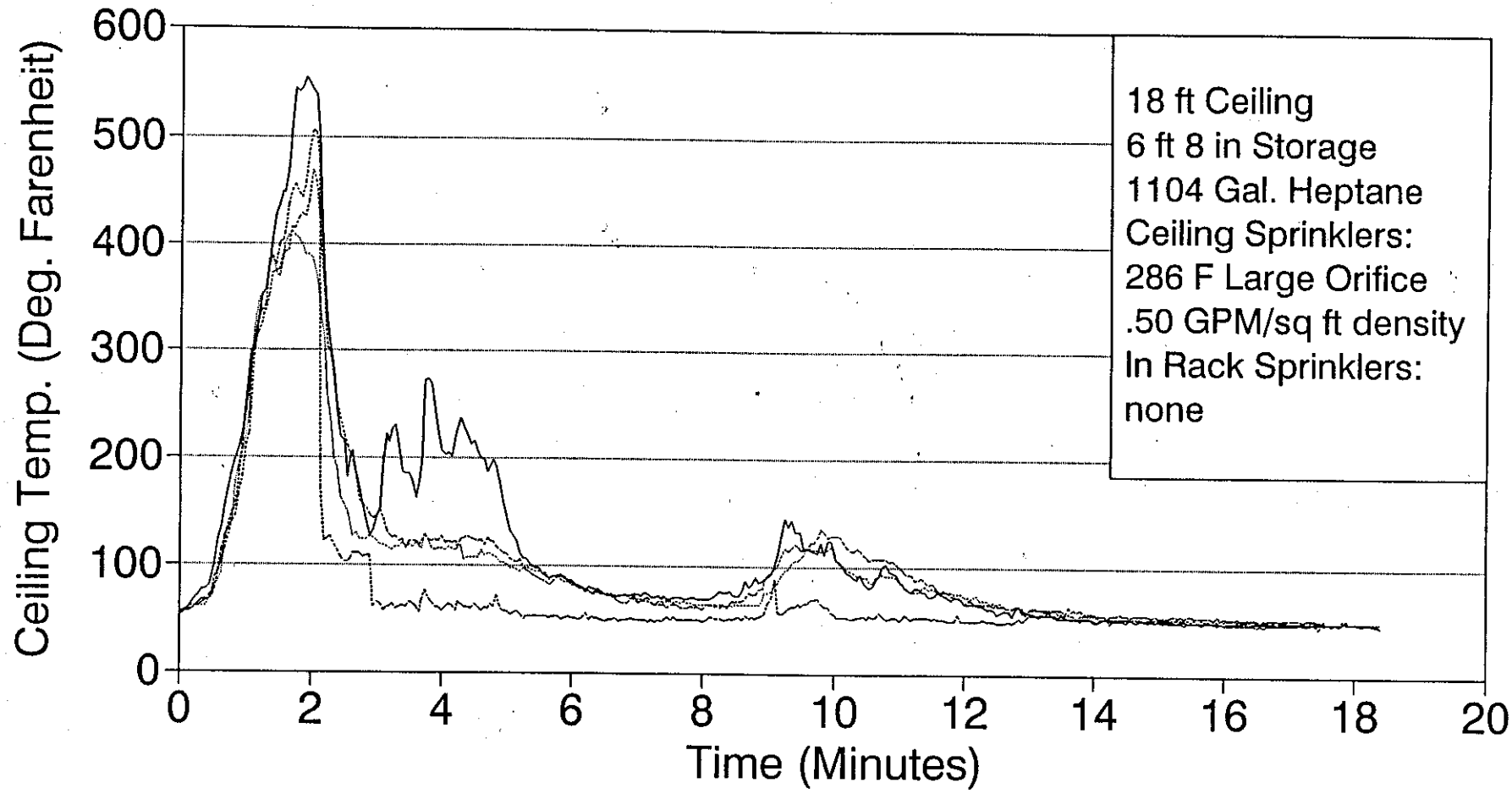
Ceiling Temperatures



NFPRF RACK FIRE TEST NO.2

Wire Shelves, Ceiling Sprinklers



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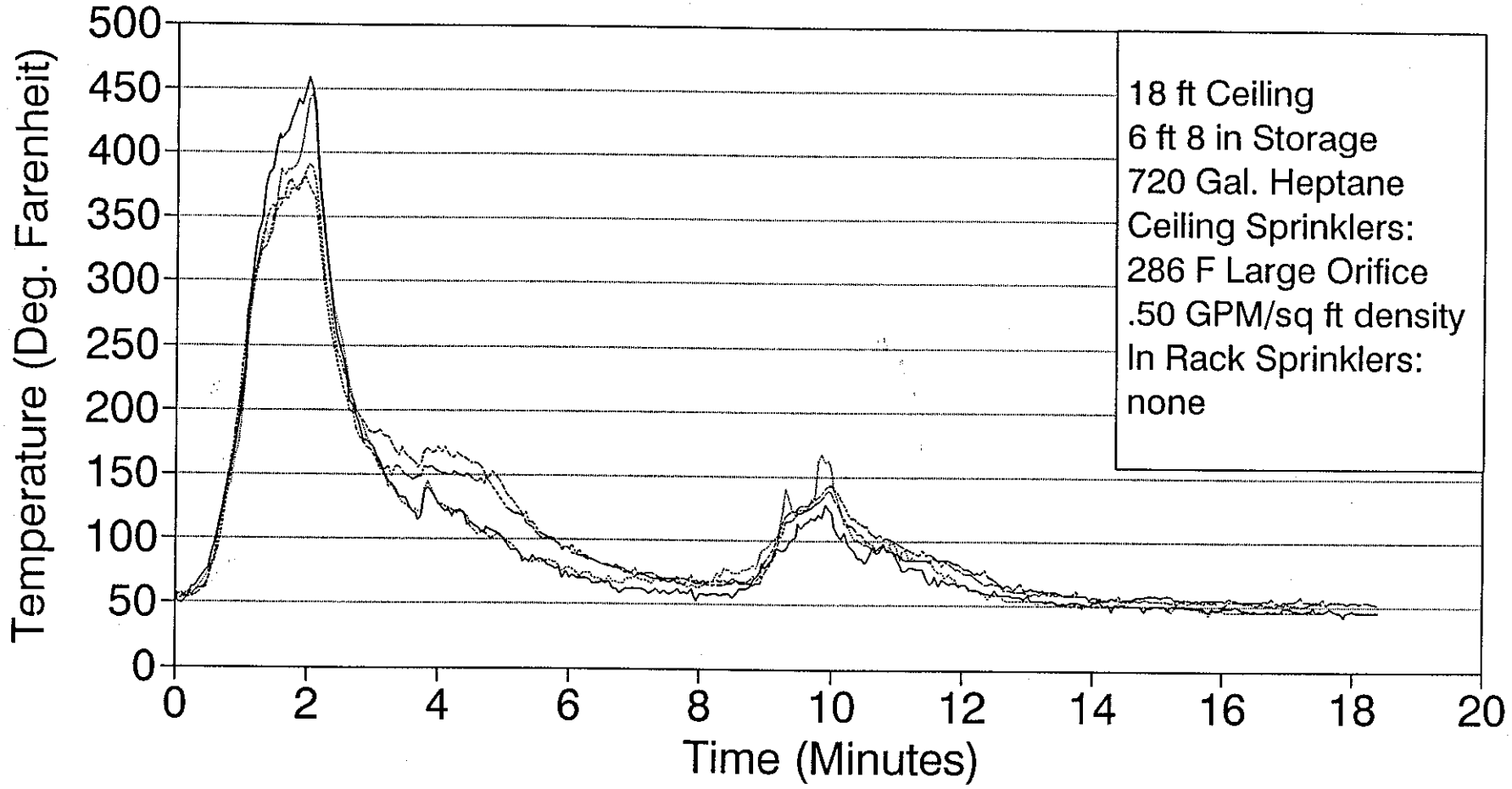
Ceiling Temperatures



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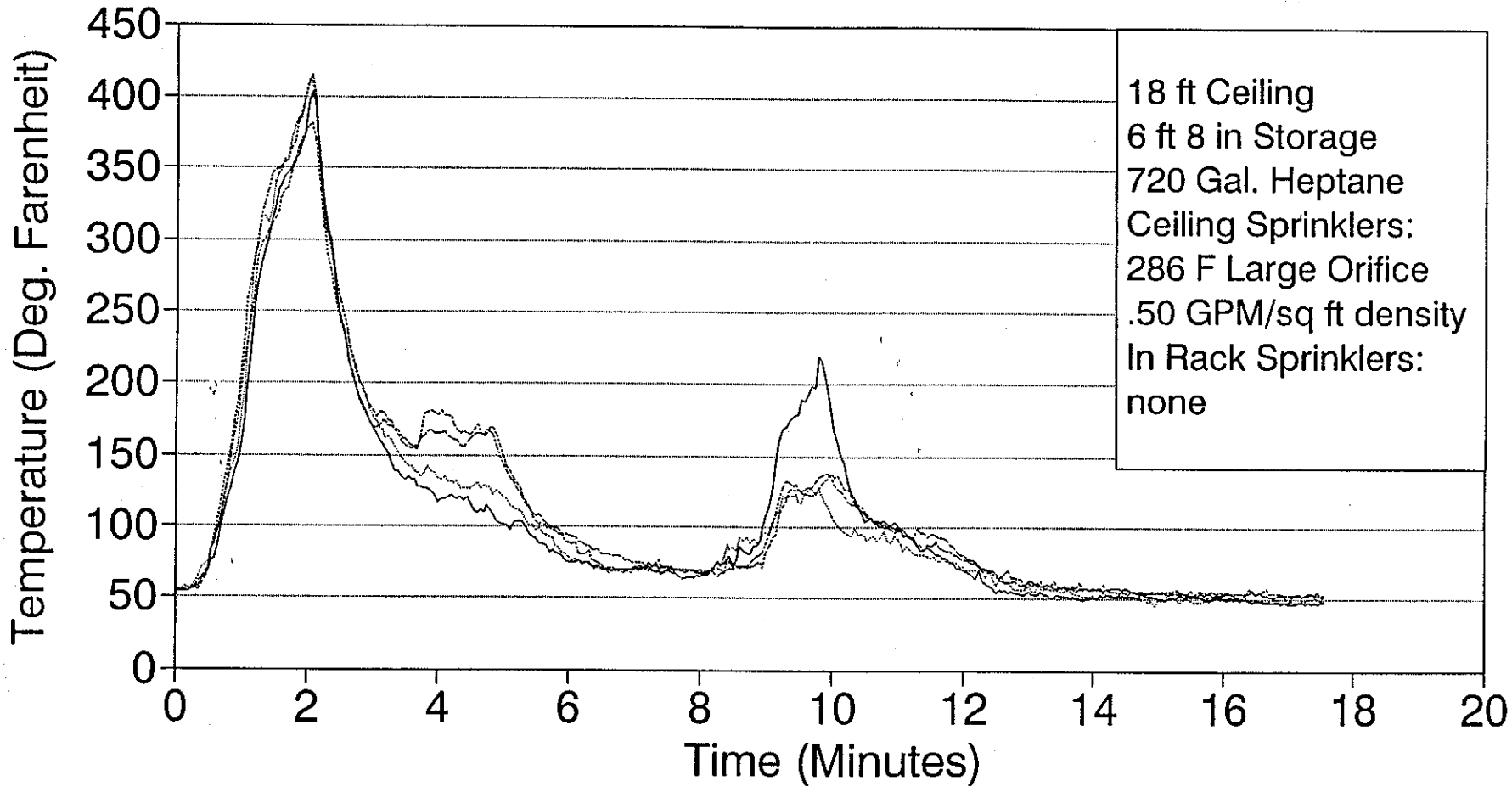
Ceiling Temperatures



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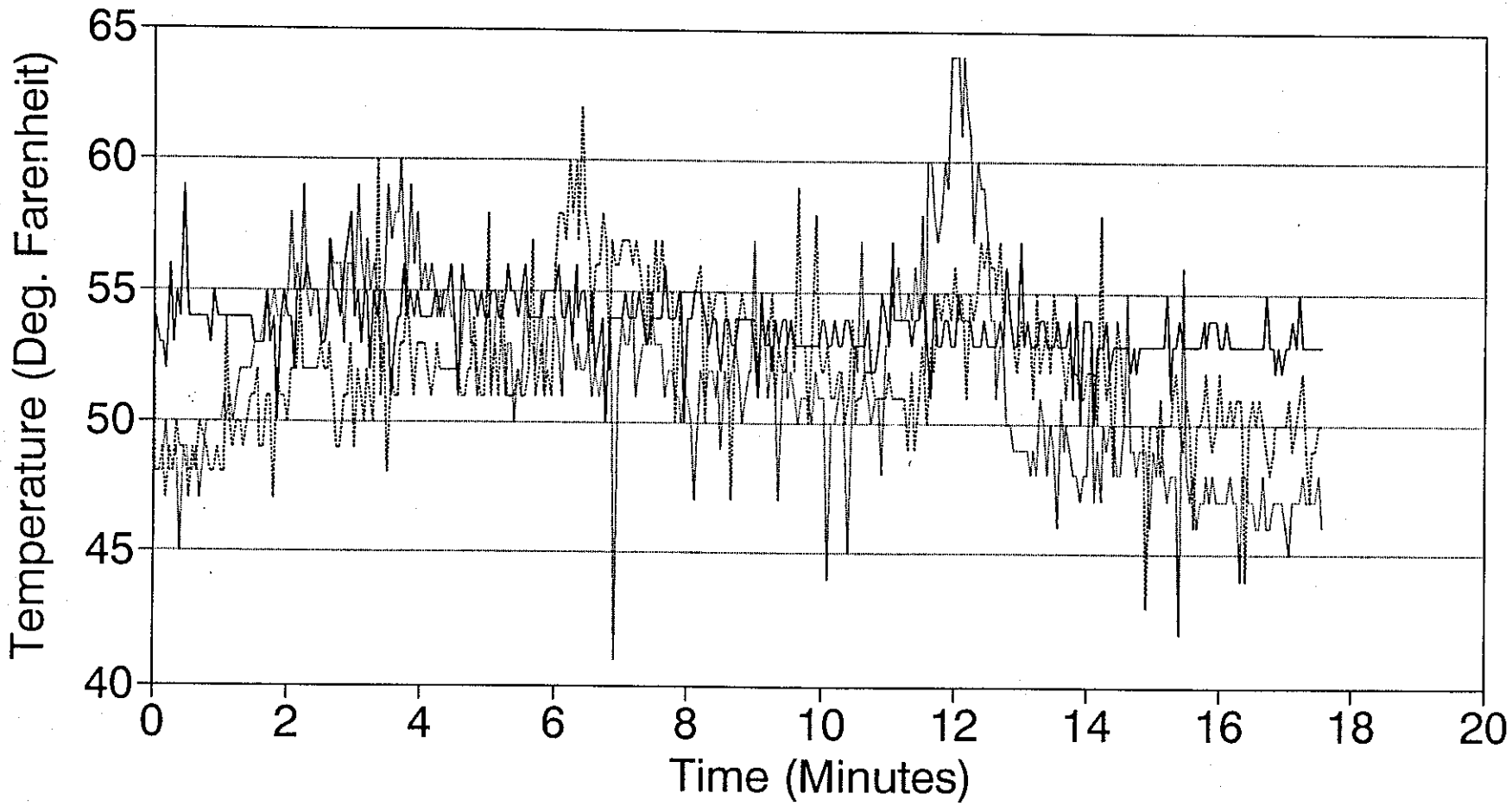
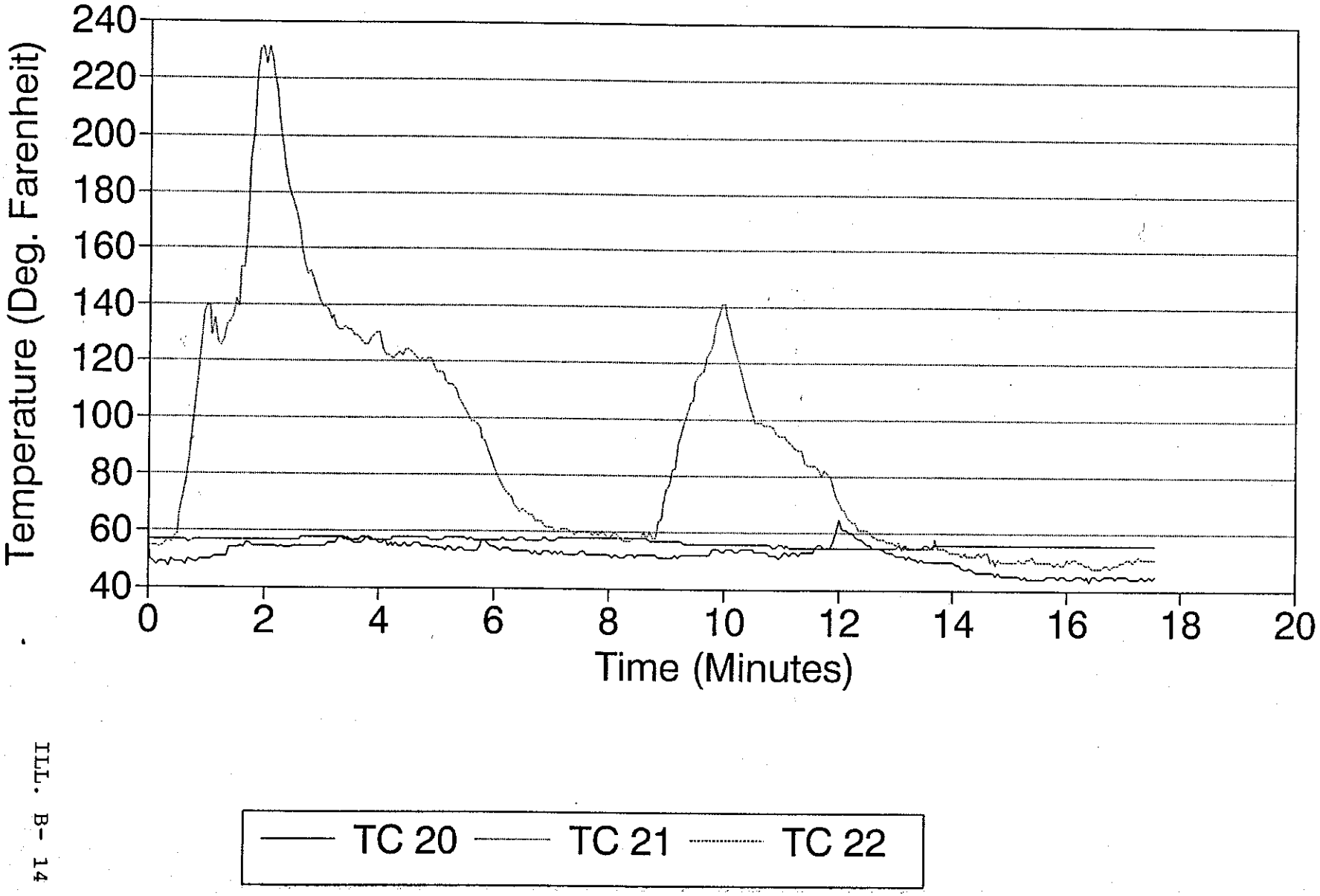
Perimeter Temperatures



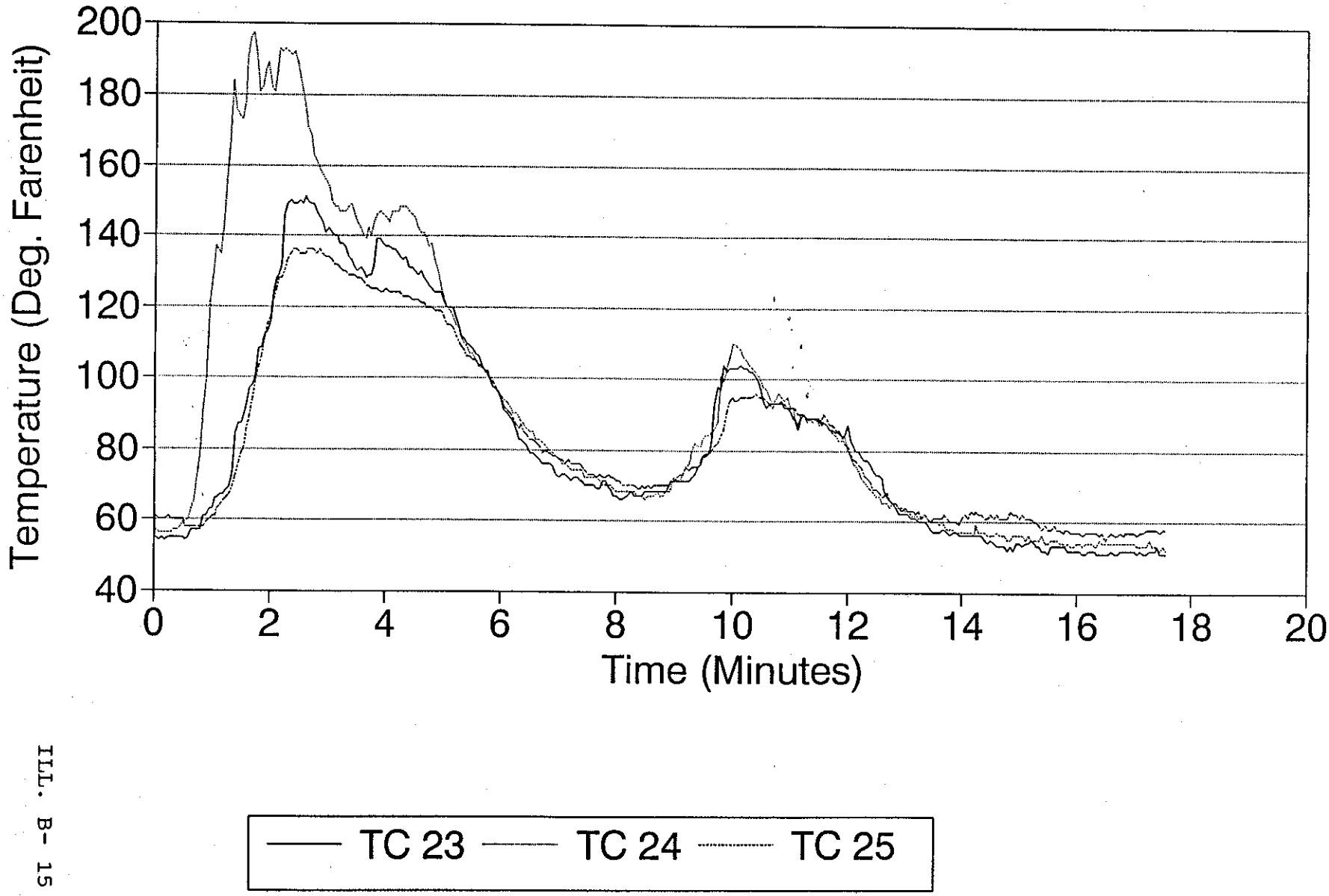
NFPRF RACK FIRE TEST NO.2

Perimeter Temperatures



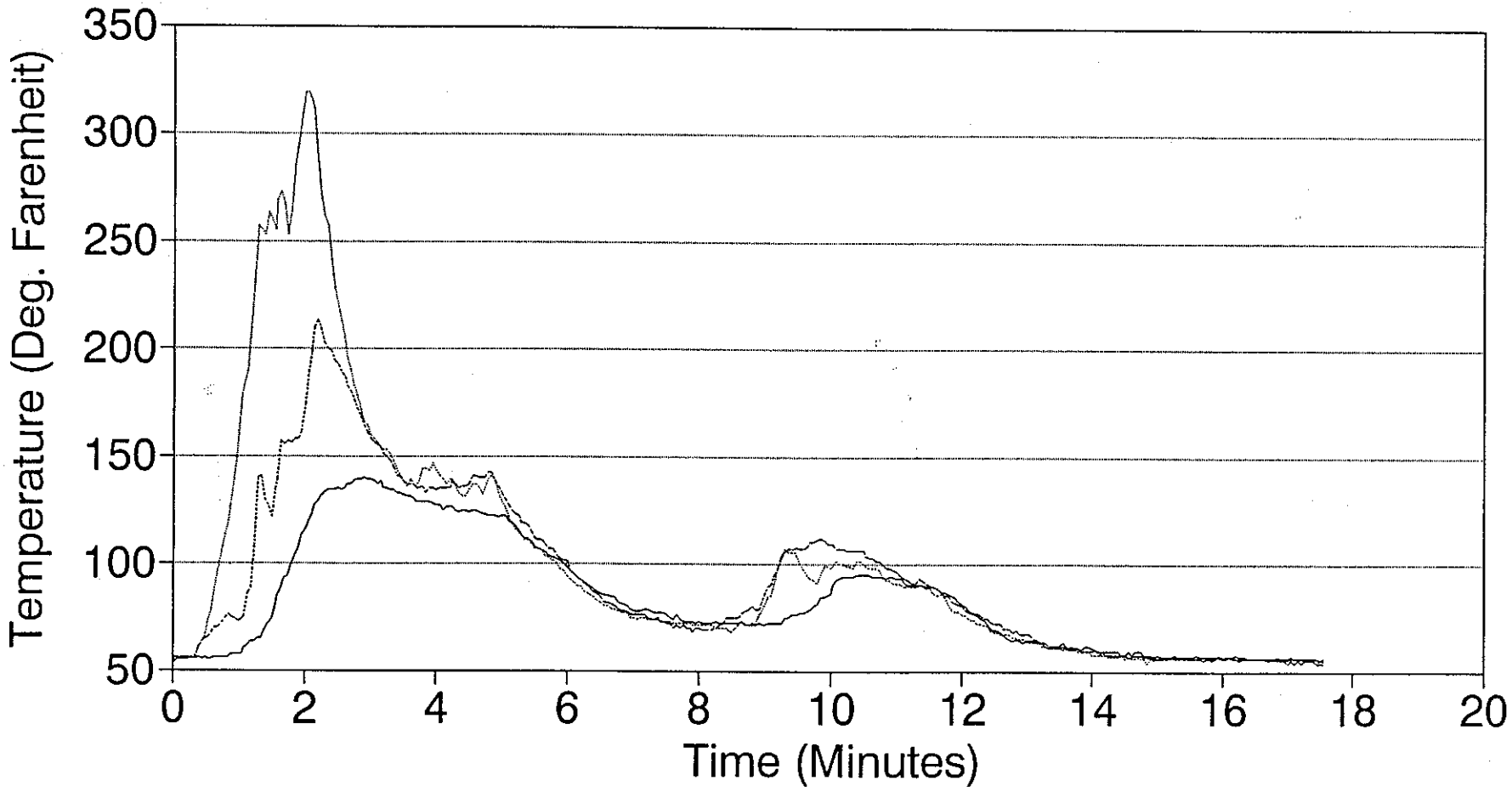
NFPRF RACK FIRE TEST NO.2

Perimeter Temperatures



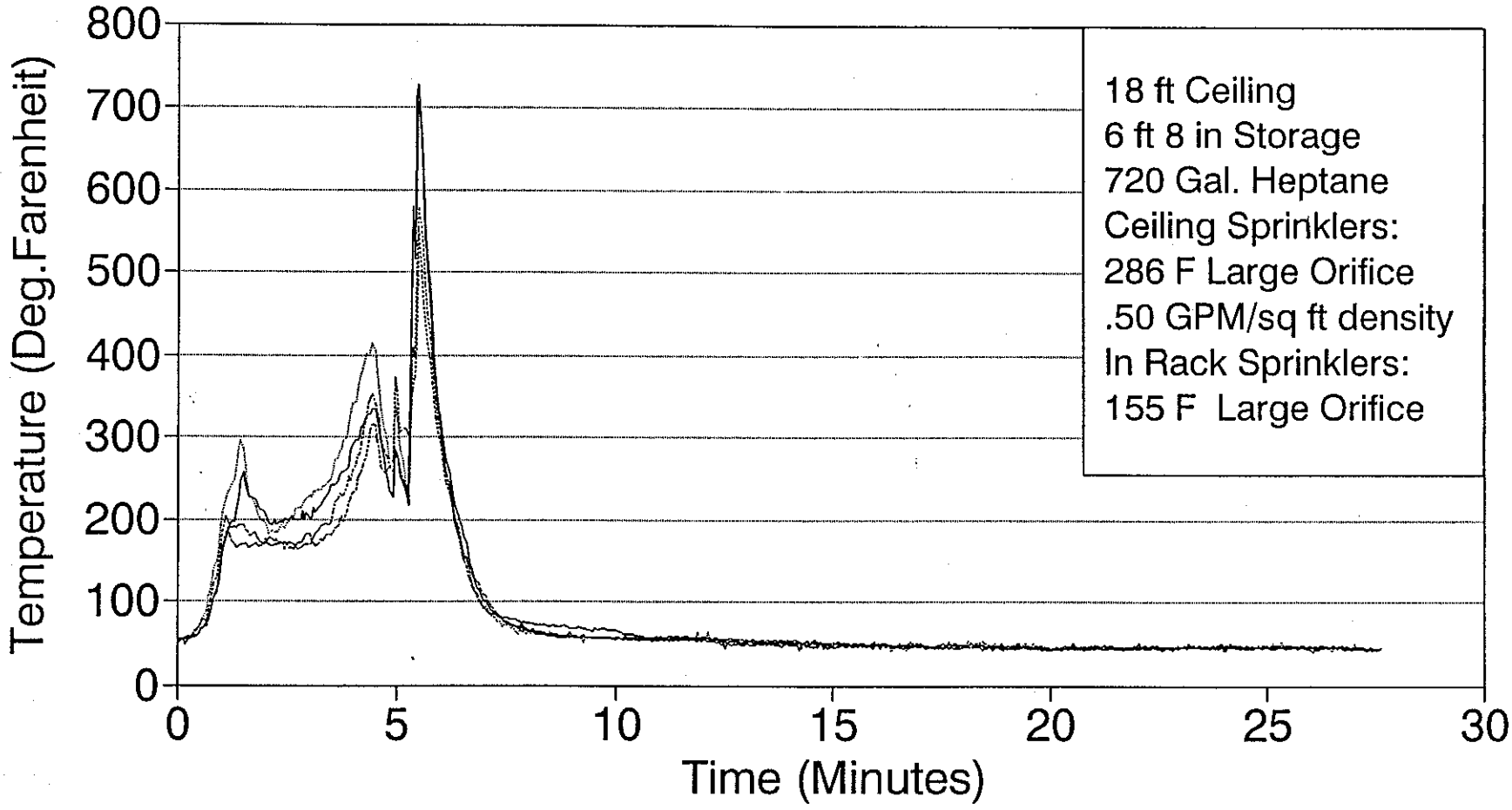
NFPRF RACK FIRE TEST NO.2

Perimeter Temperatures



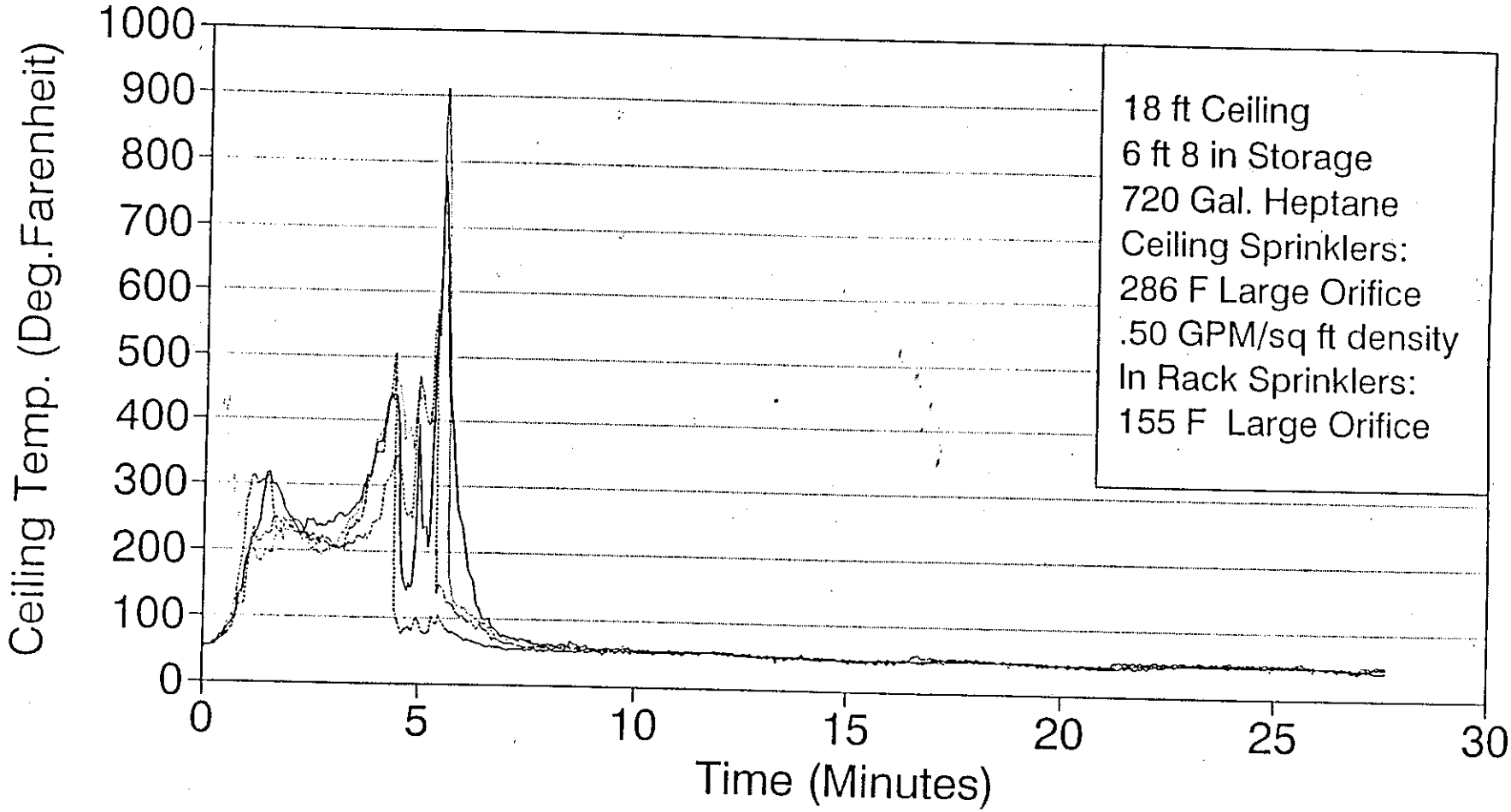
NFPRF RACK FIRE TEST NO. 3

Ceiling Temperatures



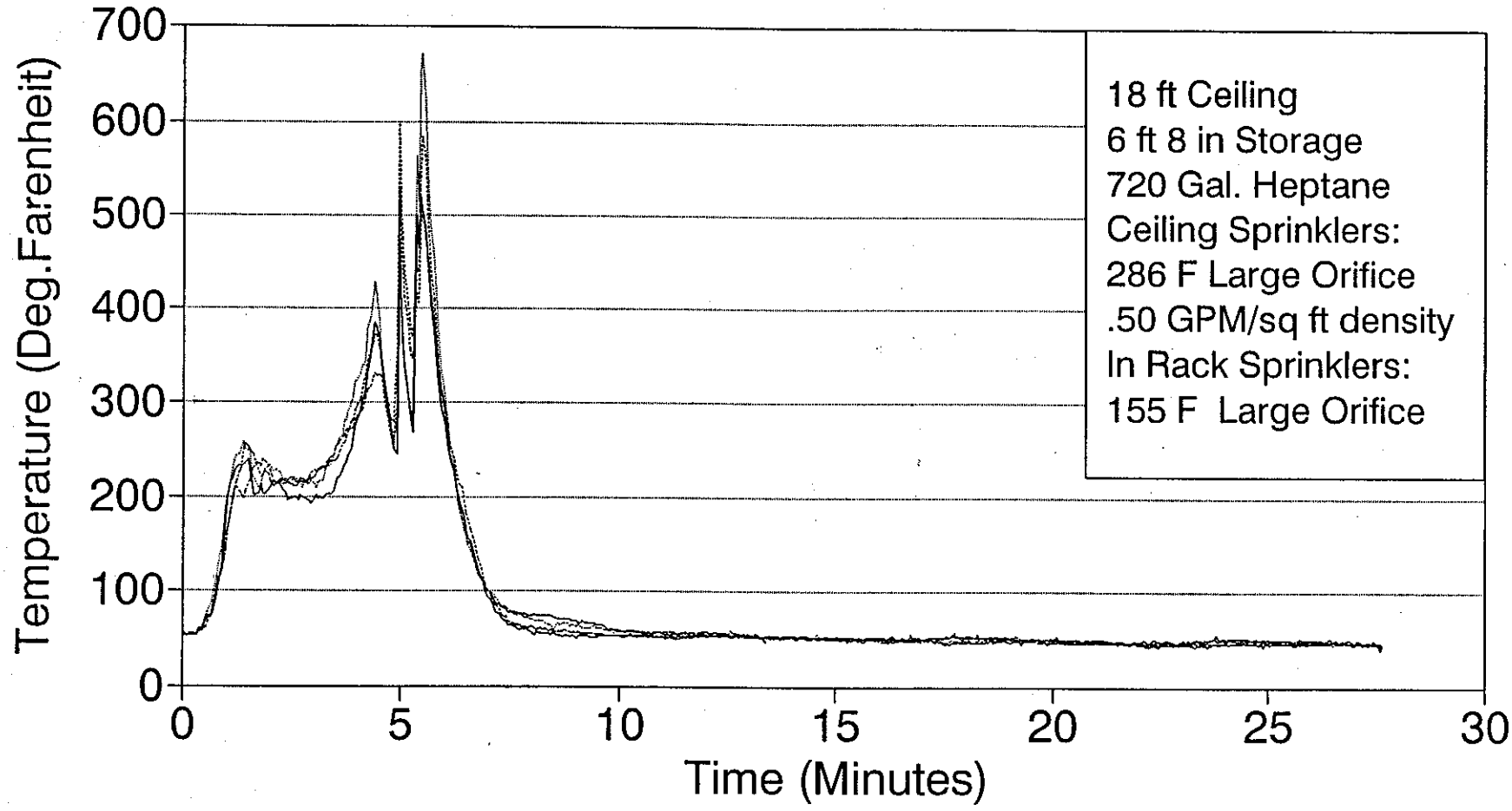
NFPRF RACK FIRE TEST NO. 3

Wood Sticker Shelves, In Rack Sprinkler



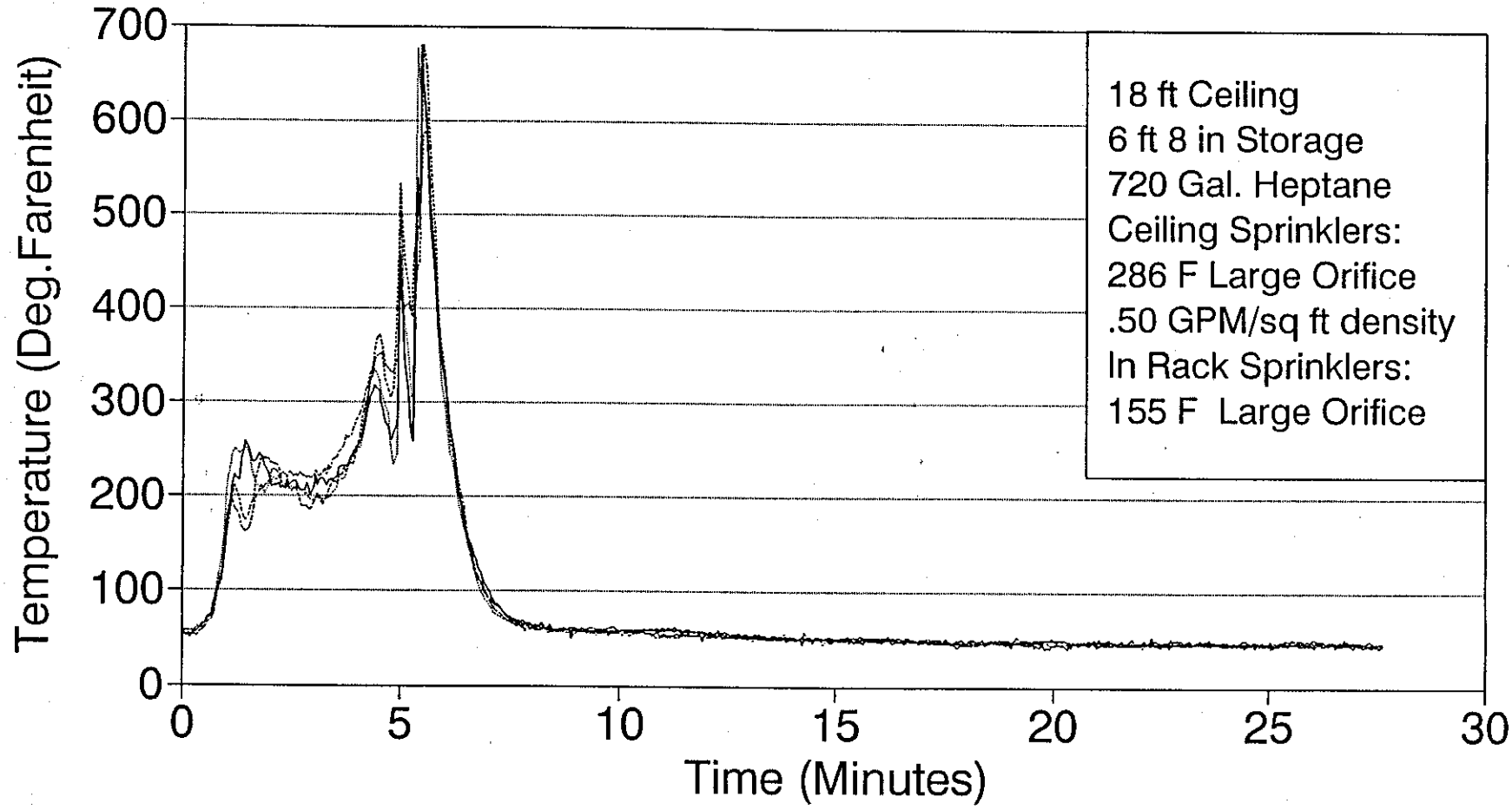
NFPRF RACK FIRE TEST NO. 3

Ceiling Temperatures



NFPRF RACK FIRE TEST NO. 3

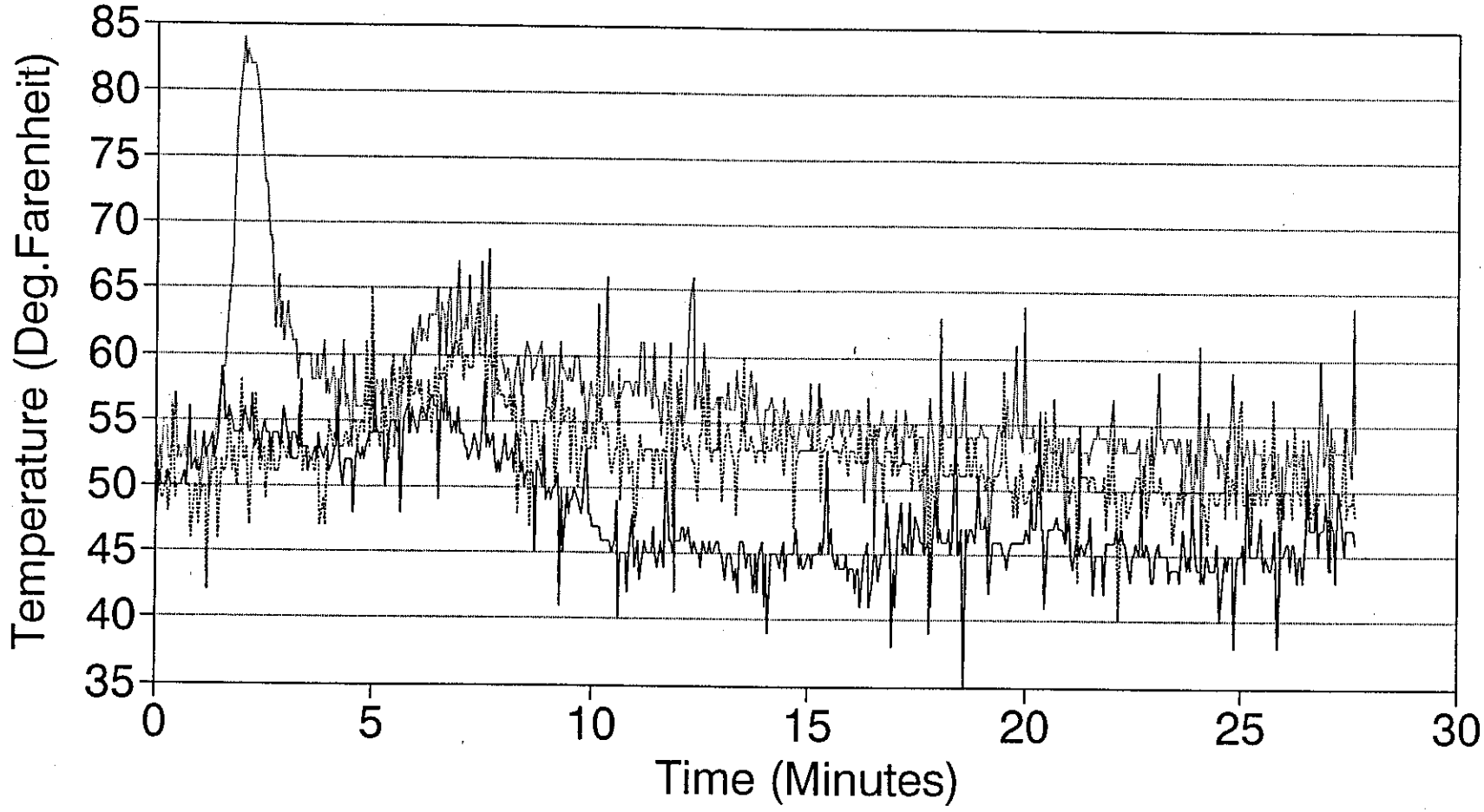
Ceiling Temperatures



TC 5 — TC 9 — TC 8 — TC 12

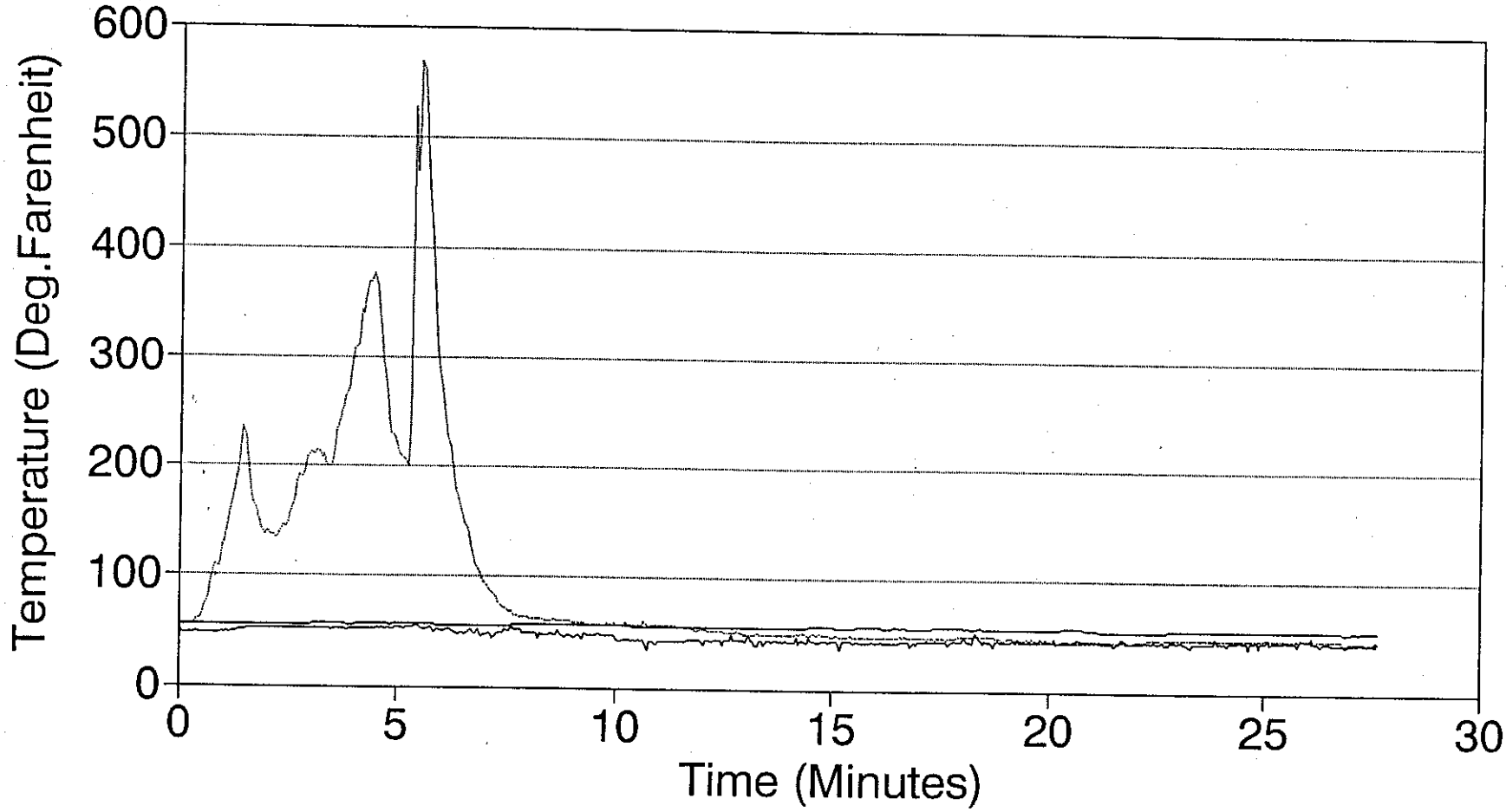
NFPRF RACK FIRE TEST NO. 3

Perimeter Temperatures



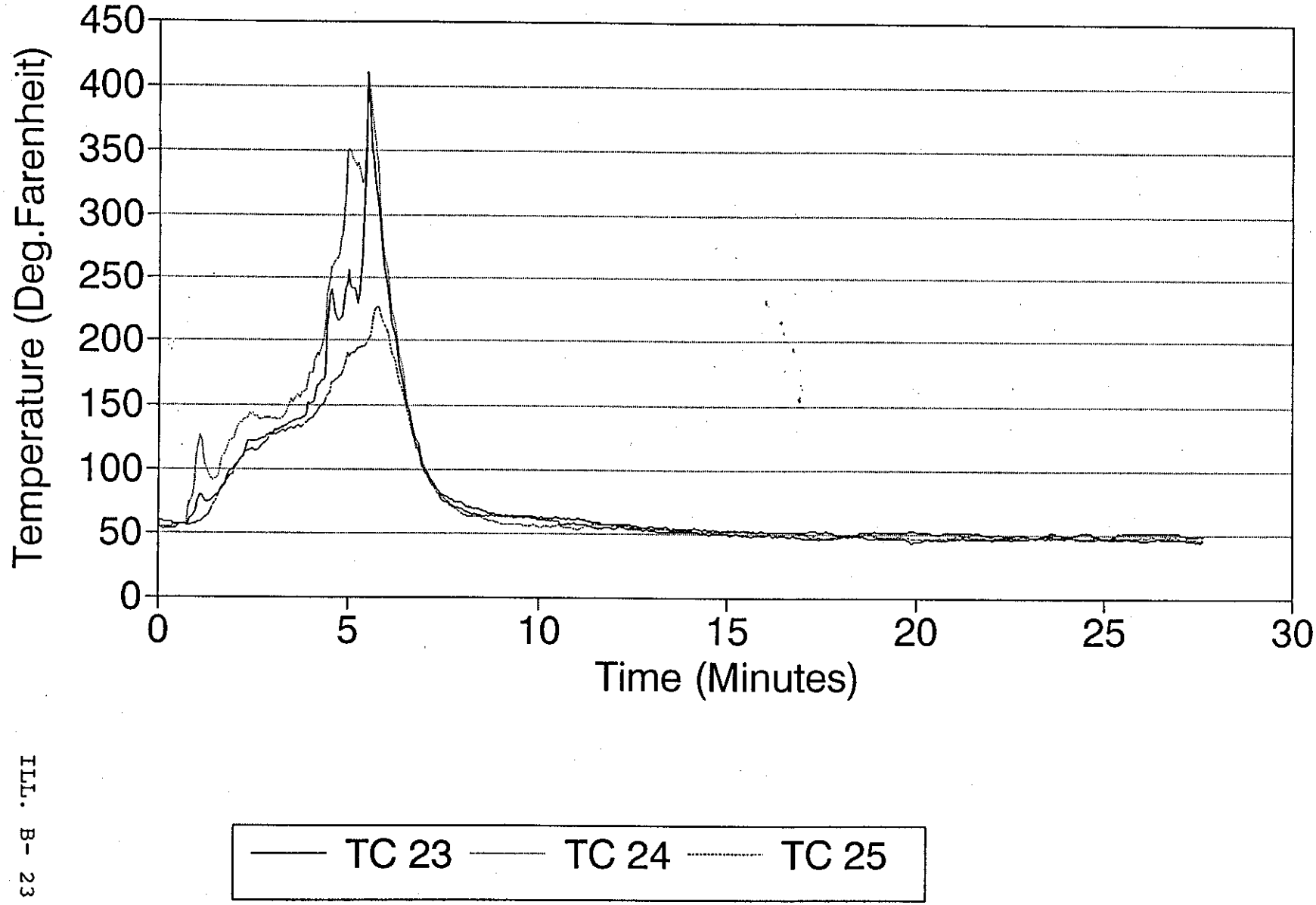
NFPRF RACK FIRE TEST NO. 3

Perimeter Temperatures



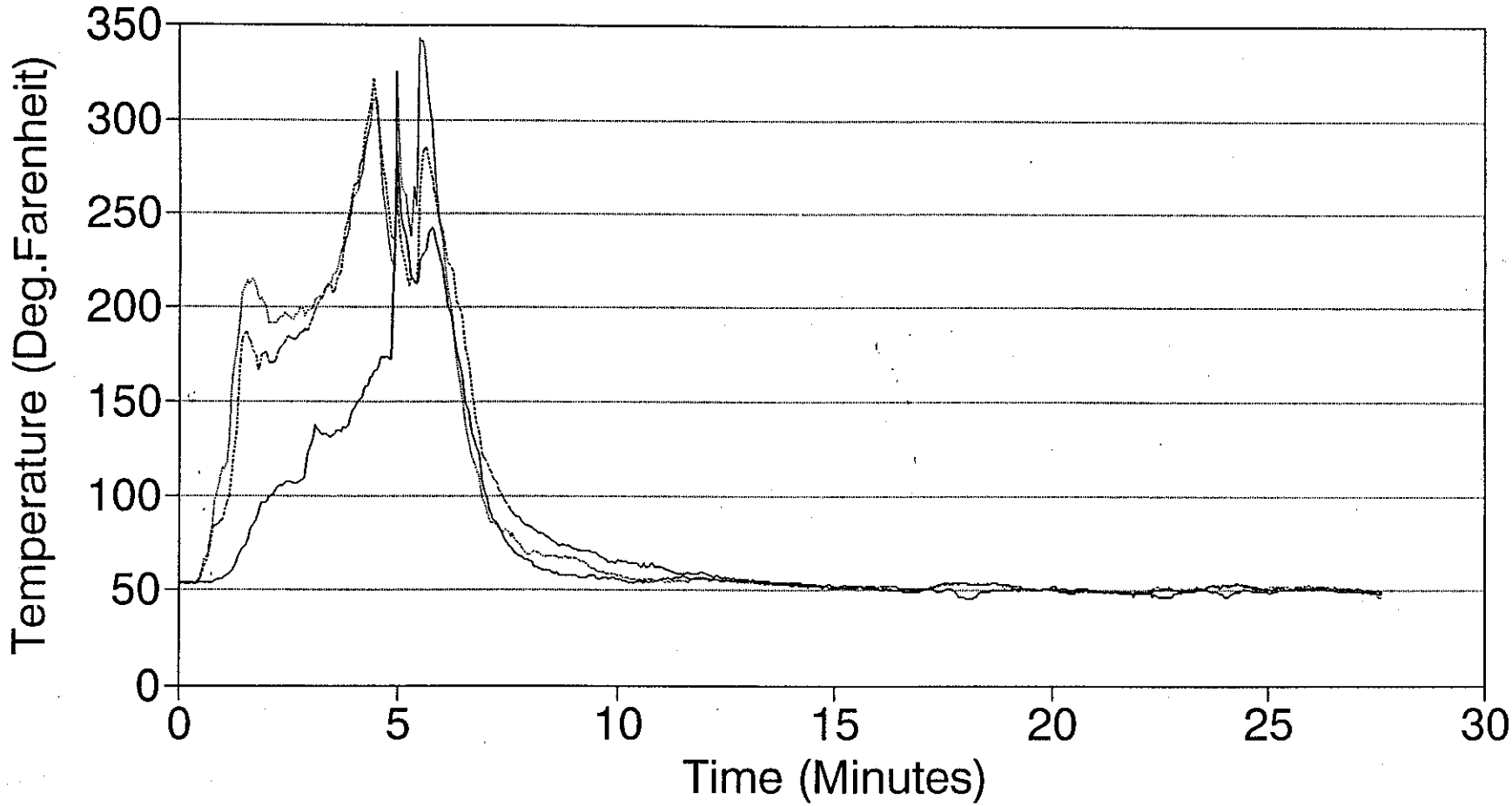
NFPRF RACK FIRE TEST NO. 3

Perimeter Temperatures



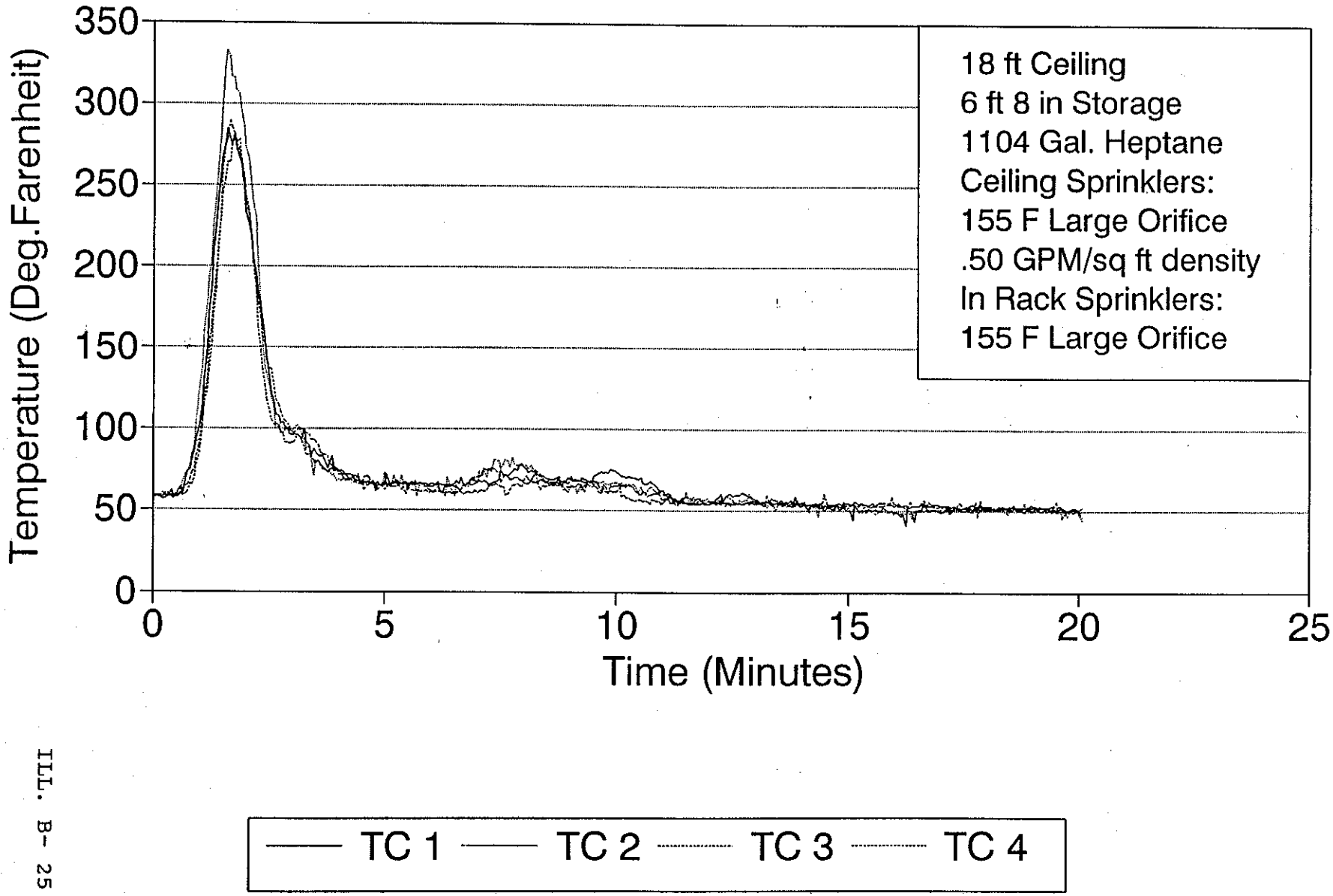
NFPRF RACK FIRE TEST NO. 3

Perimeter Temperatures



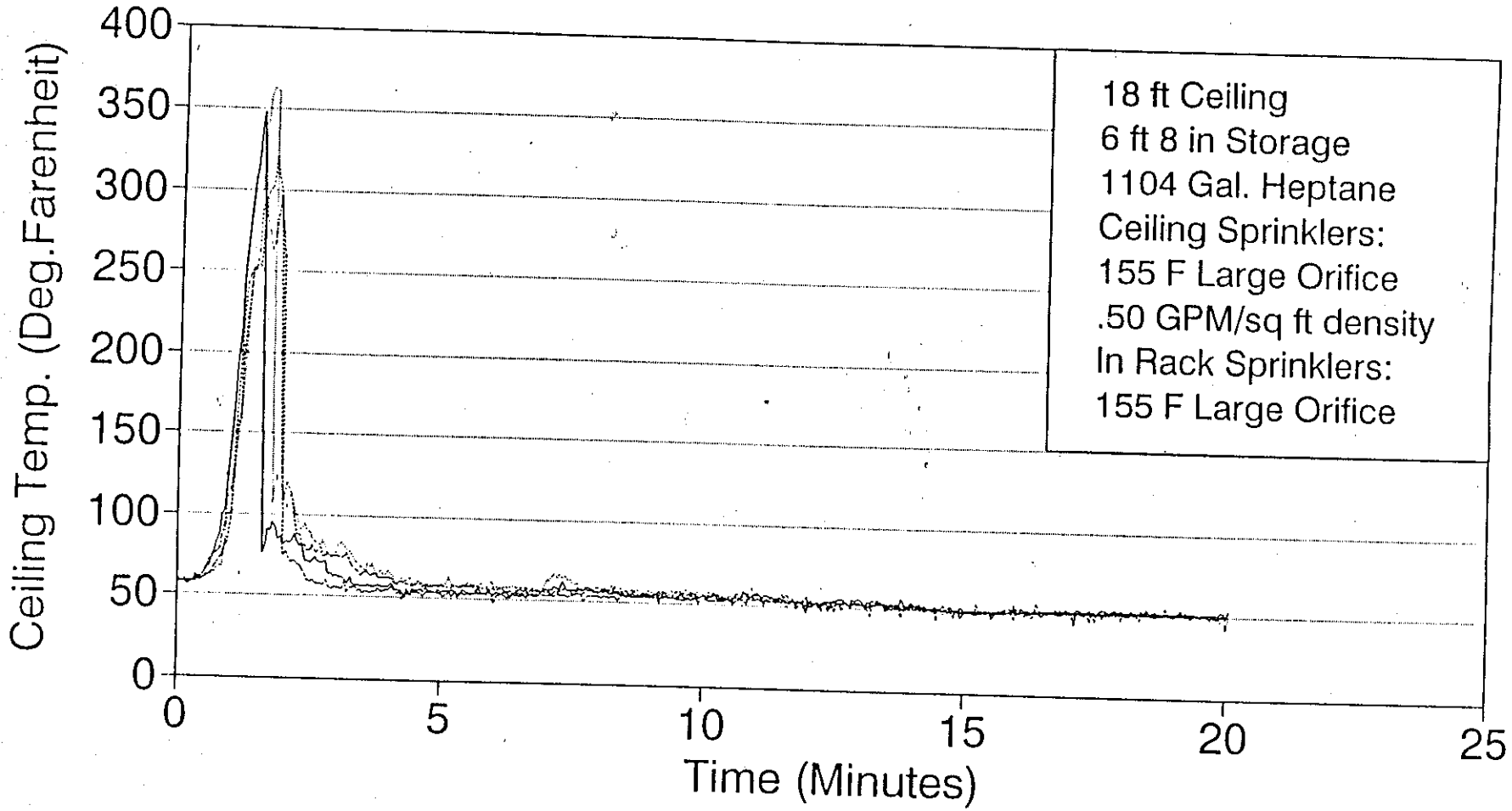
NFPRF RACK FIRE TEST NO. 4

Ceiling Temperatures



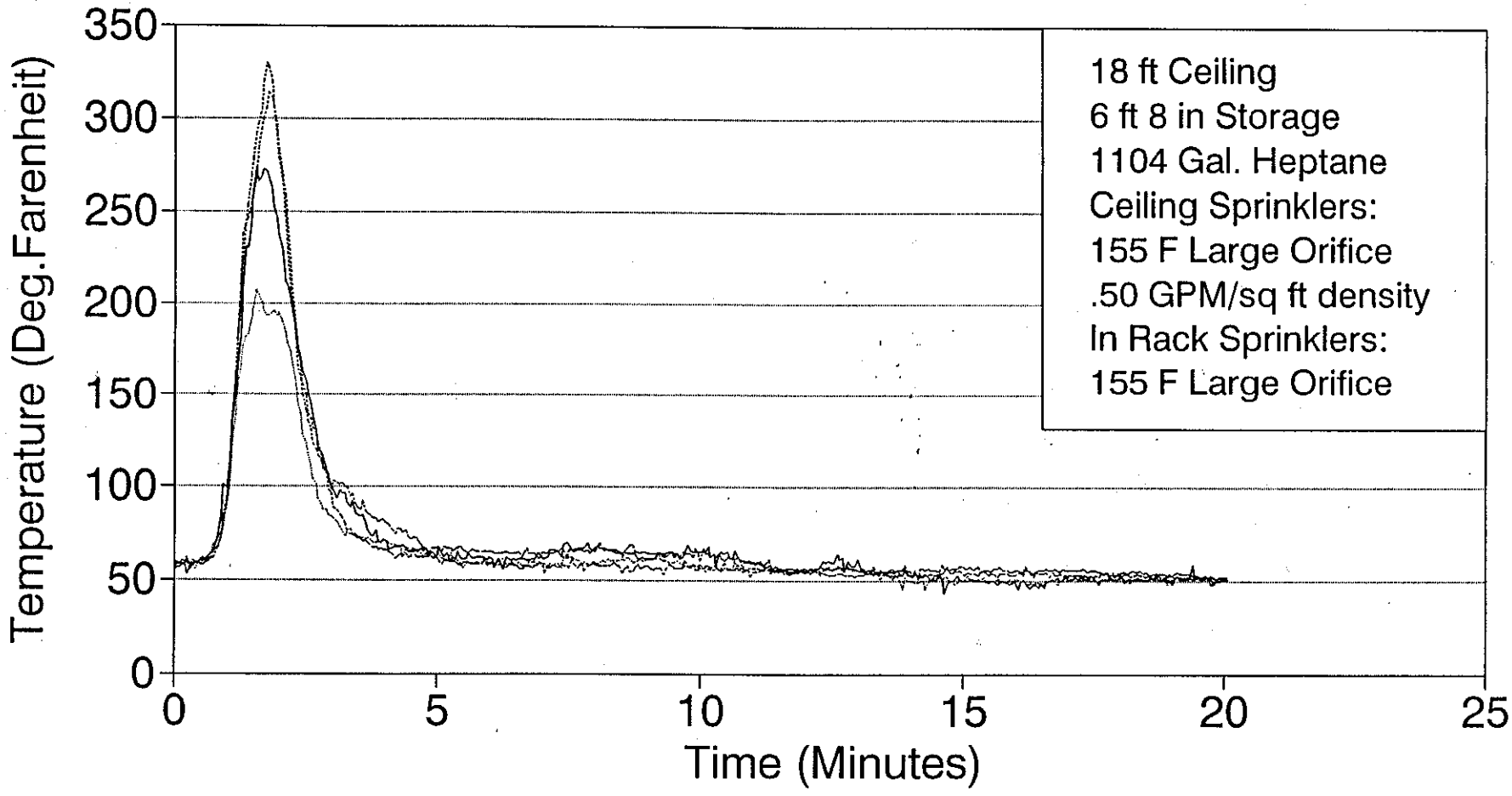
NFPRF RACK FIRE TEST NO. 4

Wood Sticker Shelves,In Rack Sprinklers



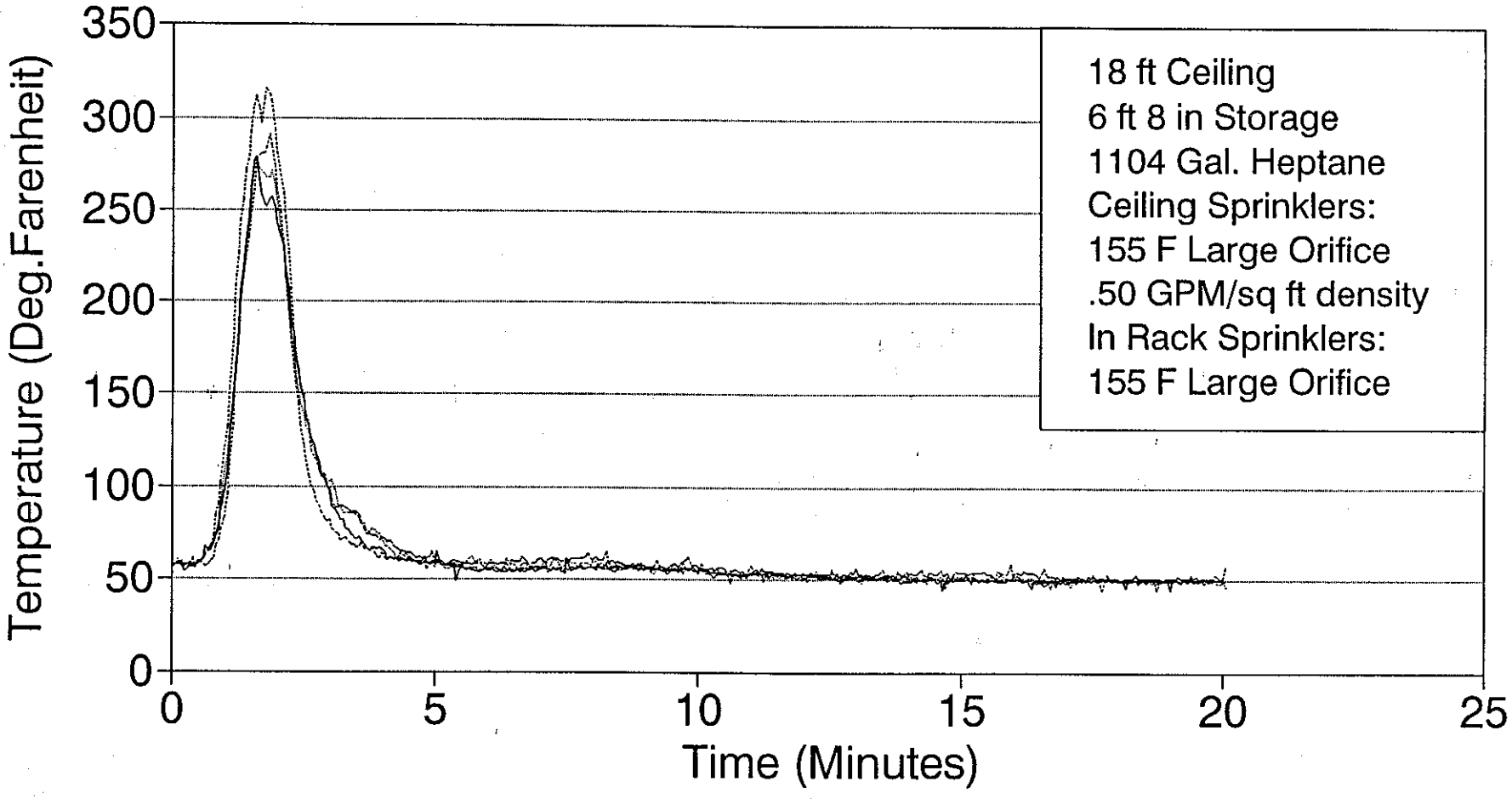
NFPRF RACK FIRE TEST NO. 4

Ceiling Temperatures



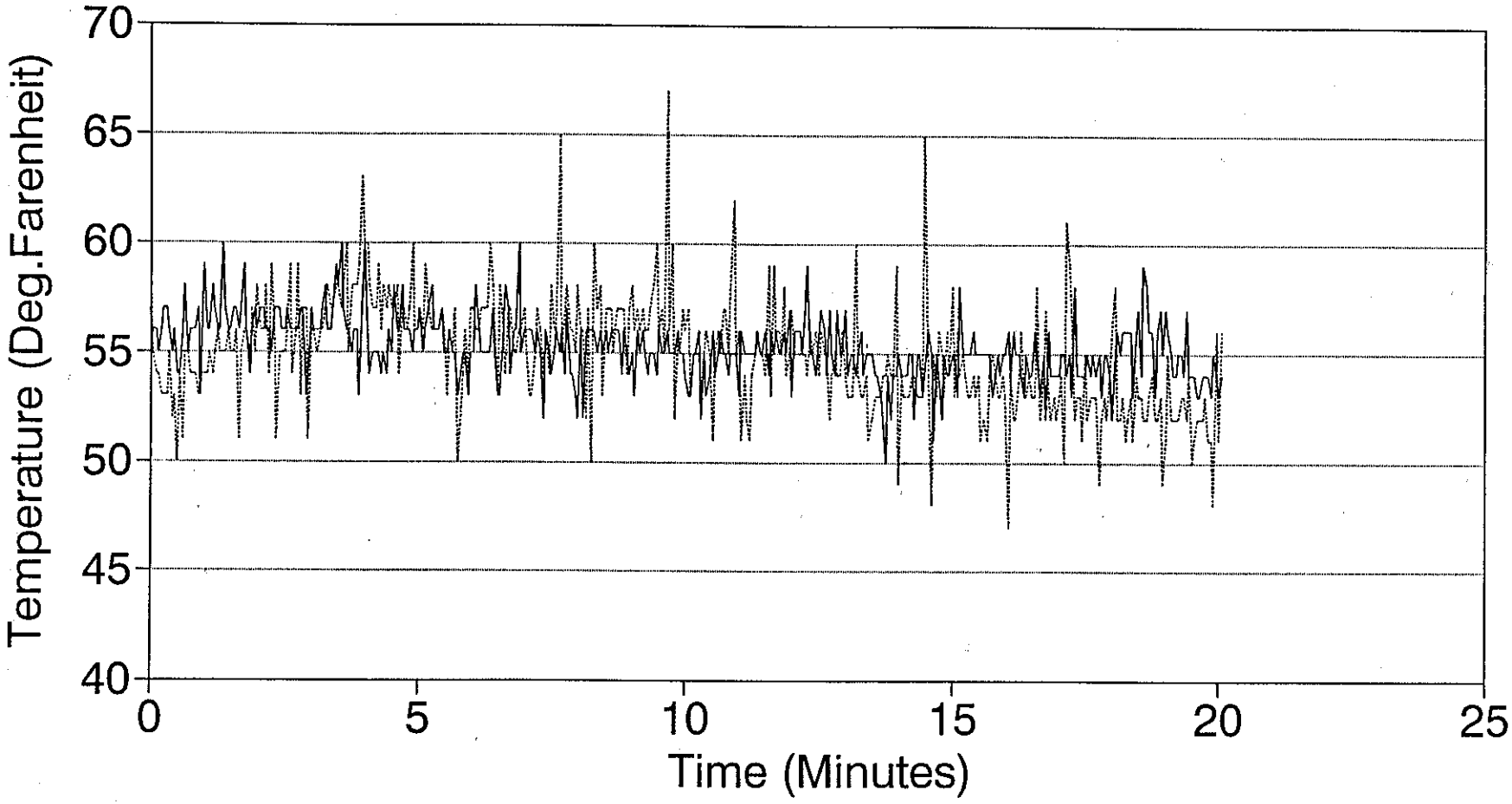
NFPRF RACK FIRE TEST NO. 4

Ceiling Temperatures



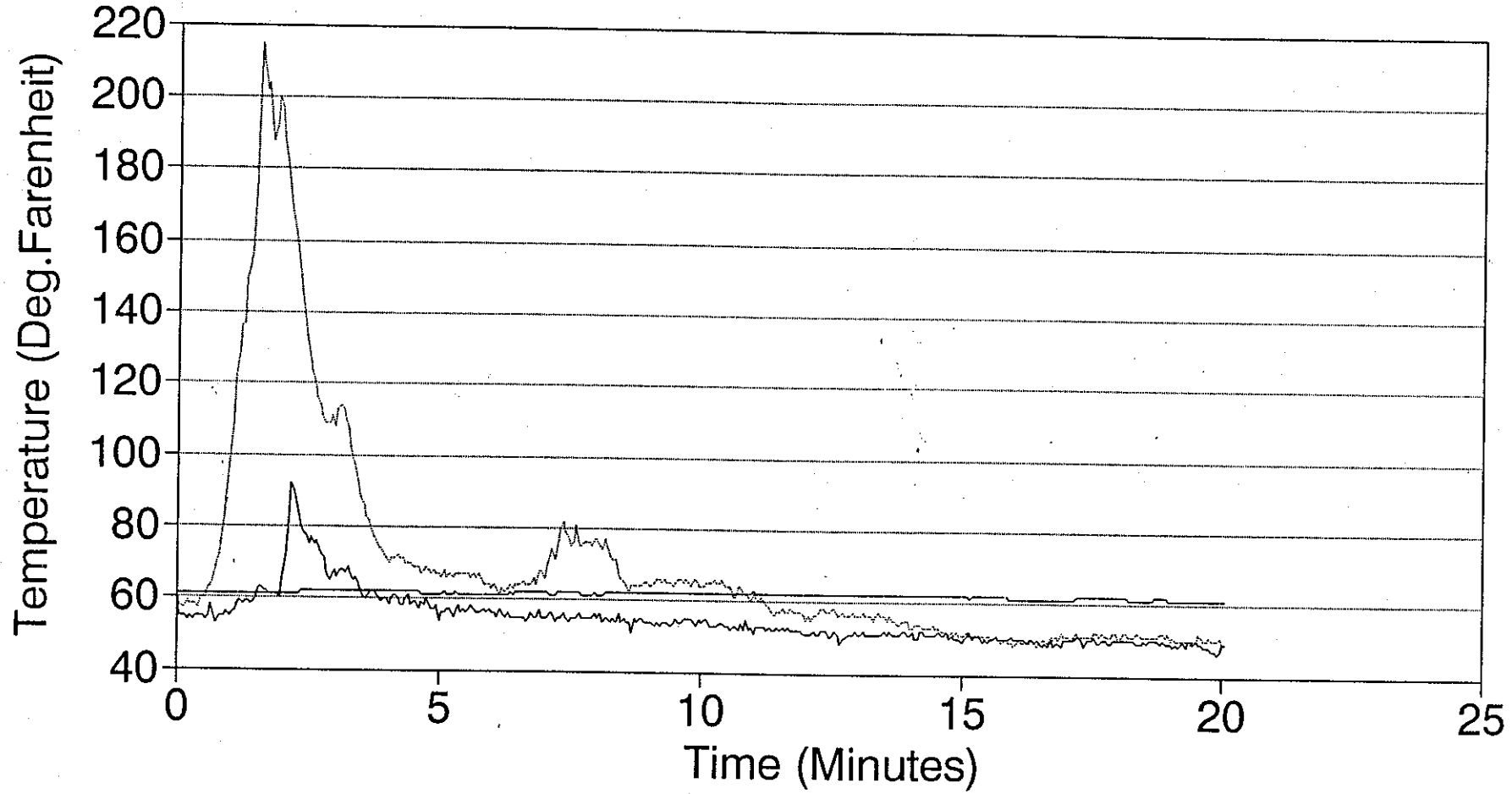
NFPRF RACK FIRE TEST NO. 4

Perimeter Temperatures



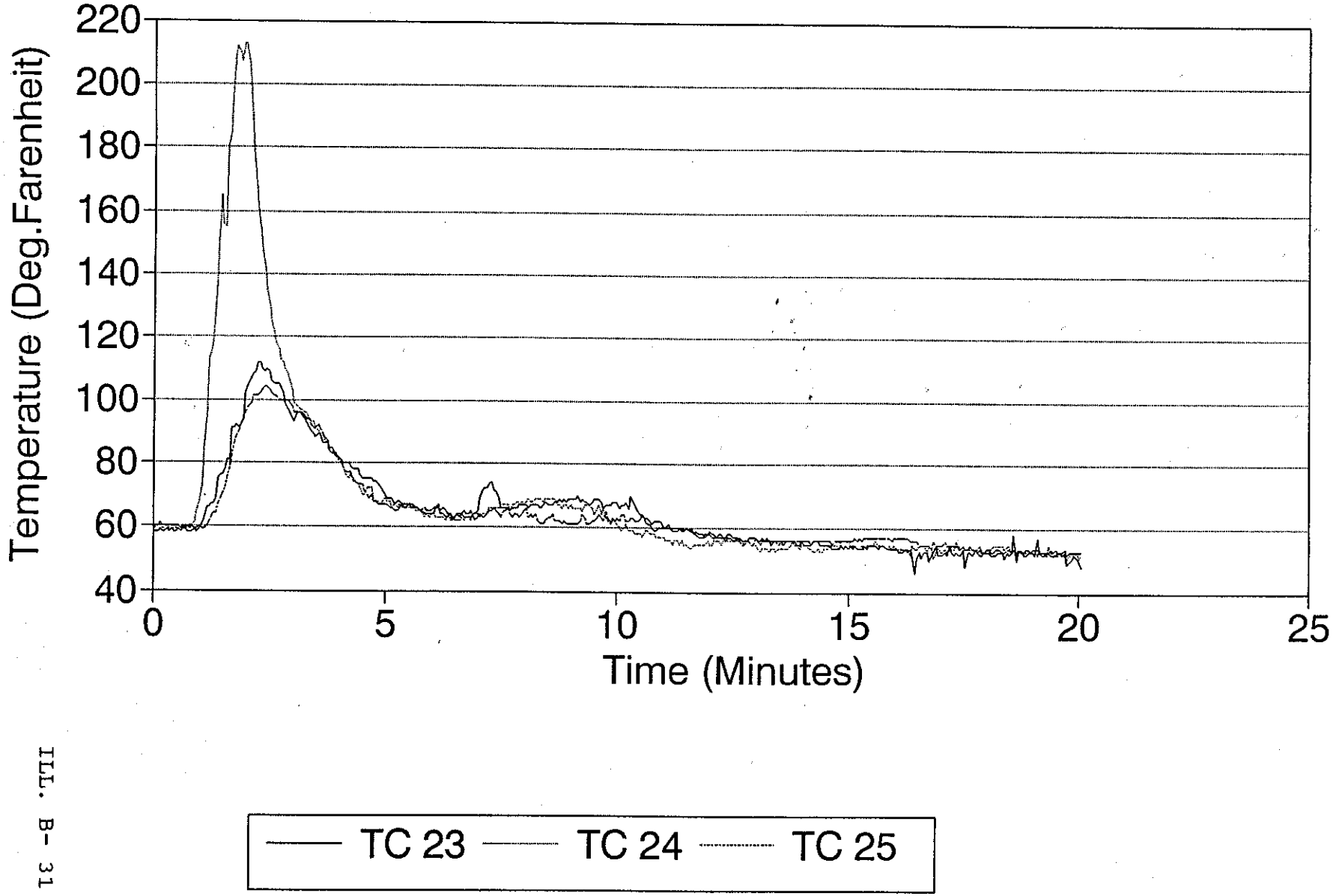
NFPRF RACK FIRE TEST NO. 4

Perimeter Temperatures



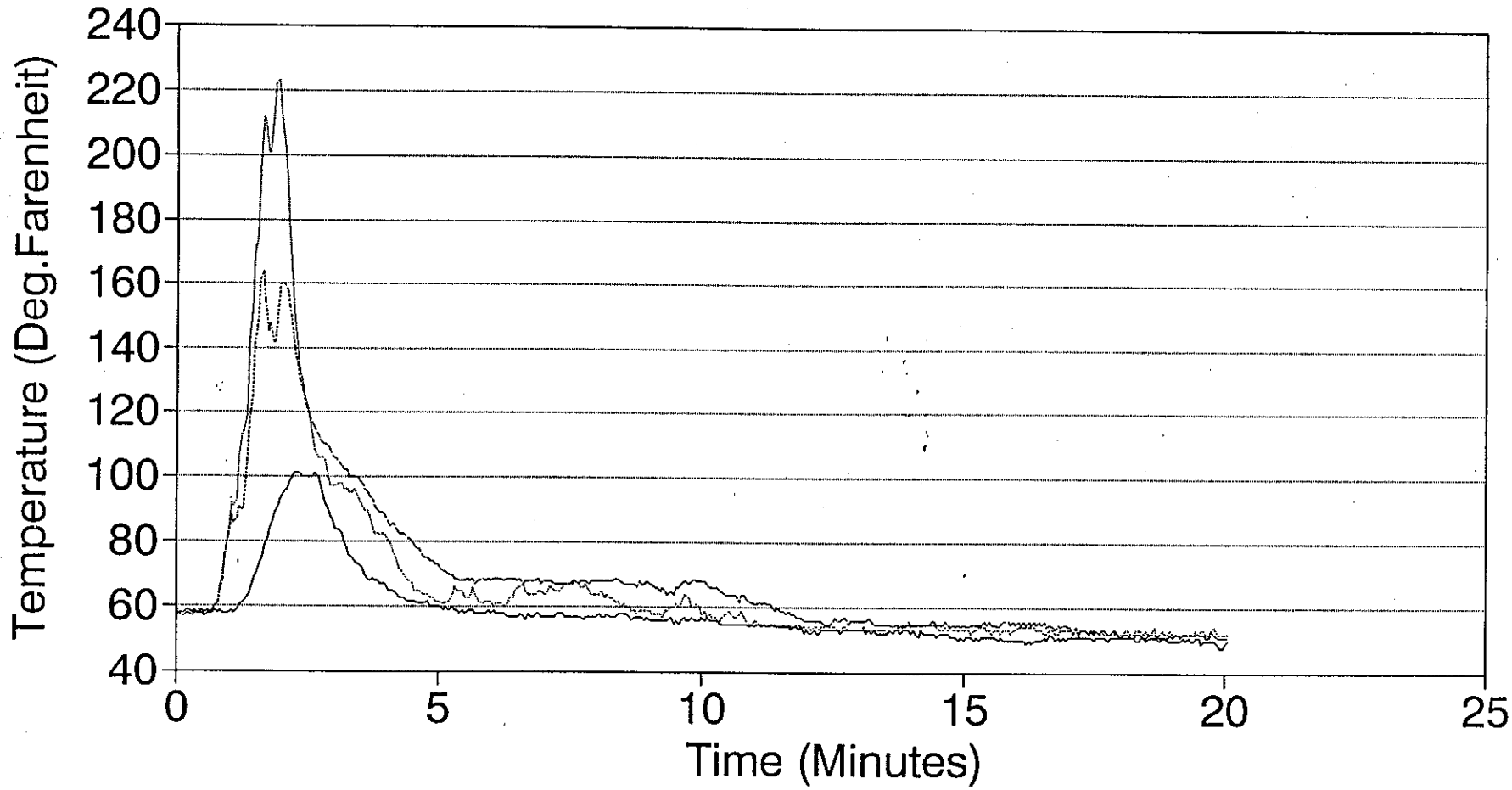
NFPRF RACK FIRE TEST NO. 4

Perimeter Temperatures



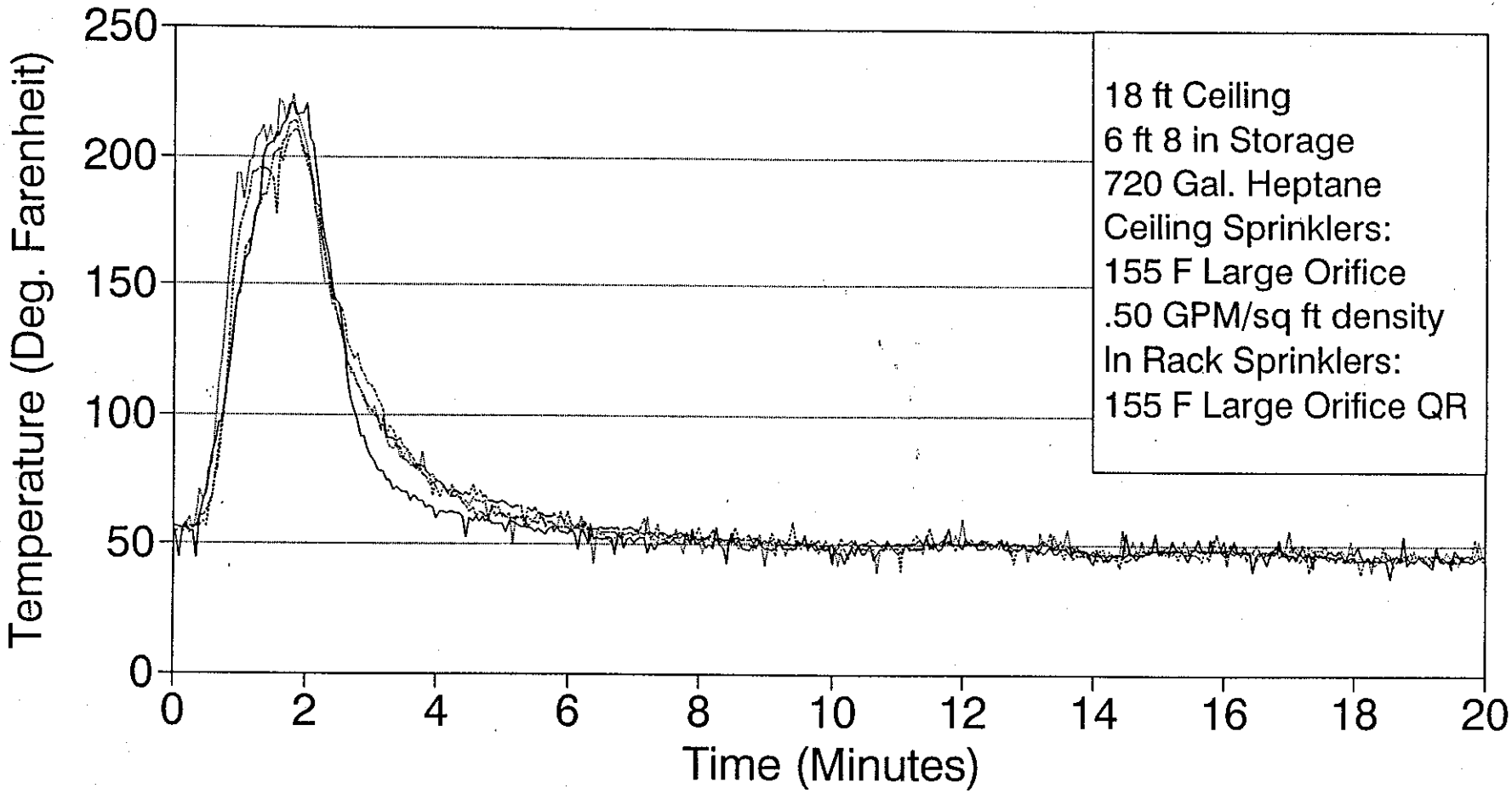
NFPRF RACK FIRE TEST NO. 4

Perimeter Temperatures



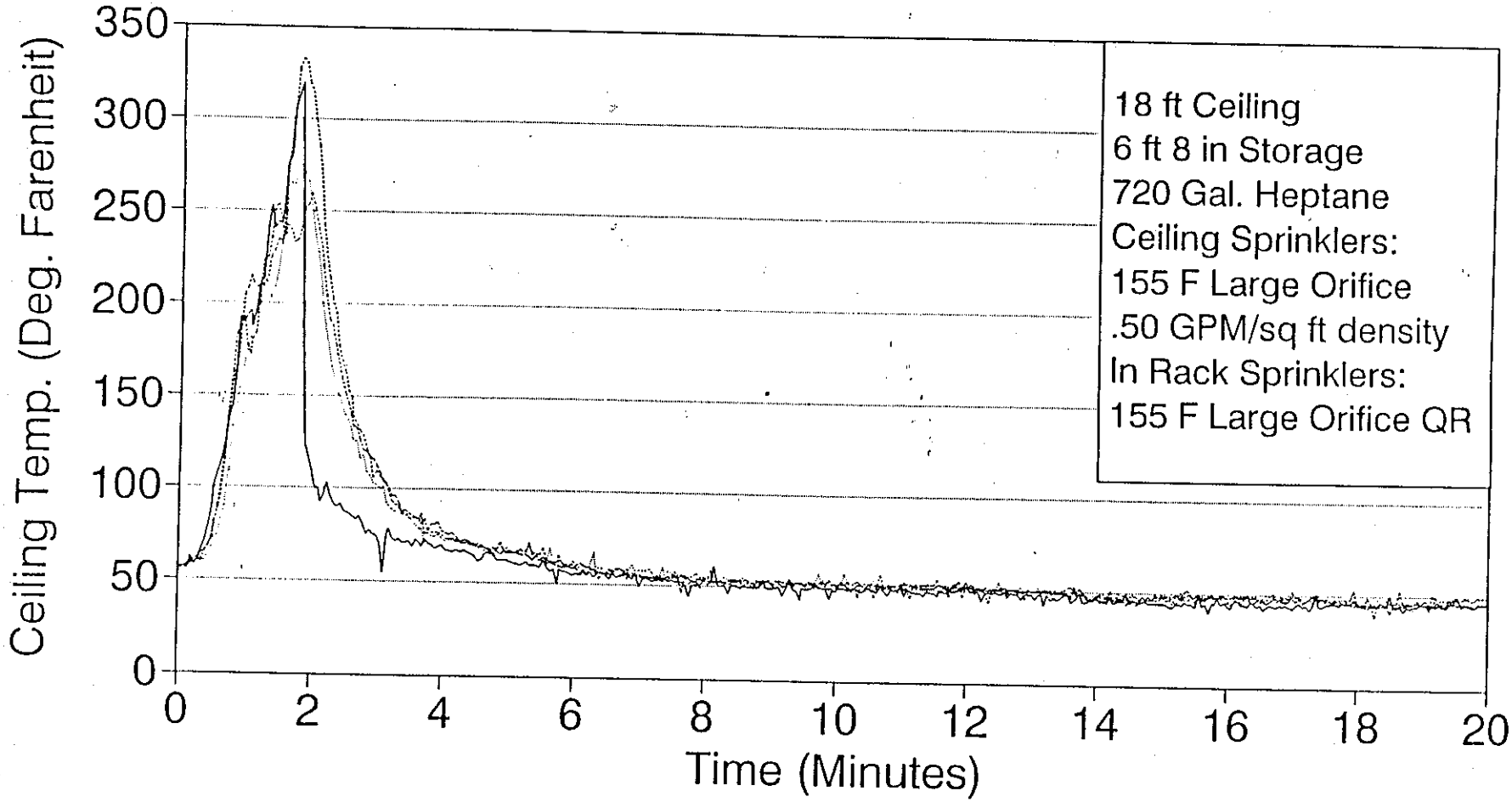
NFPRF RACK FIRE TEST NO. 5

Ceiling Temperatures



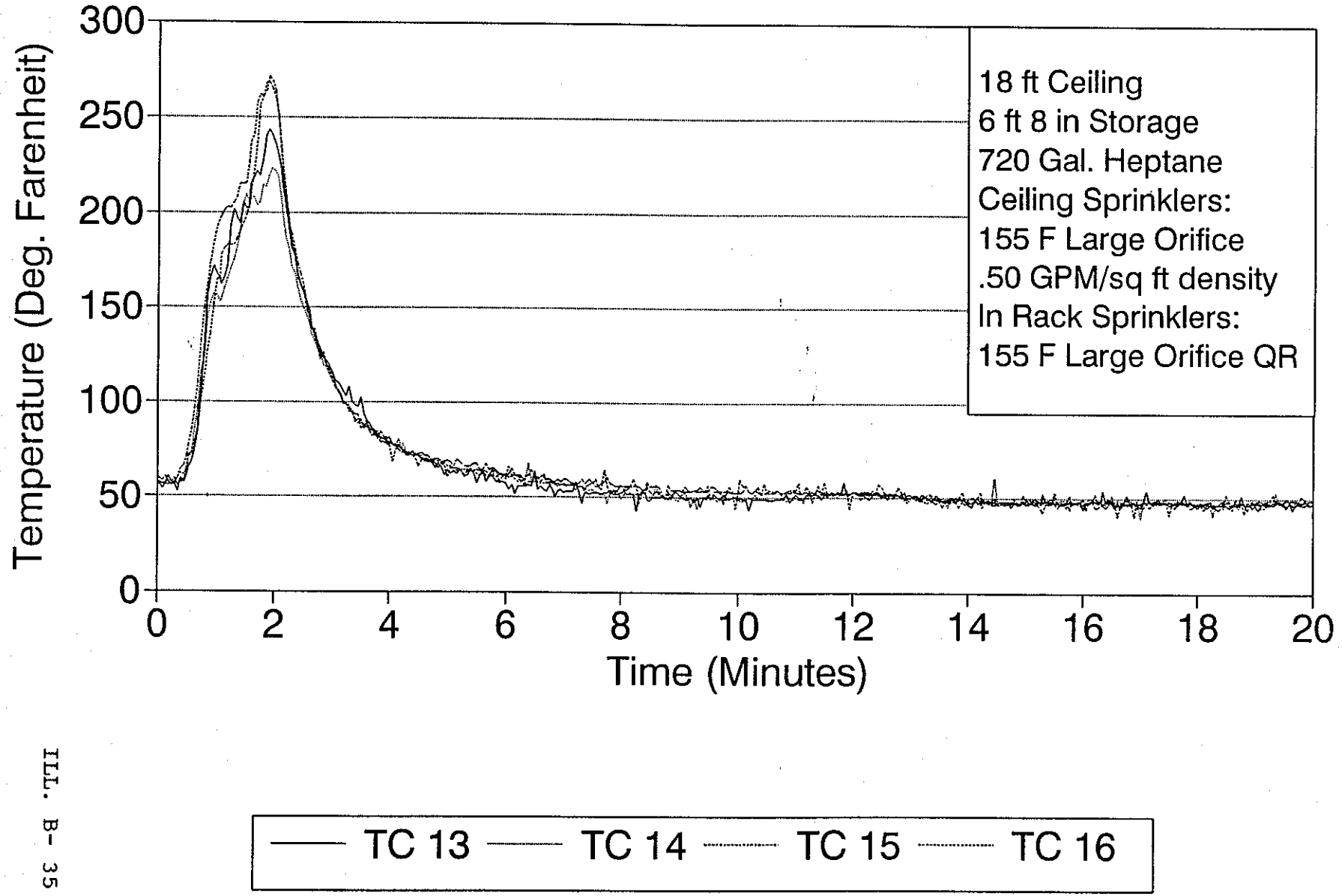
NFPRF RACK FIRE TEST NO. 5

Wood Sticker Shelves,In Rack Sprinklers



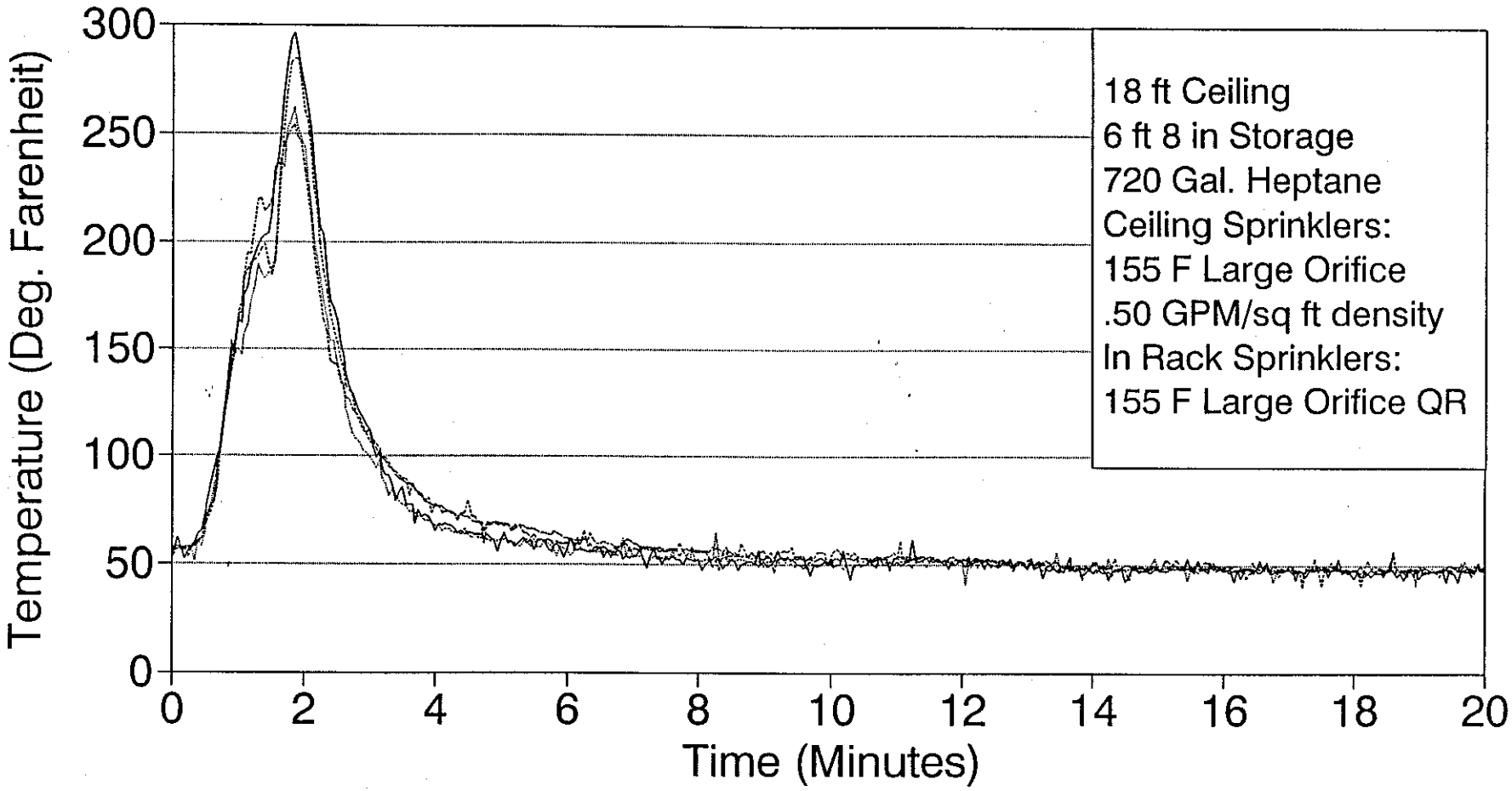
NFPRF RACK FIRE TEST NO. 5

Ceiling Temperatures



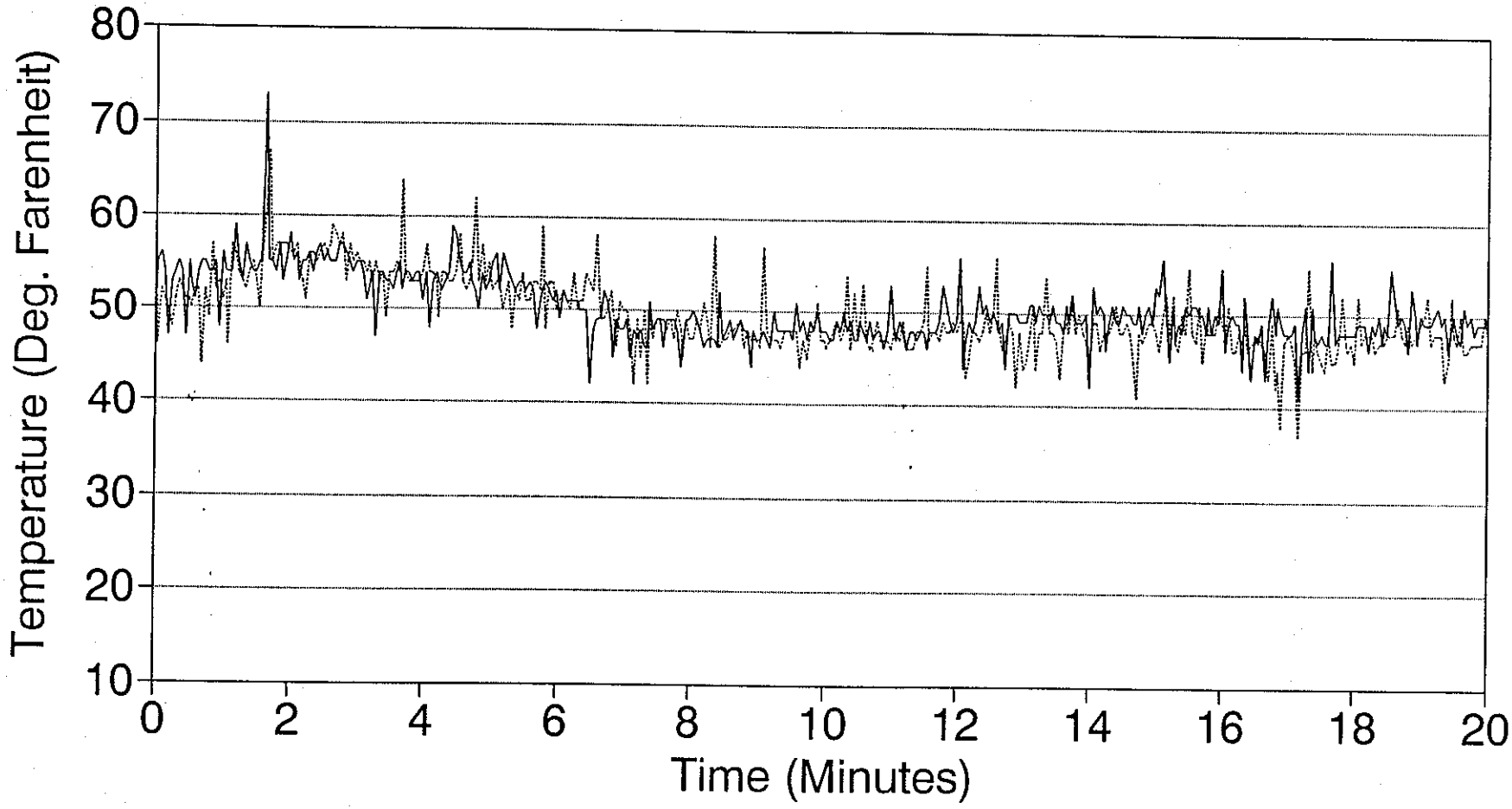
NFPRF RACK FIRE TEST NO. 5

Ceiling Temperatures



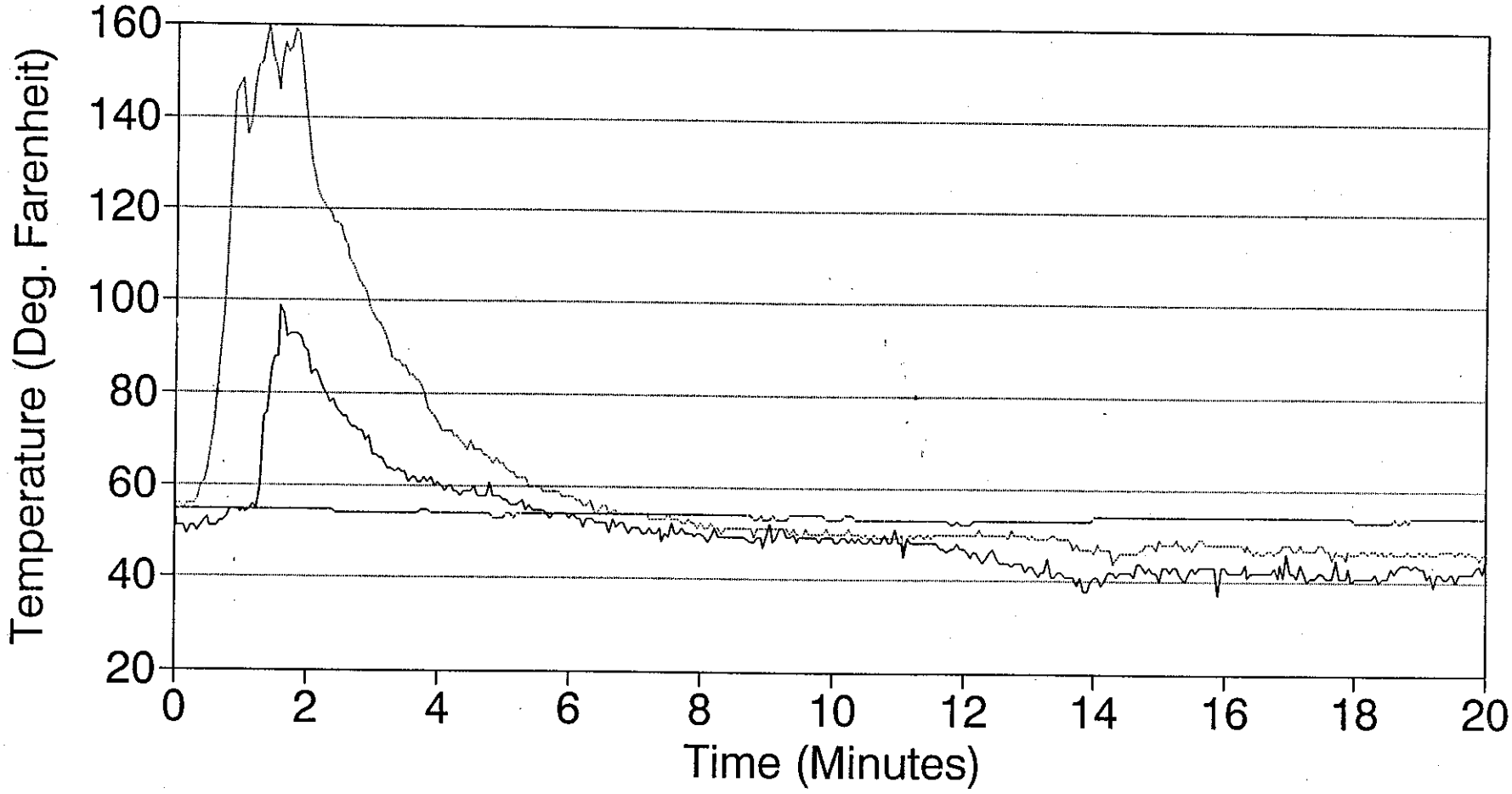
NFPRF RACK FIRE TEST NO. 5

Perimeter Temperatures



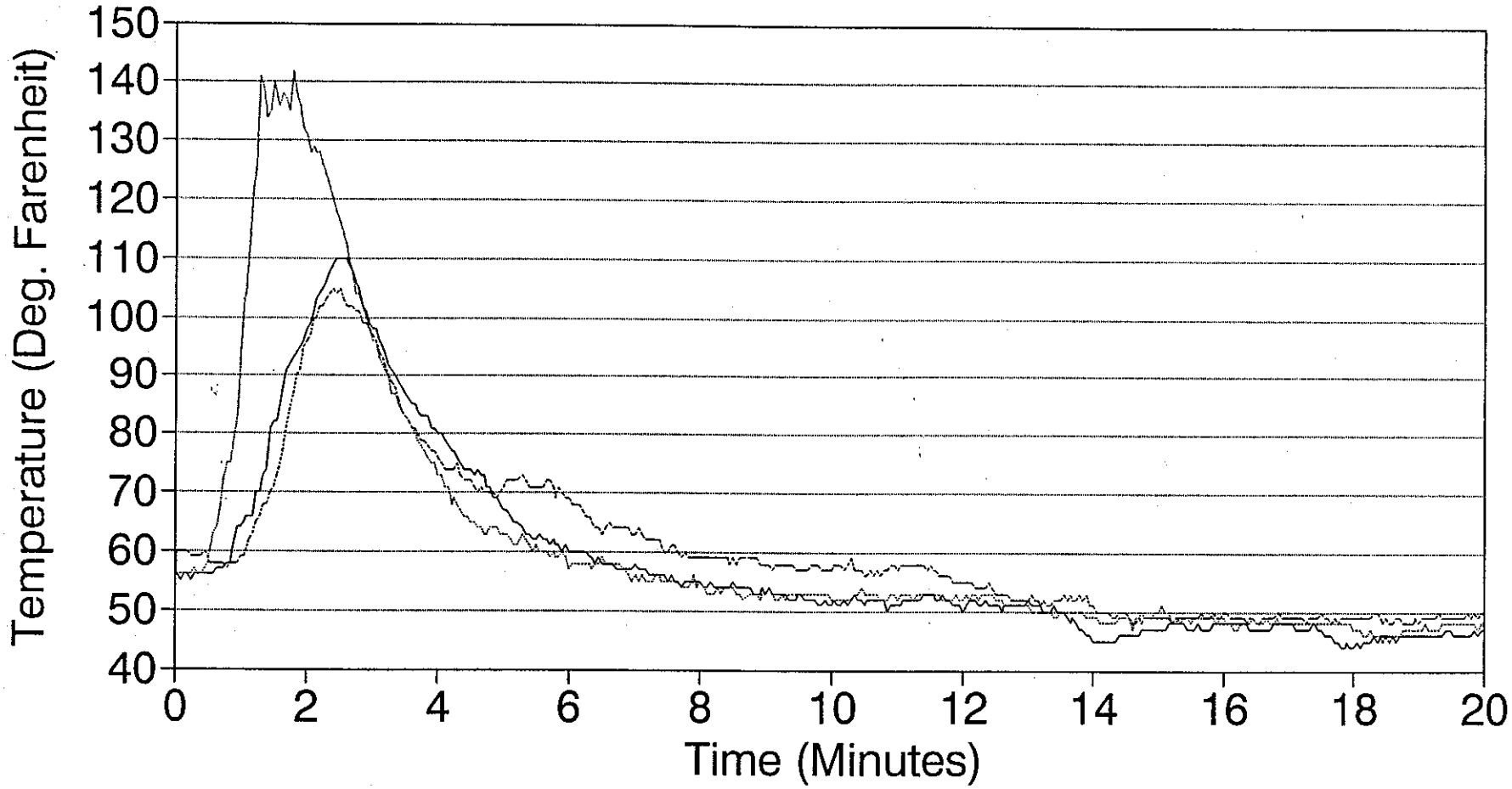
NFPRF RACK FIRE TEST NO. 5

Perimeter Temperatures



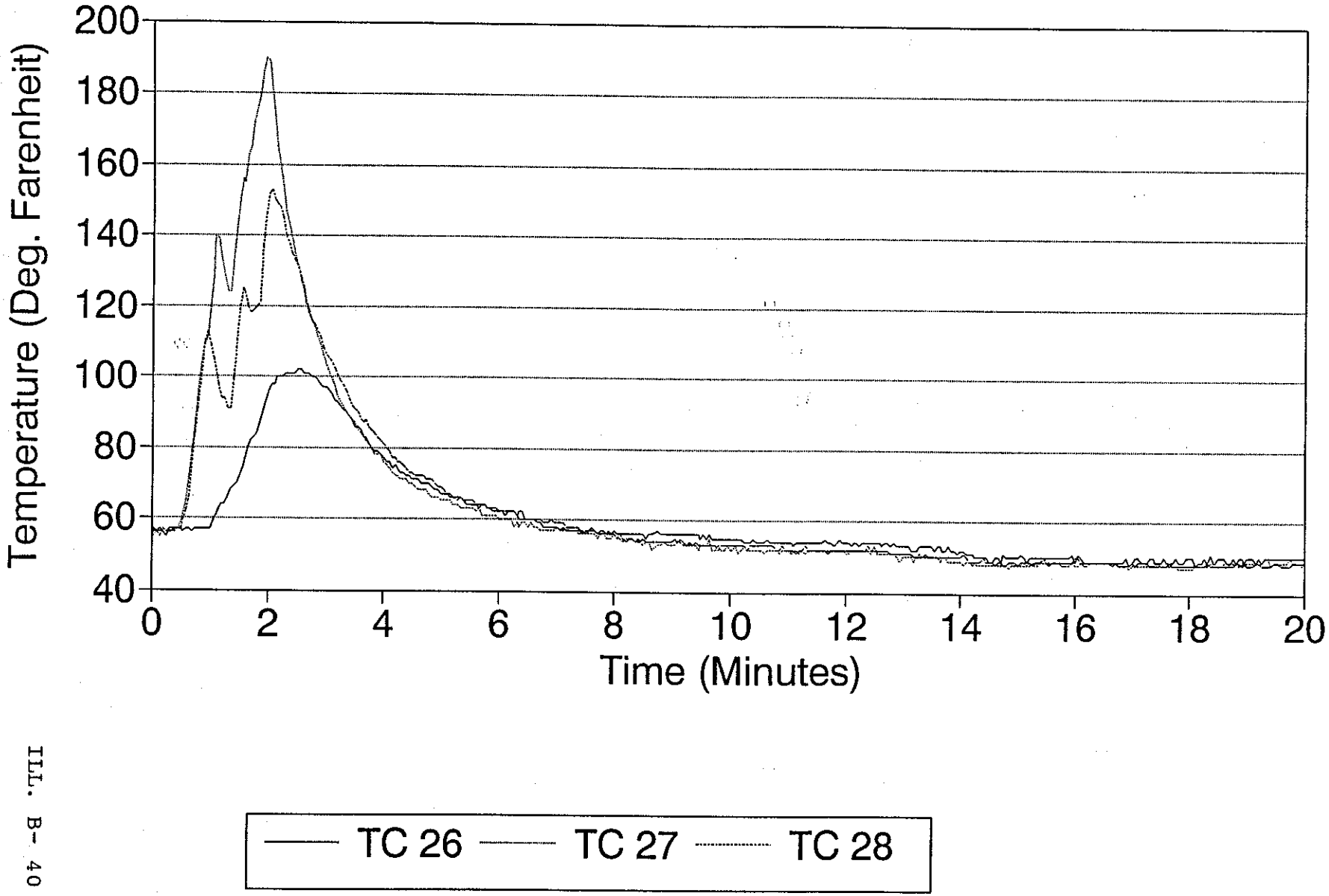
NFPRF RACK FIRE TEST NO. 5

Perimeter Temperatures



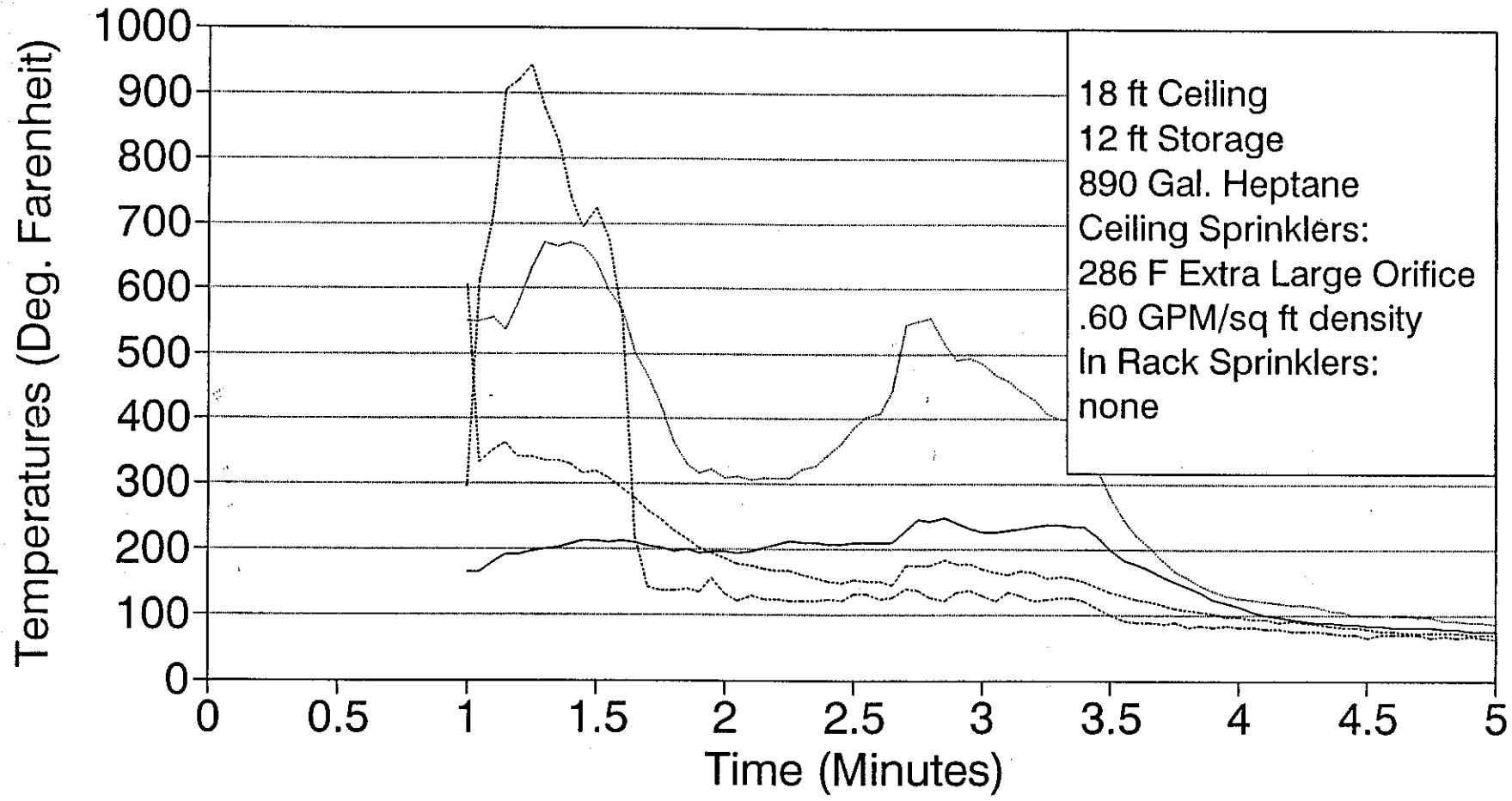
NFPRF RACK FIRE TEST NO. 5

Perimeter Temperatures



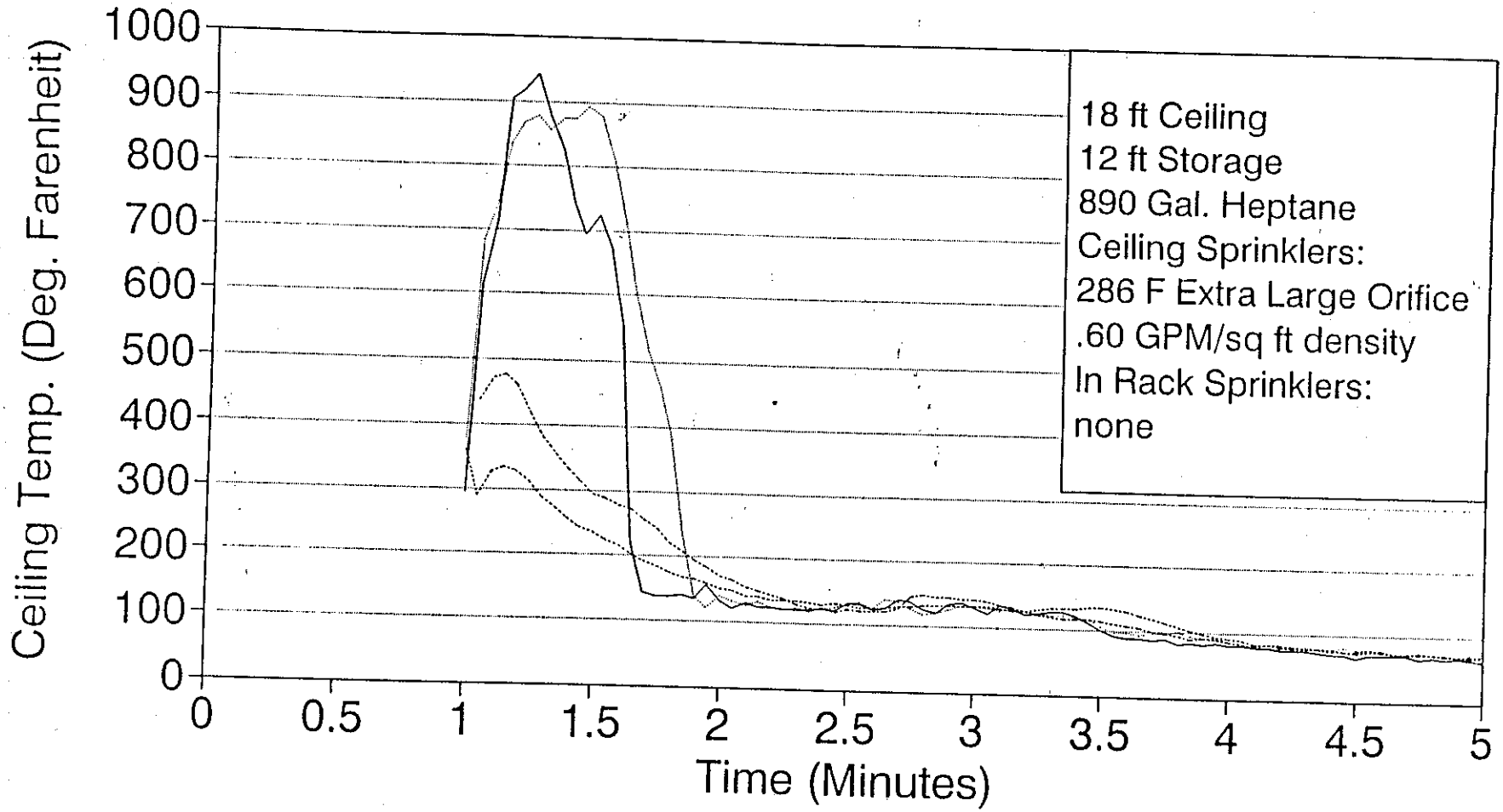
NFPRF RACK FIRE TEST NO. 6

Ceiling Temperatures



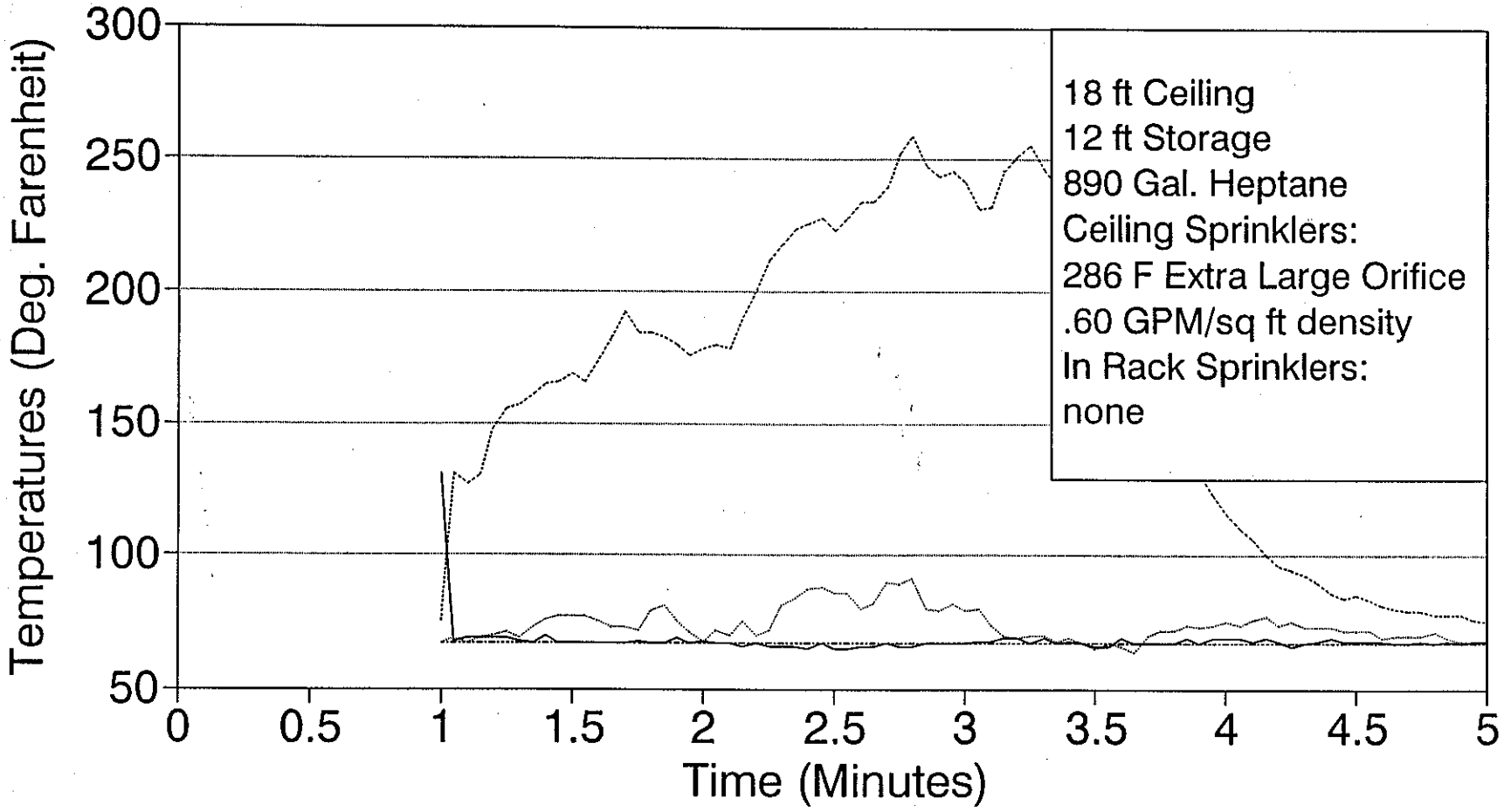
NFPRF RACK FIRE TEST NO. 6

Wire Shelf, Ceiling Sprinklers



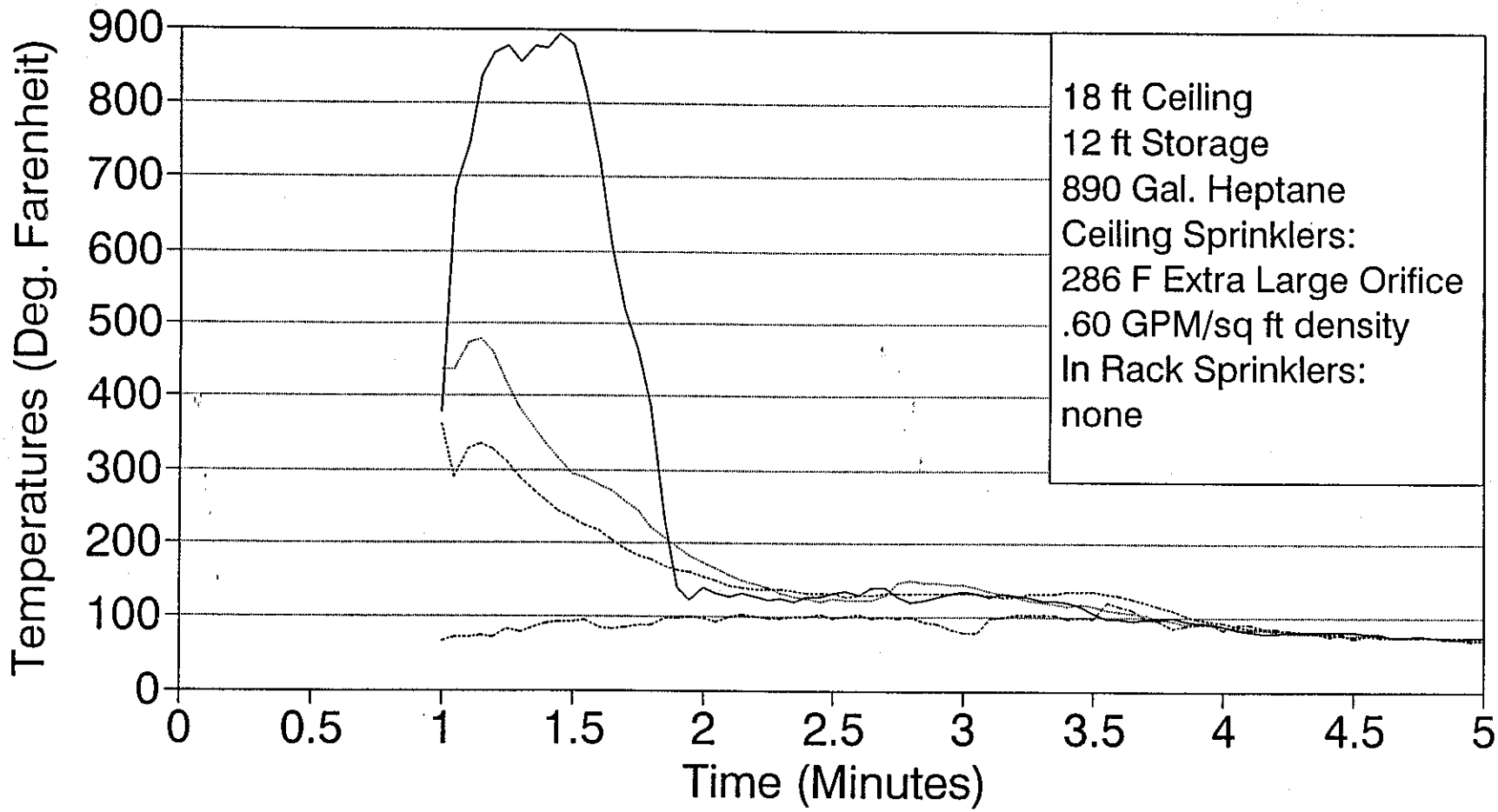
NFPRF RACK FIRE TEST NO. 6

Ceiling Temperatures



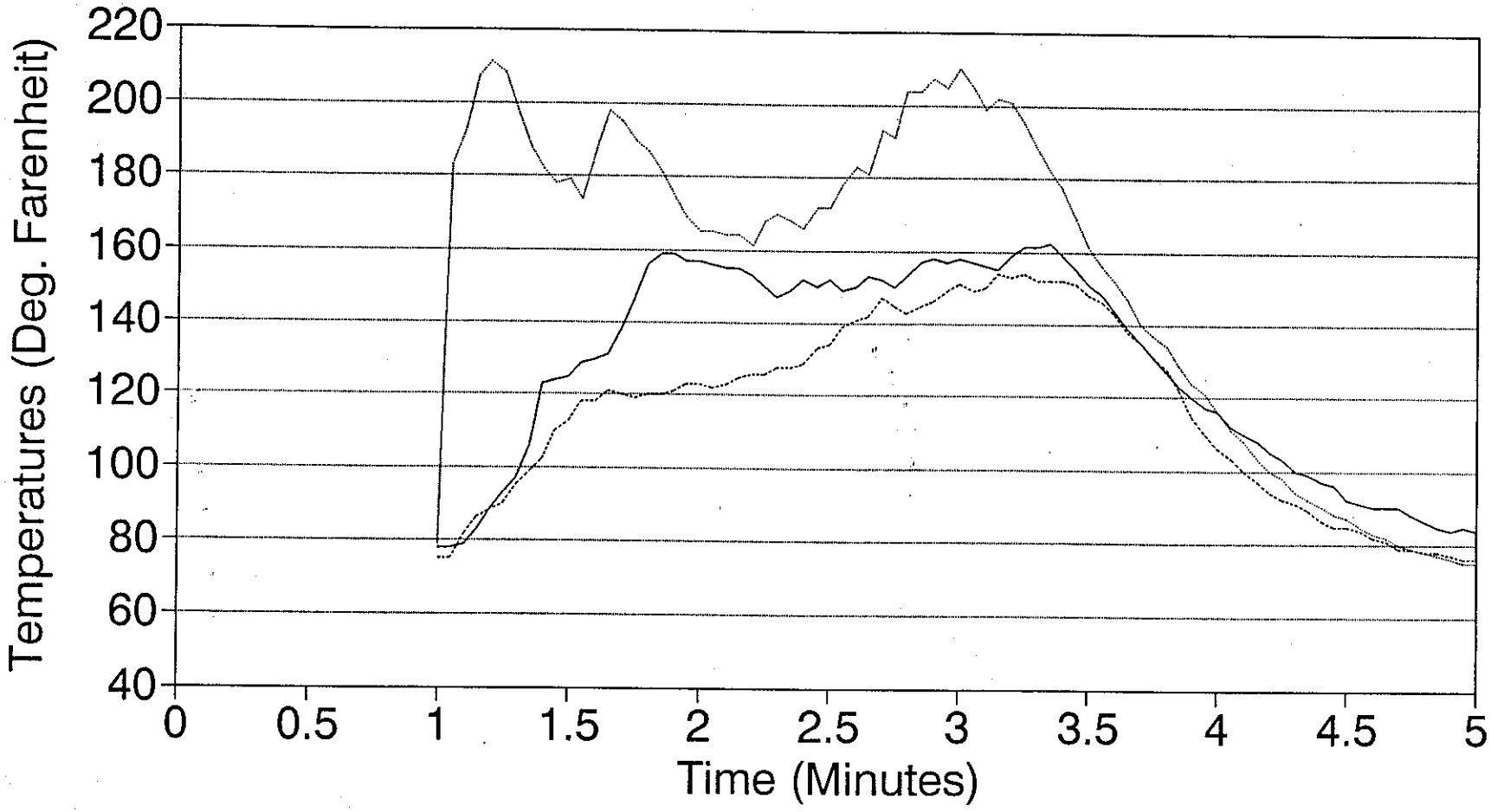
NFPRF RACK FIRE TEST NO. 6

Ceiling Temperatures



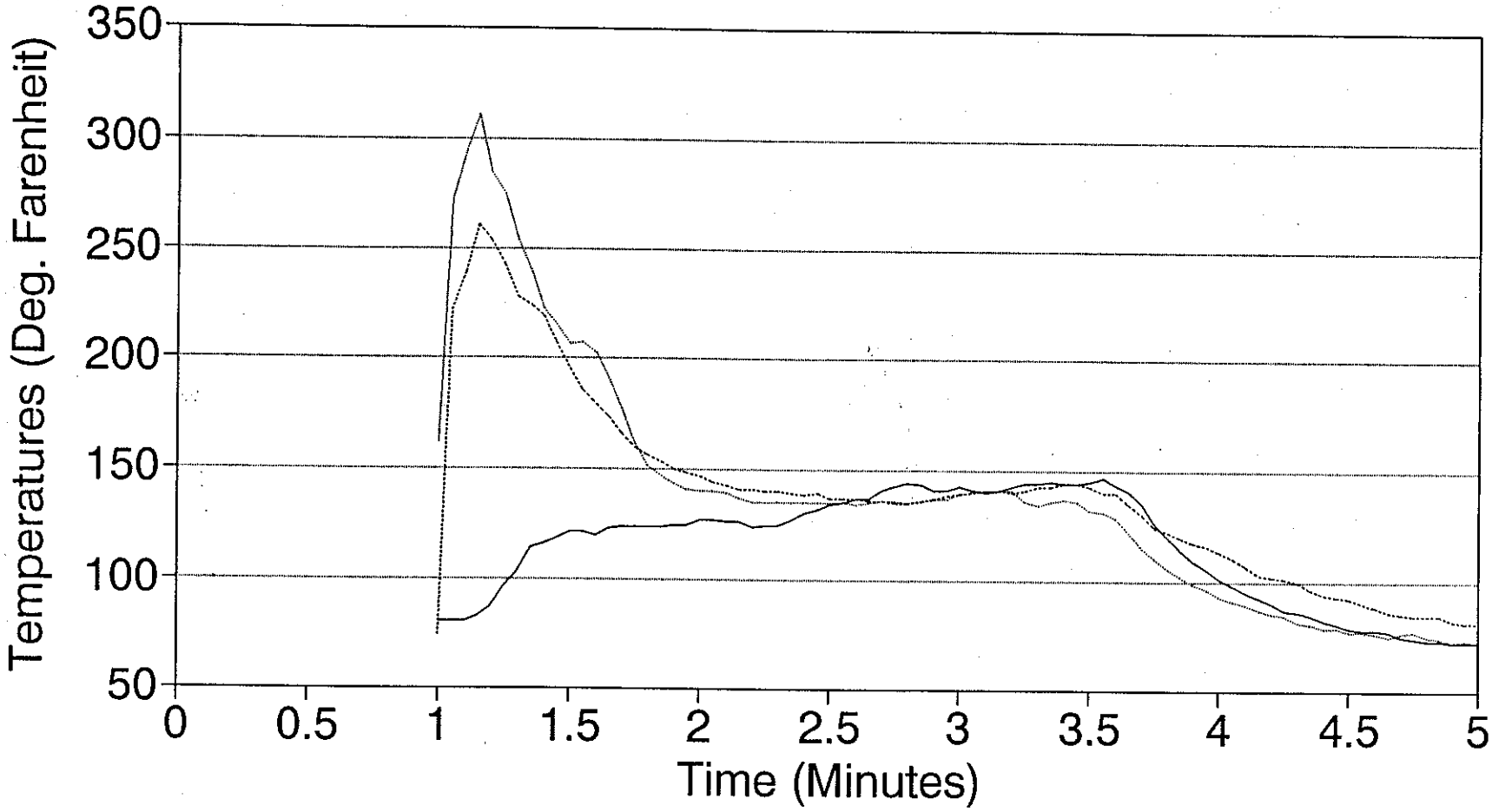
NFPRF RACK FIRE TEST NO. 6

Perimeter Temperatures



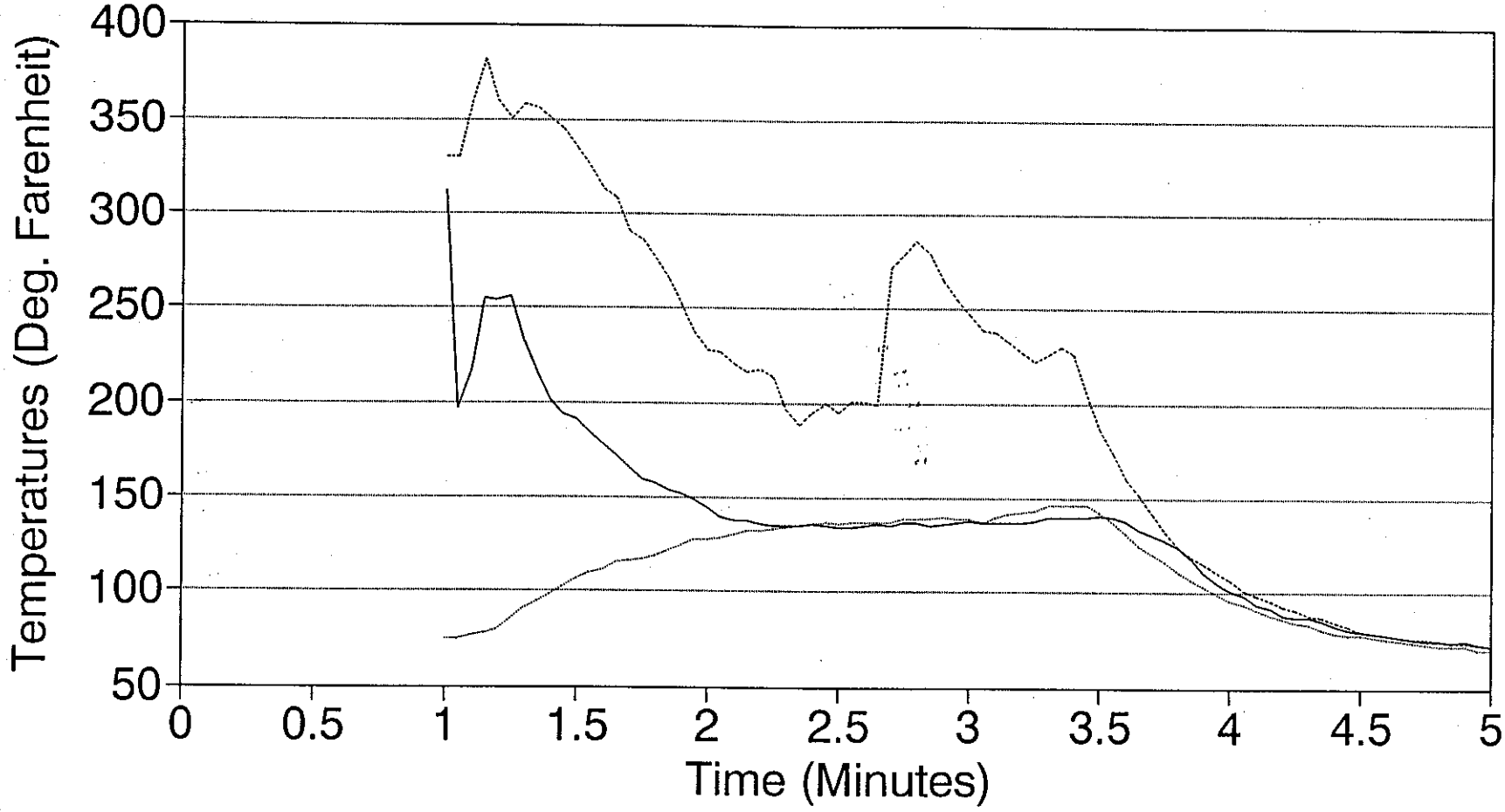
NFPRF RACK FIRE TEST NO. 6

Perimeter Temperatures



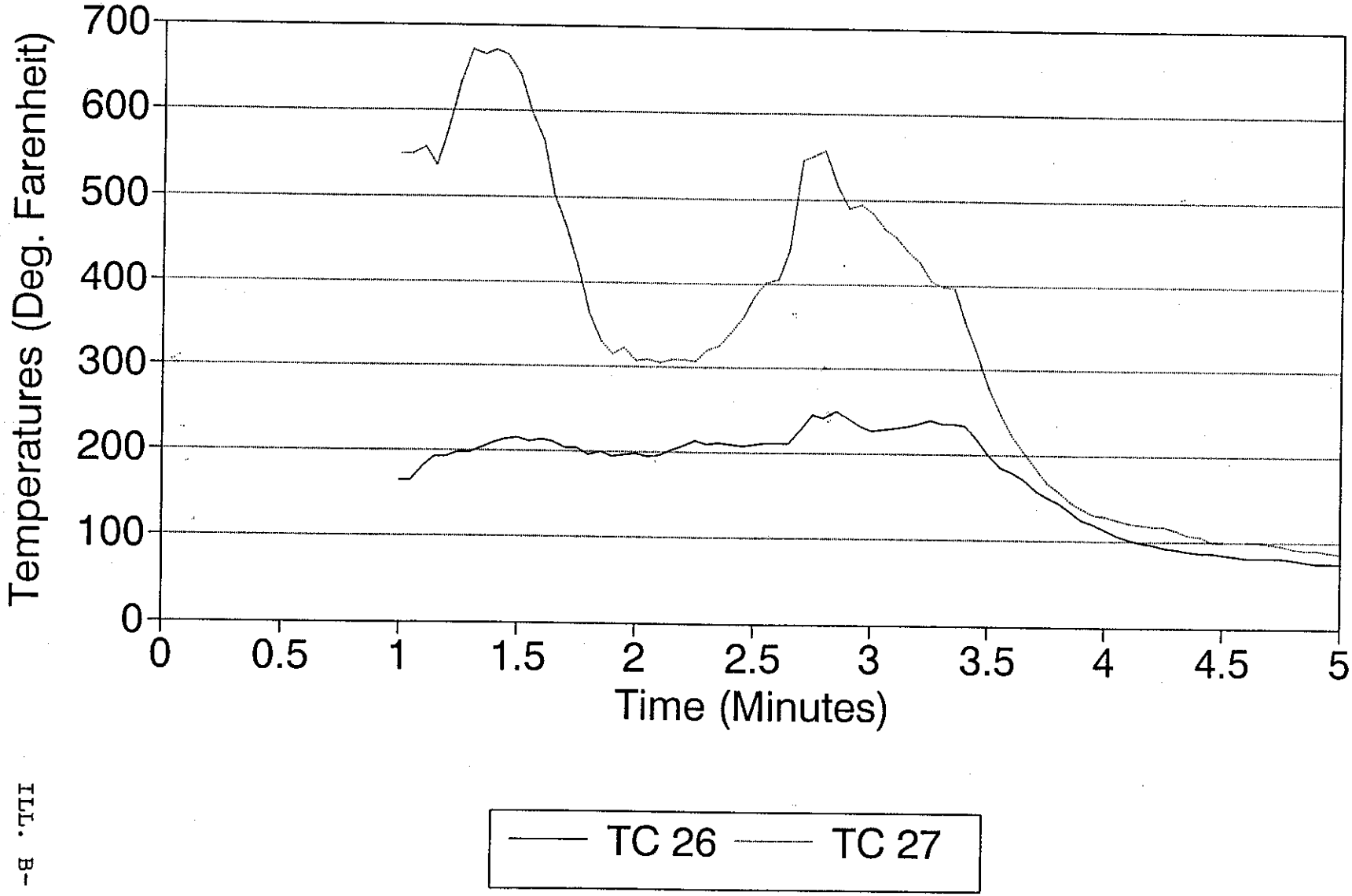
NFPRF RACK FIRE TEST NO. 6

Perimeter Temperatures



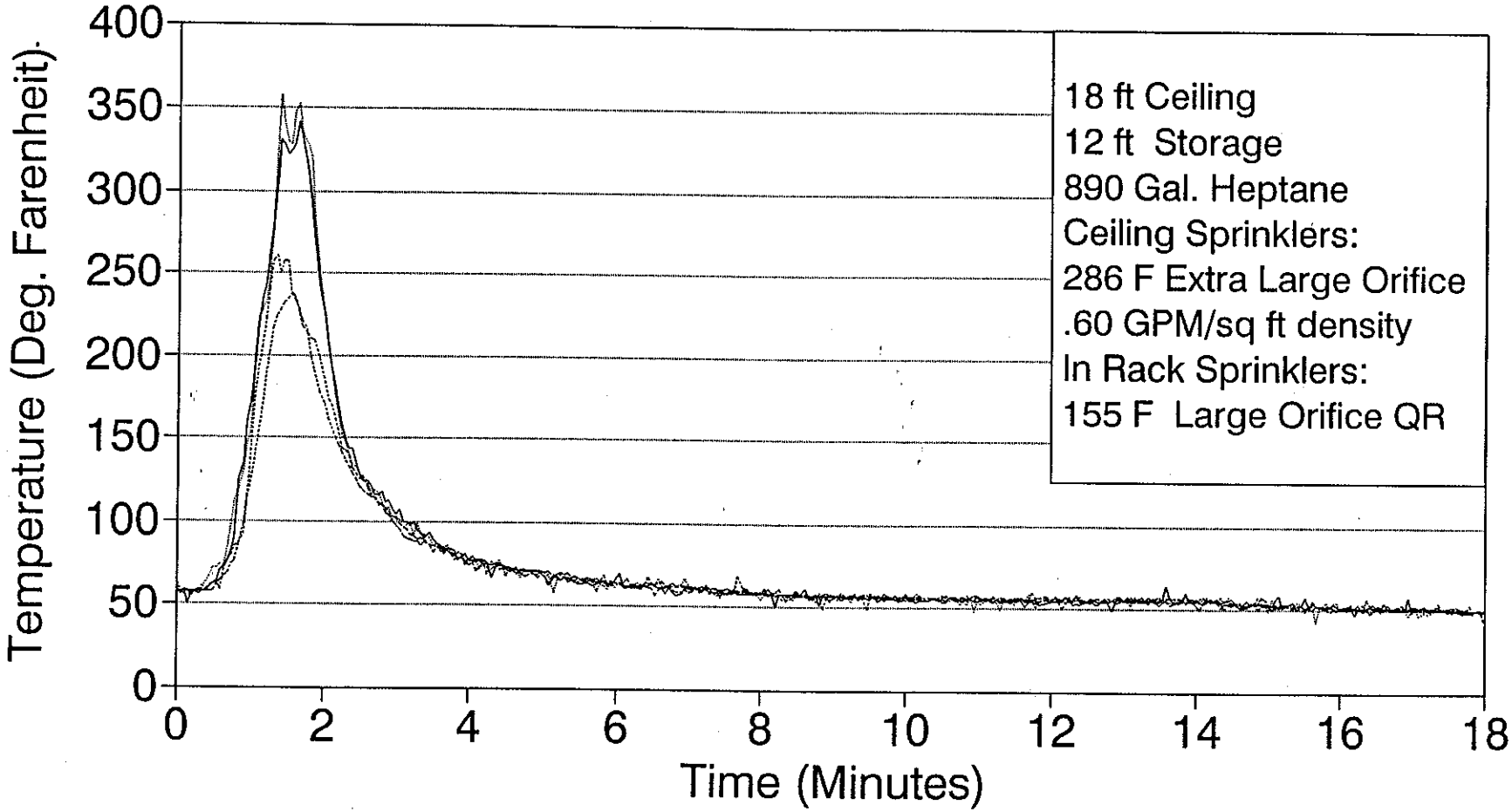
NFPRF RACK FIRE TEST NO. 6

Perimeter Temperatures



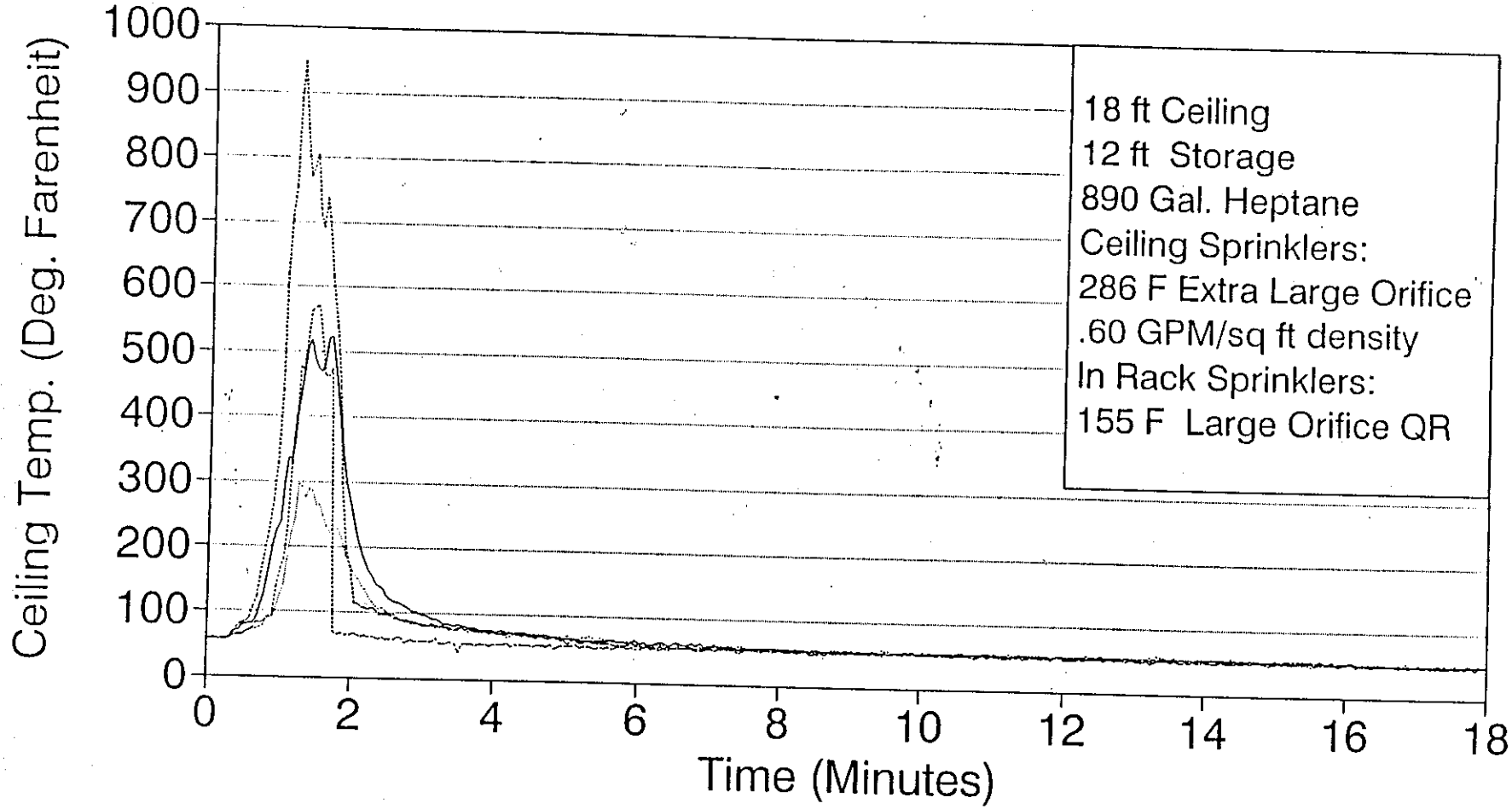
NFPRF RACK FIRE TEST NO.7

Ceiling Temperatures



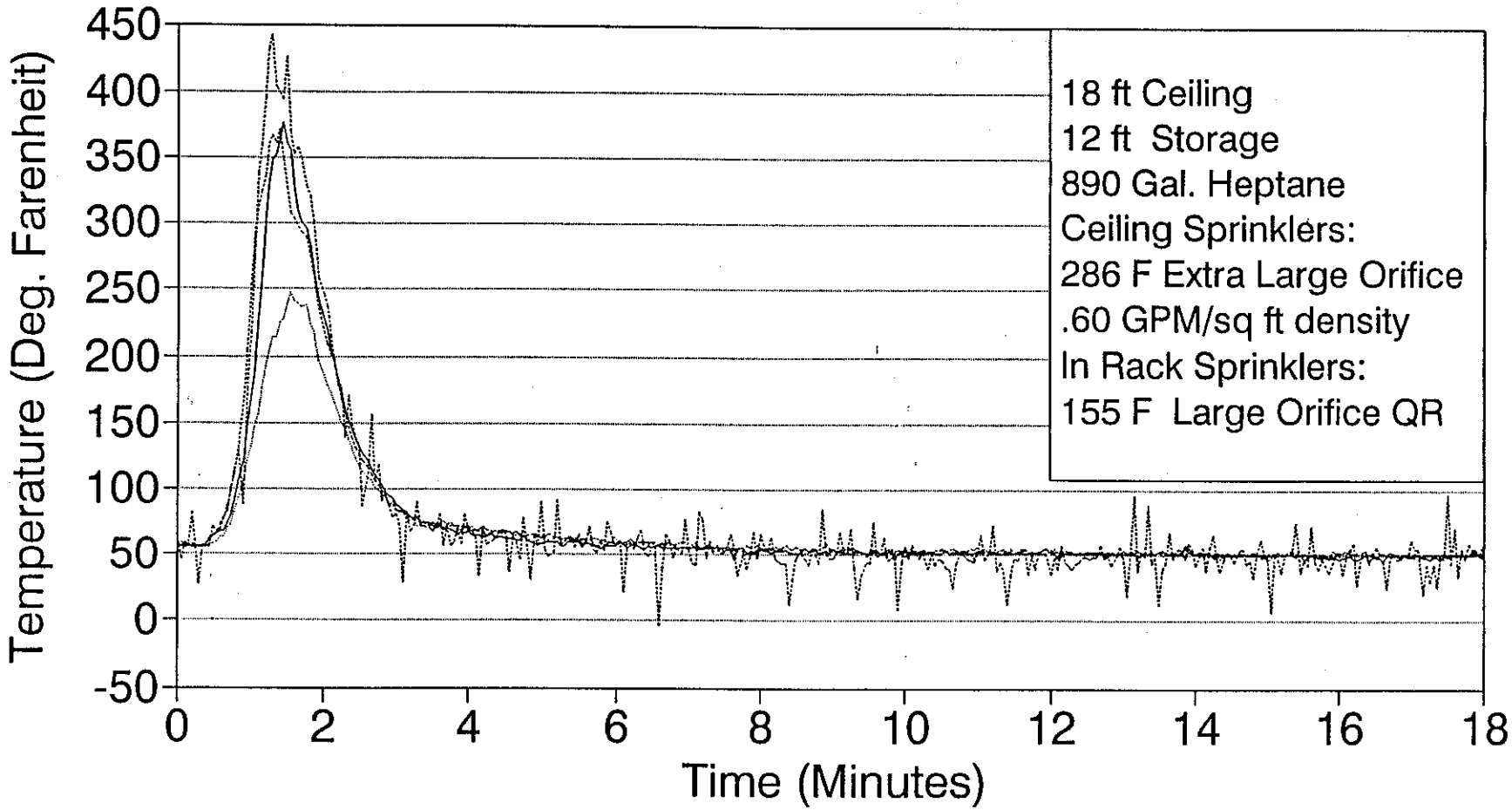
NFPRF RACK FIRE TEST NO.7

Wire Shelf, In Rack Sprinklers



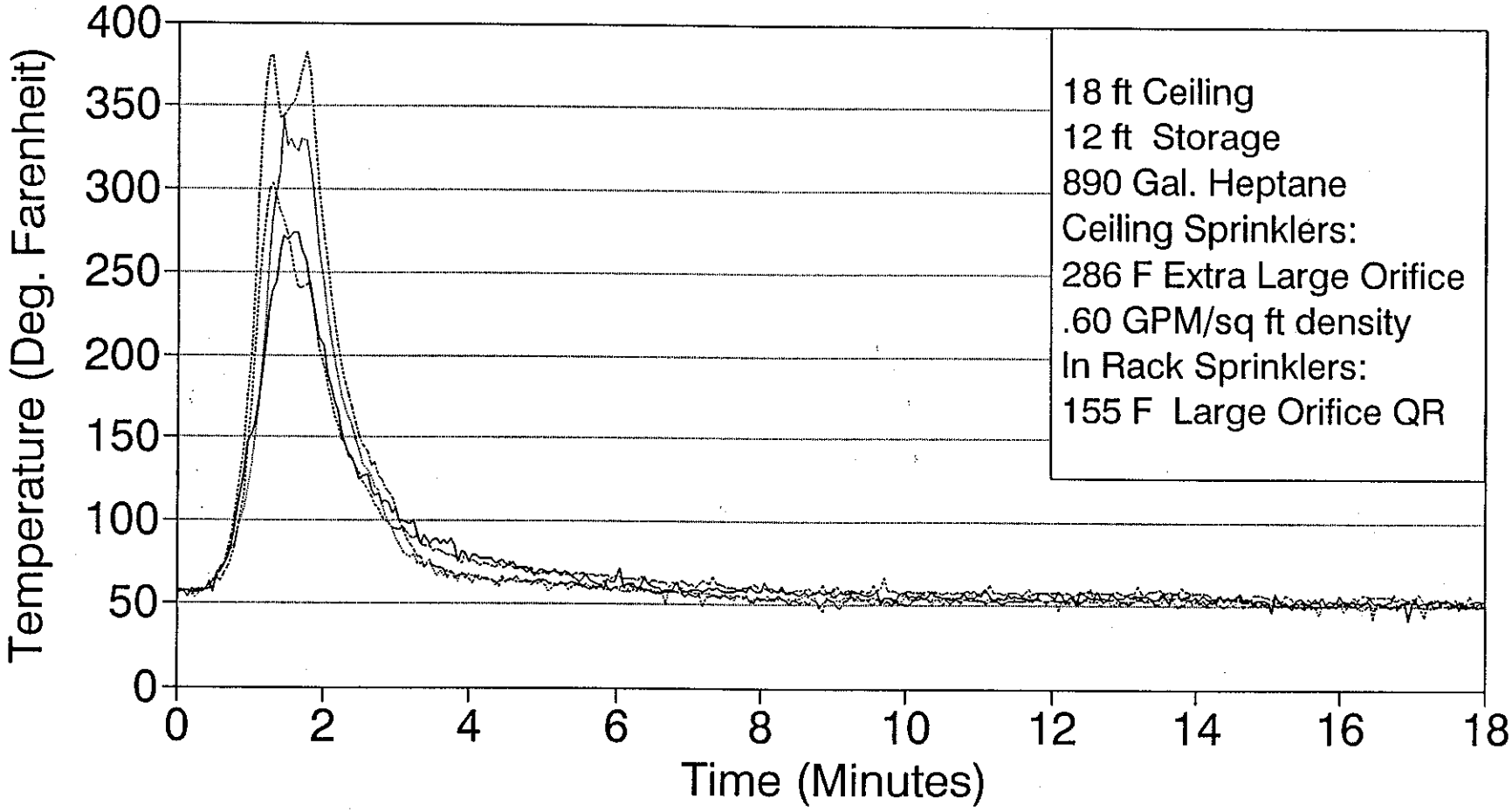
NFPRF RACK FIRE TEST NO.7

Ceiling Temperatures



NFPRF RACK FIRE TEST NO.7

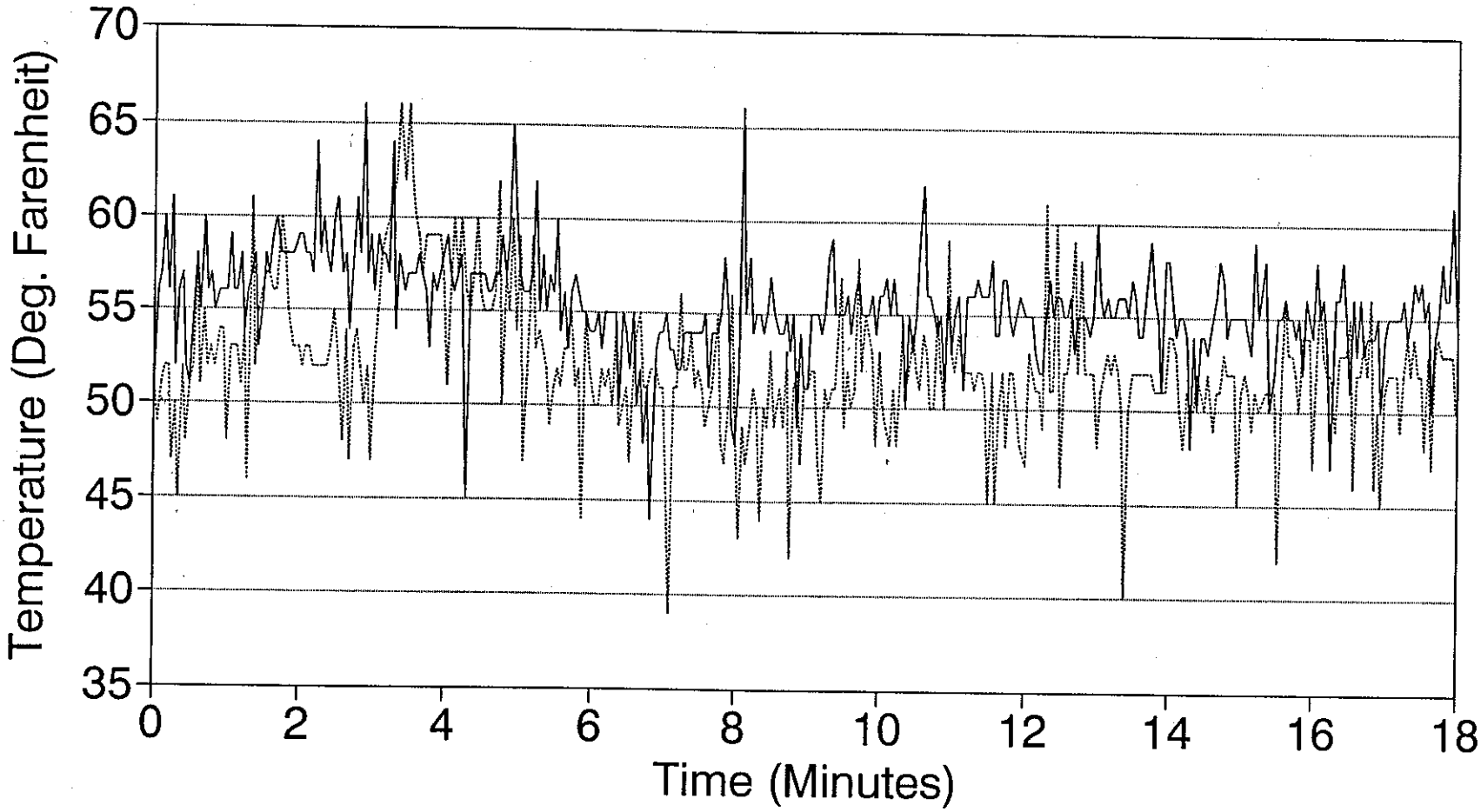
Ceiling Temperatures



TC 5 — TC 9 ····· TC 8 ····· TC 12

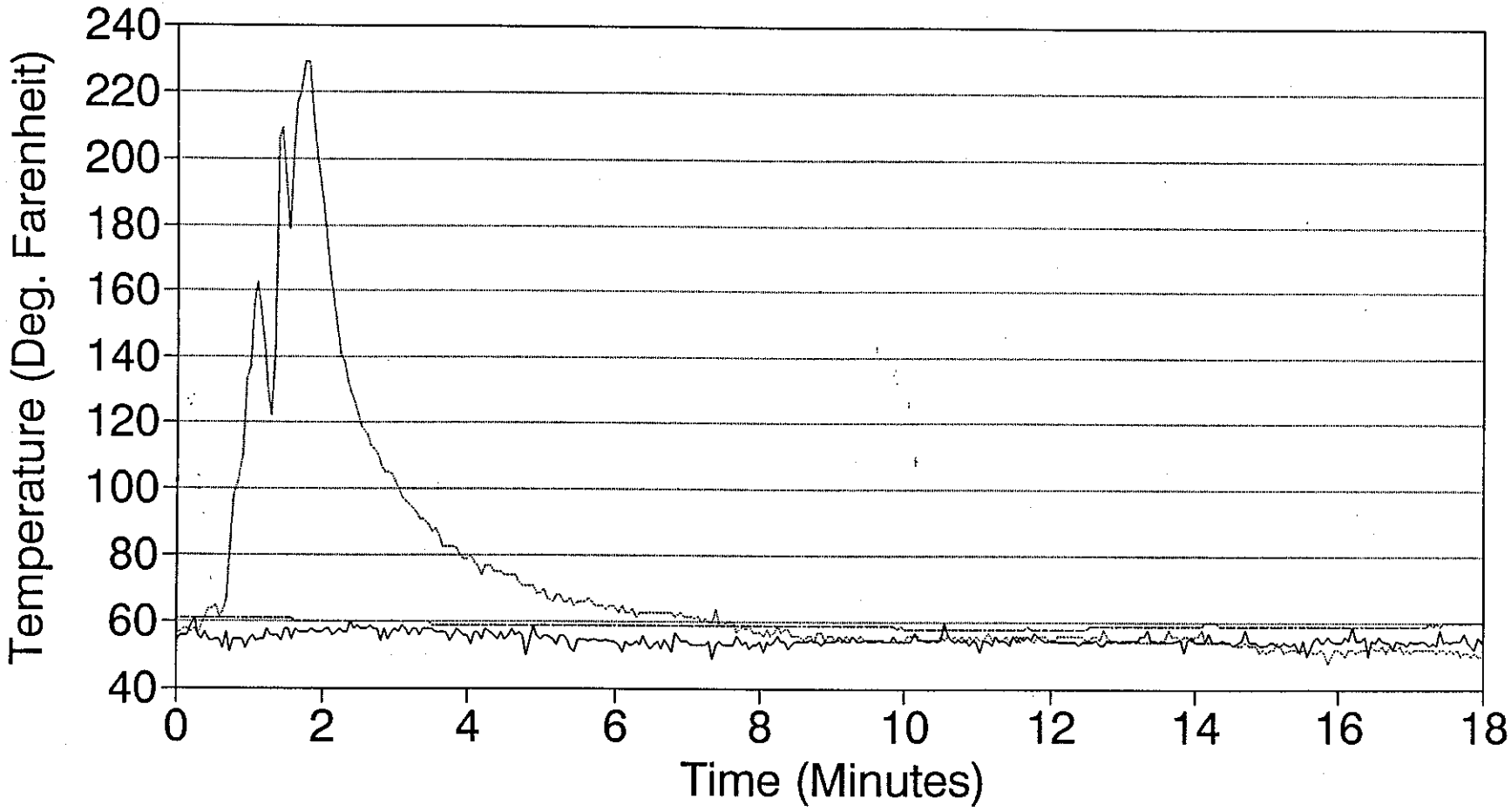
NFPRF RACK FIRE TEST NO.7

Perimeter Temperatures



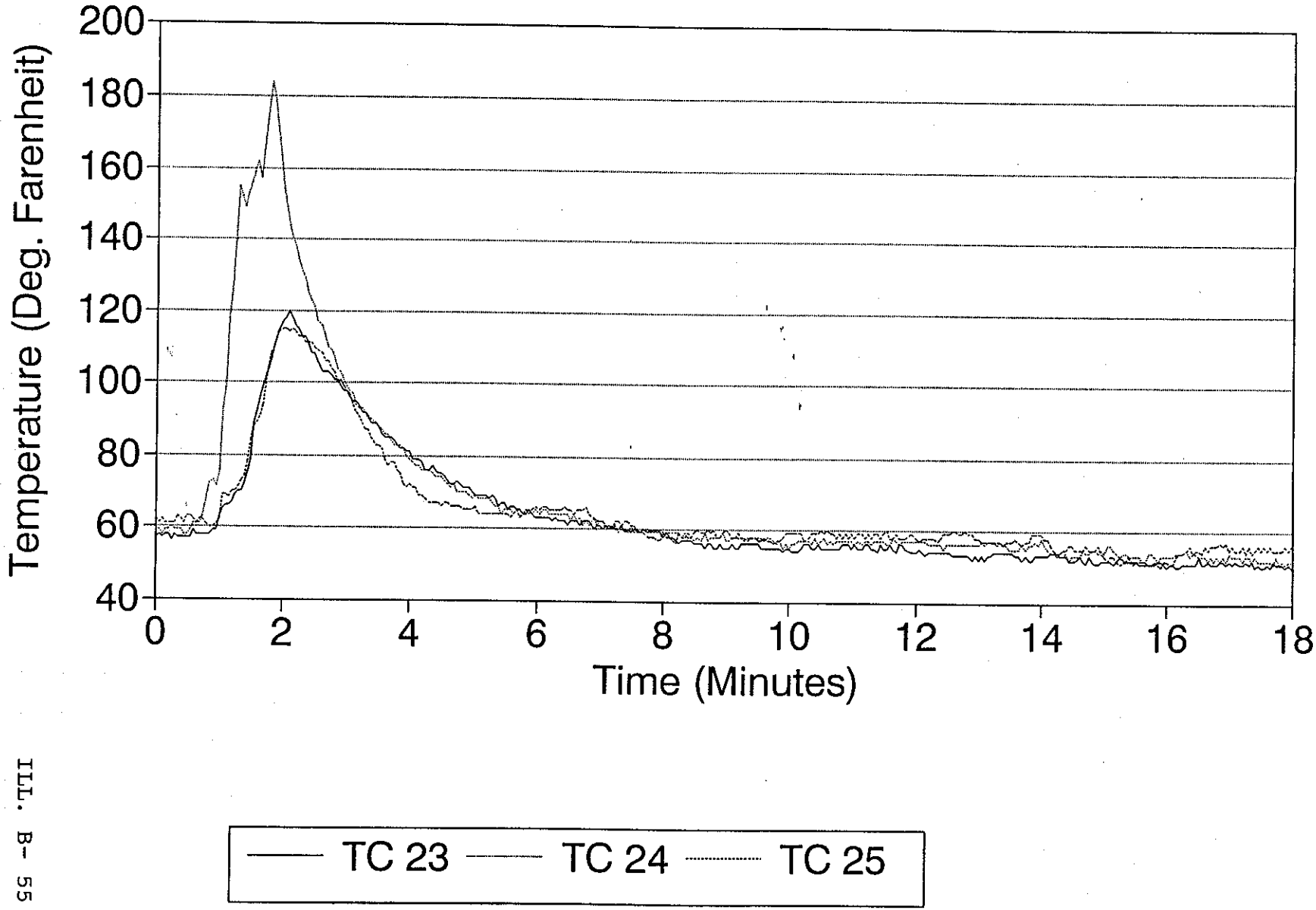
NFPRF RACK FIRE TEST NO.7

Perimeter Temperatures



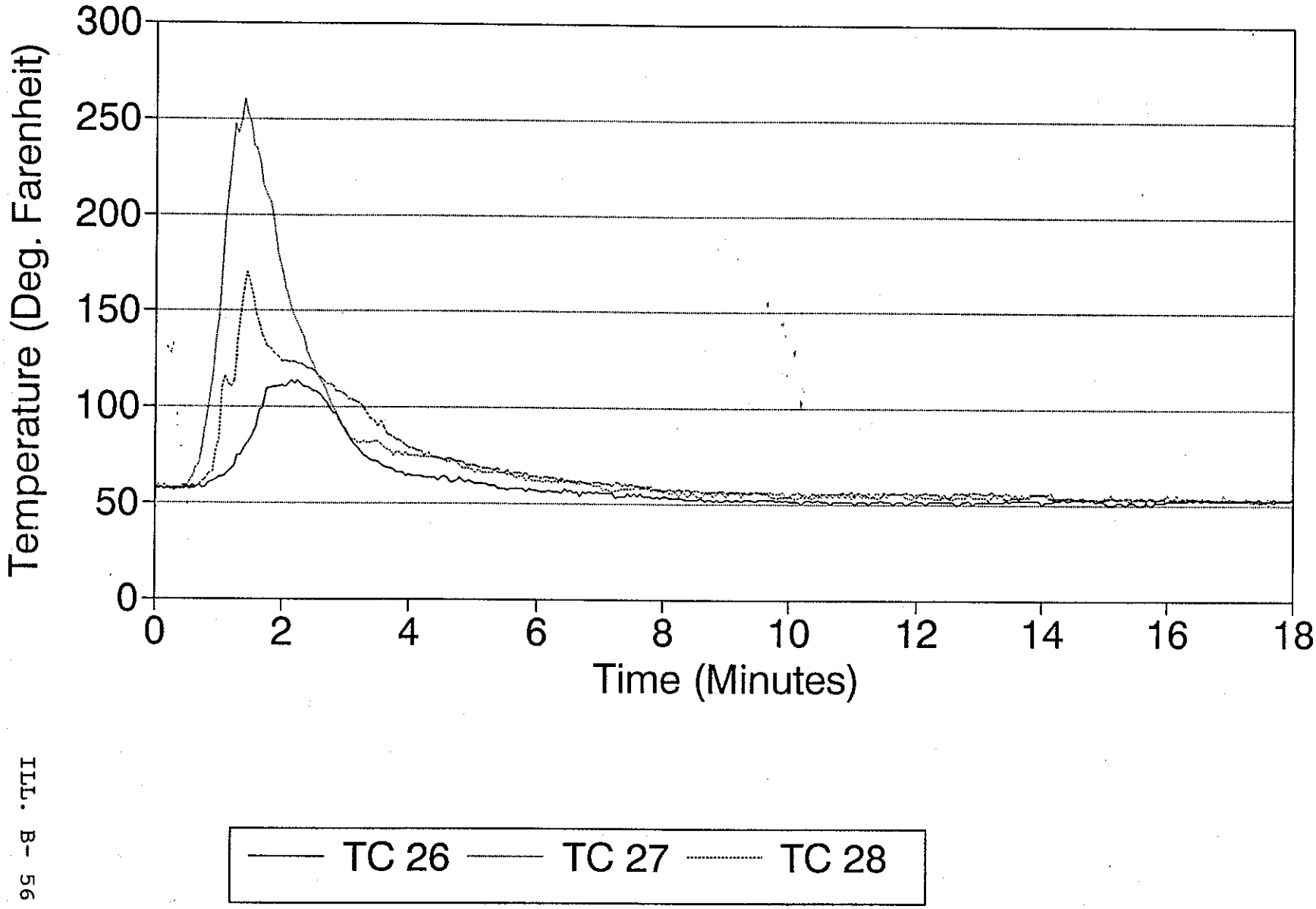
NFPRF RACK FIRE TEST NO.7

Perimeter Temperatures



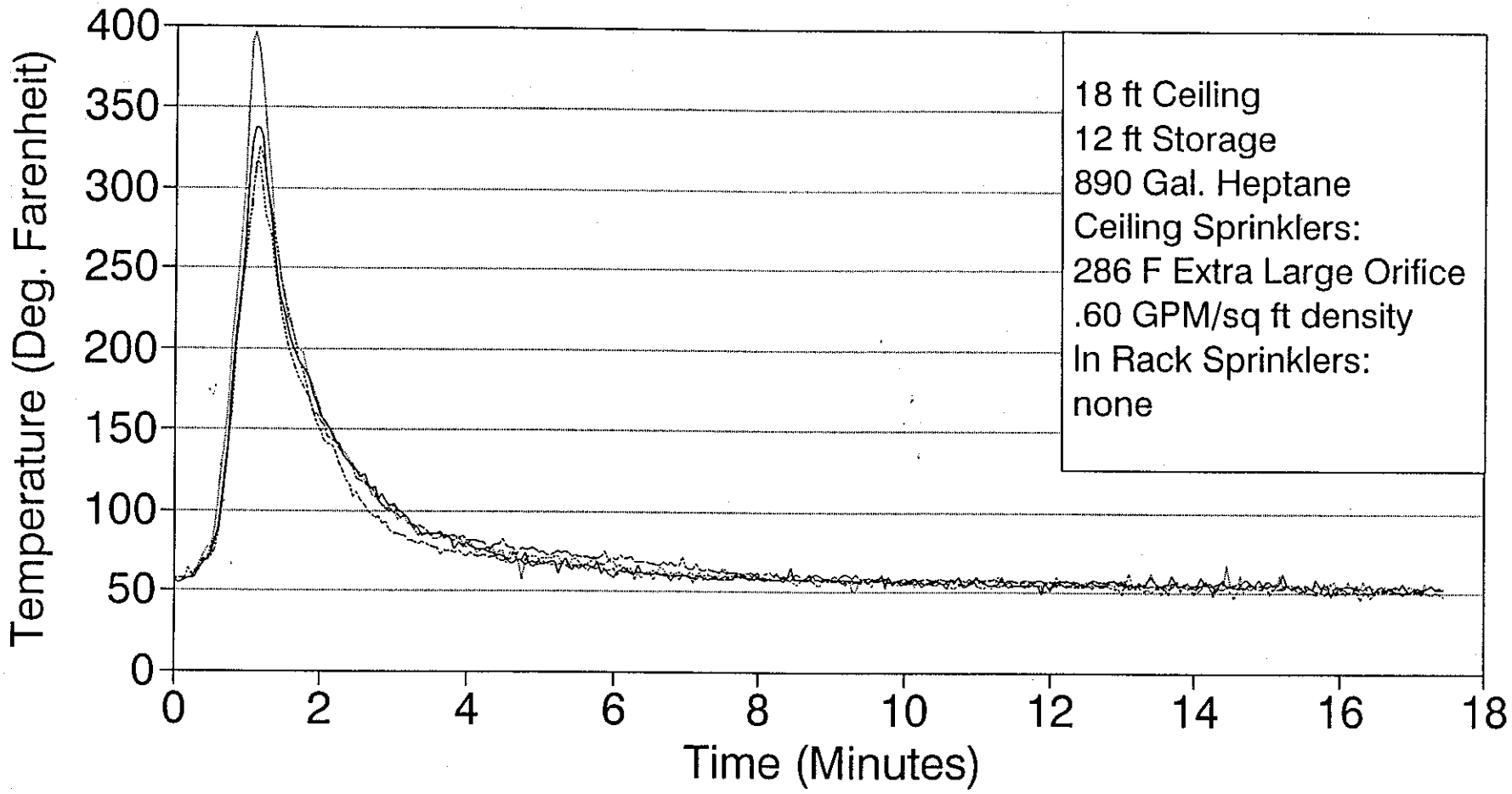
NFPRF RACK FIRE TEST NO.7

Perimeter Temperatures



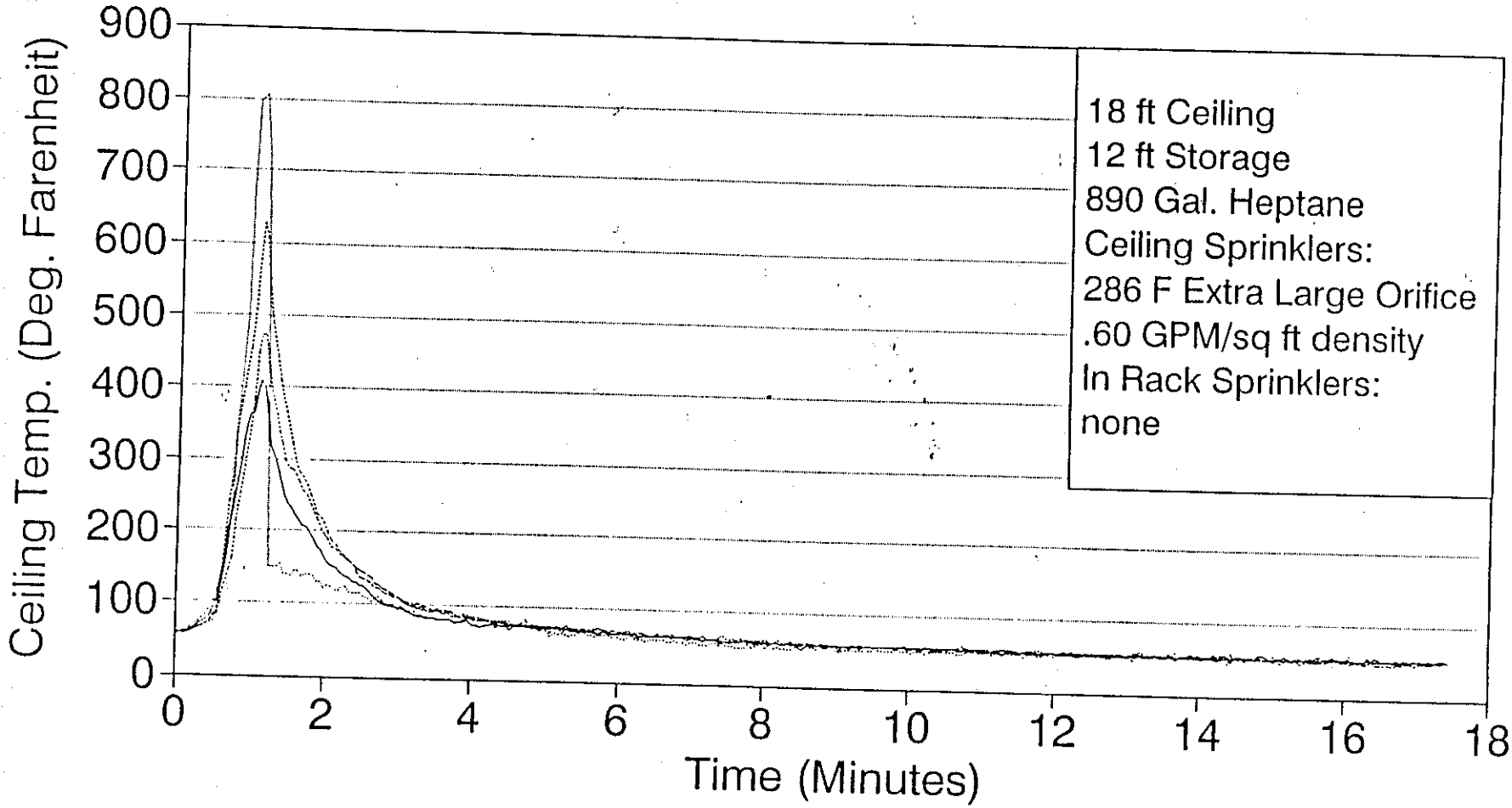
NFPRF RACK FIRE TEST NO.8

Ceiling Temperatures



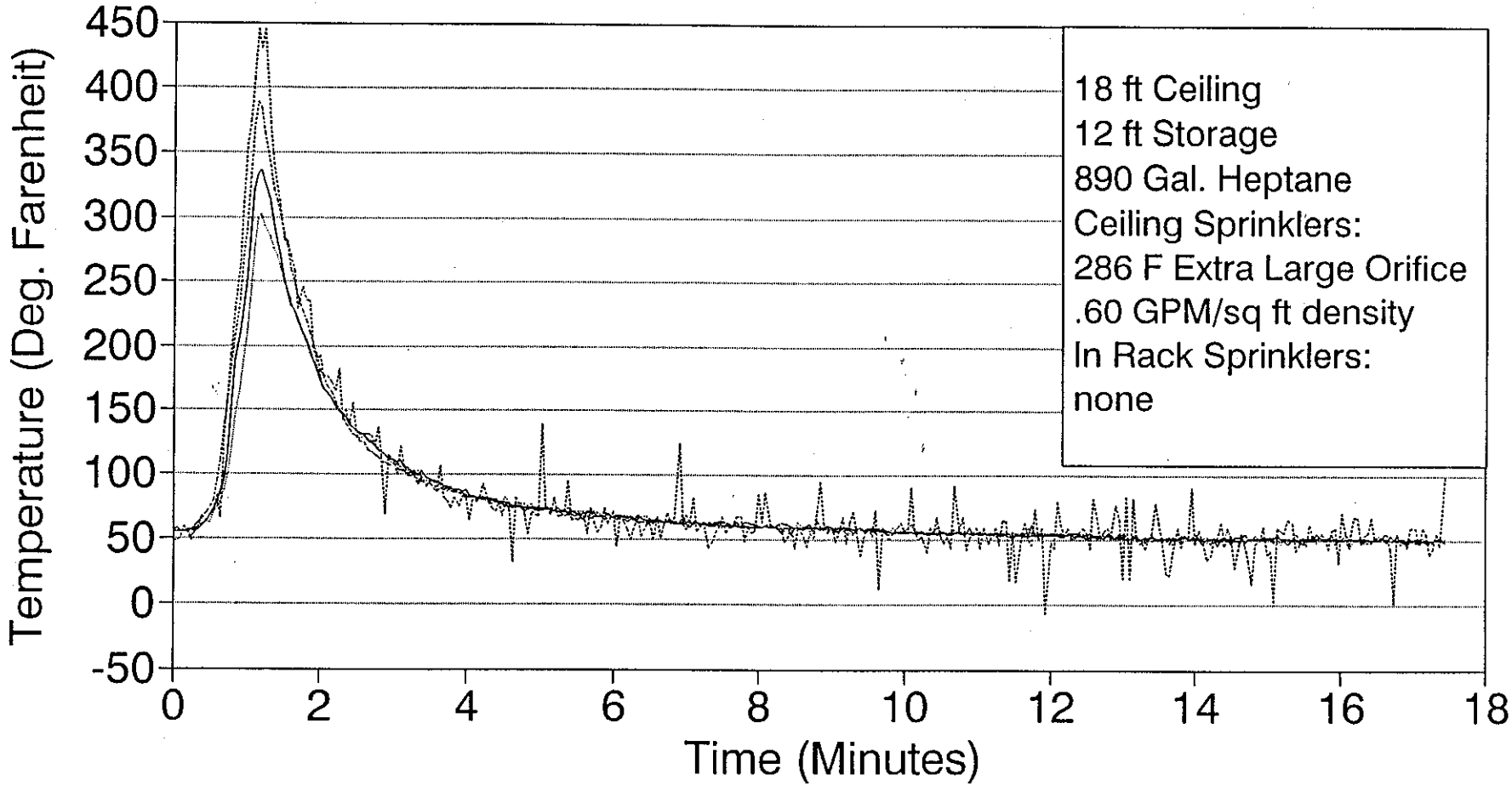
NFPRF RACK FIRE TEST NO.8

Wire Shelves, Ceiling Sprinklers



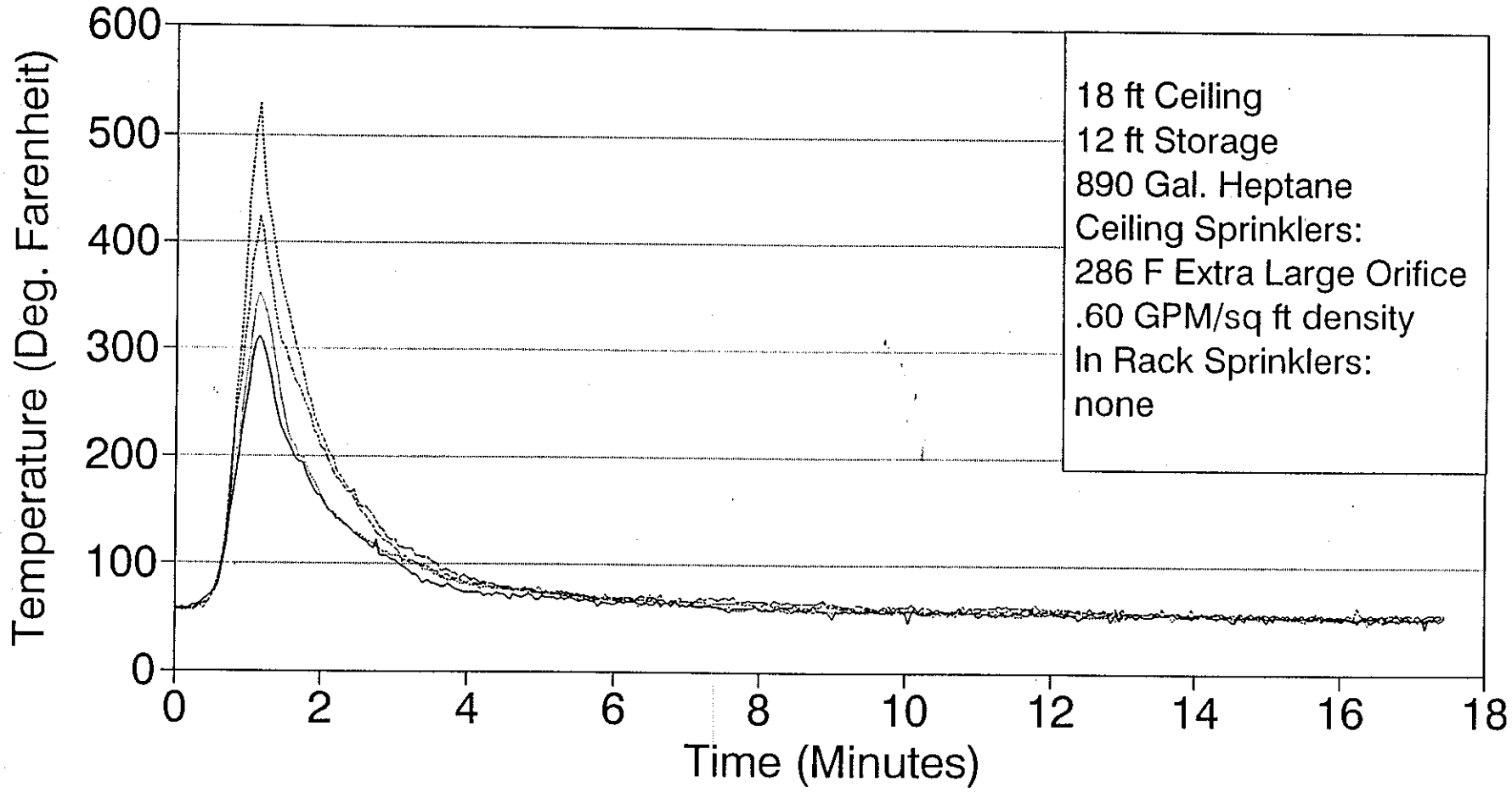
NFPRF RACK FIRE TEST NO.8

Ceiling Temperatures



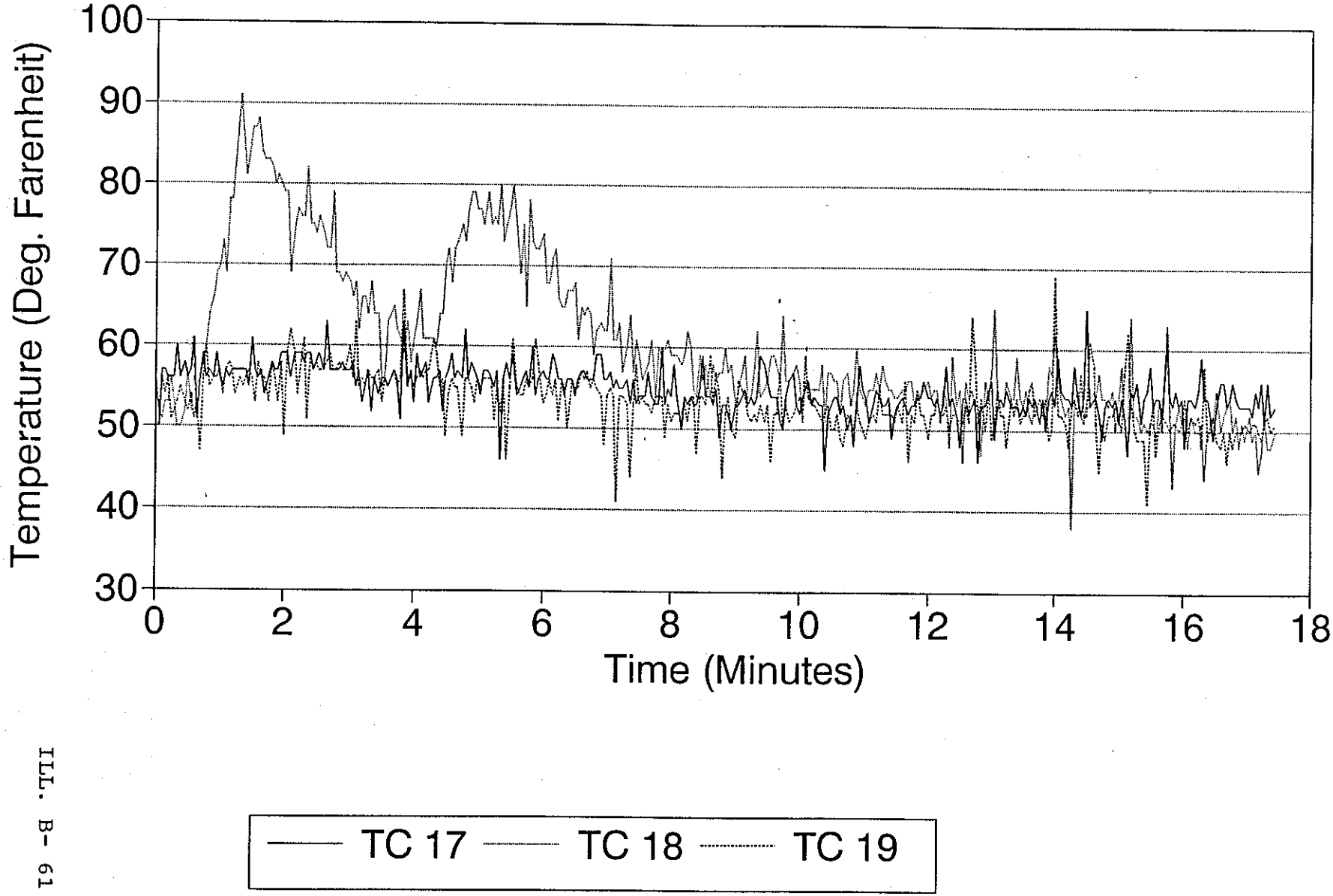
NFPRF RACK FIRE TEST NO.8

Ceiling Temperatures



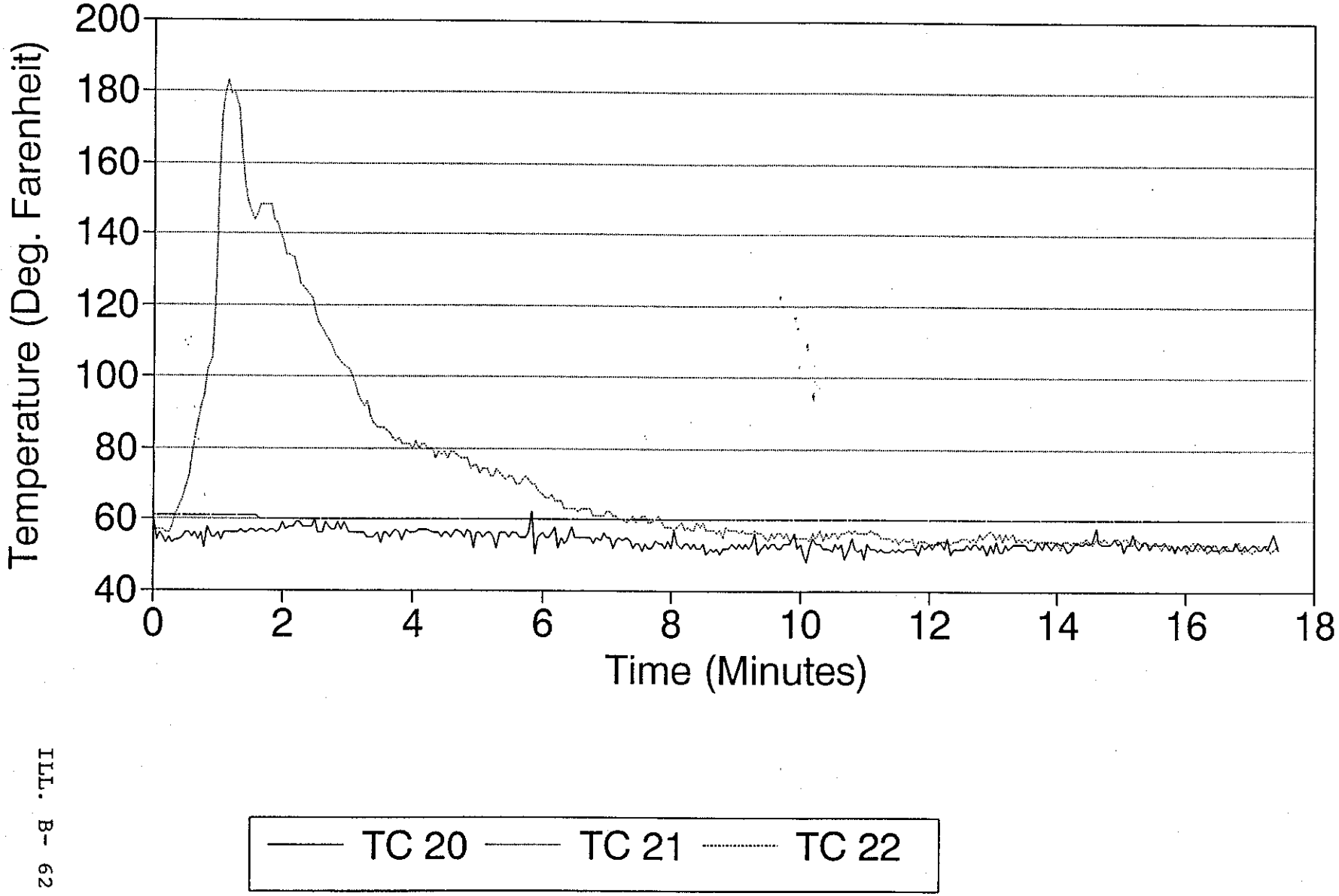
NFPRF RACK FIRE TEST NO.8

Perimeter Temperatures



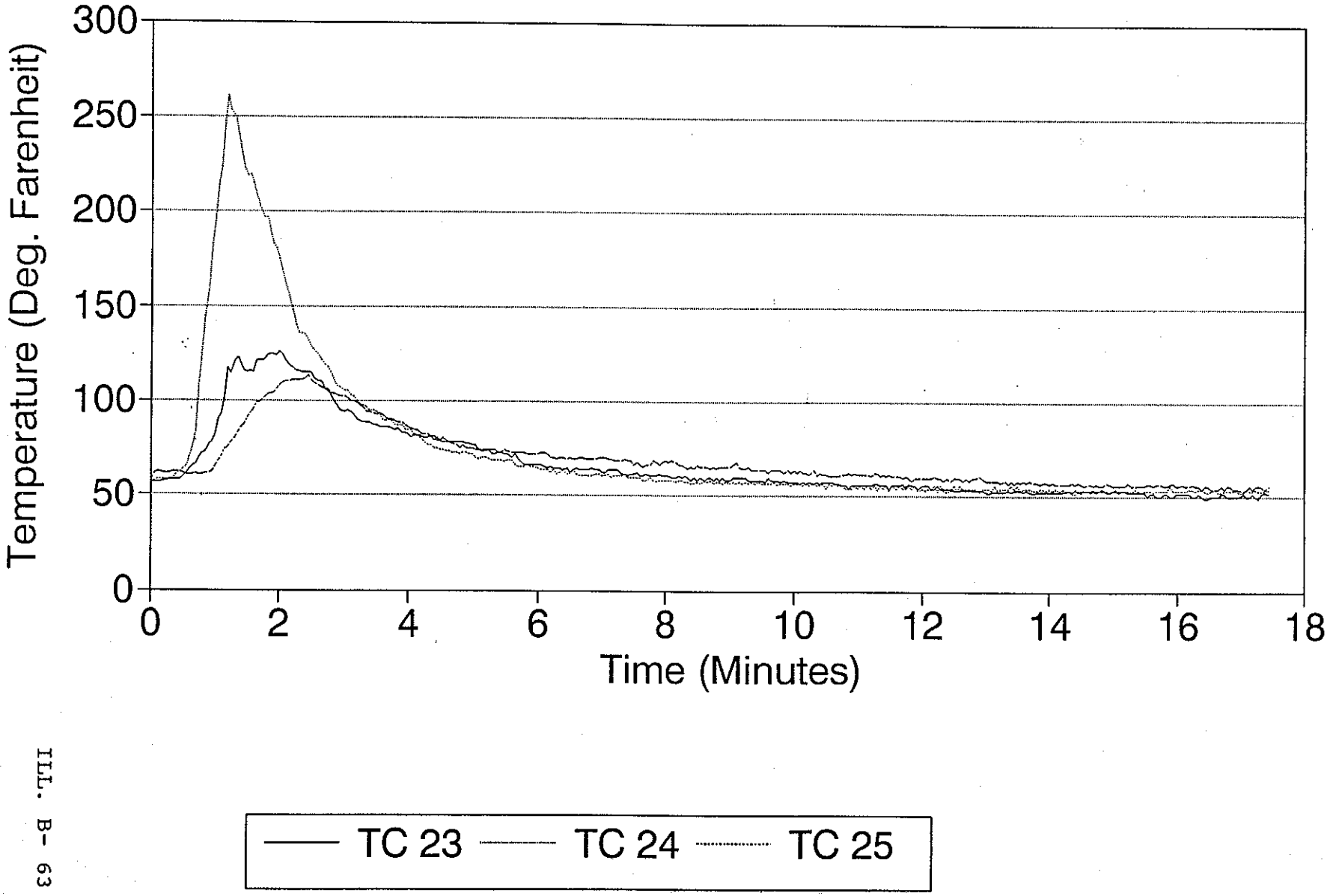
NFPRF RACK FIRE TEST NO.8

Perimeter Temperatures



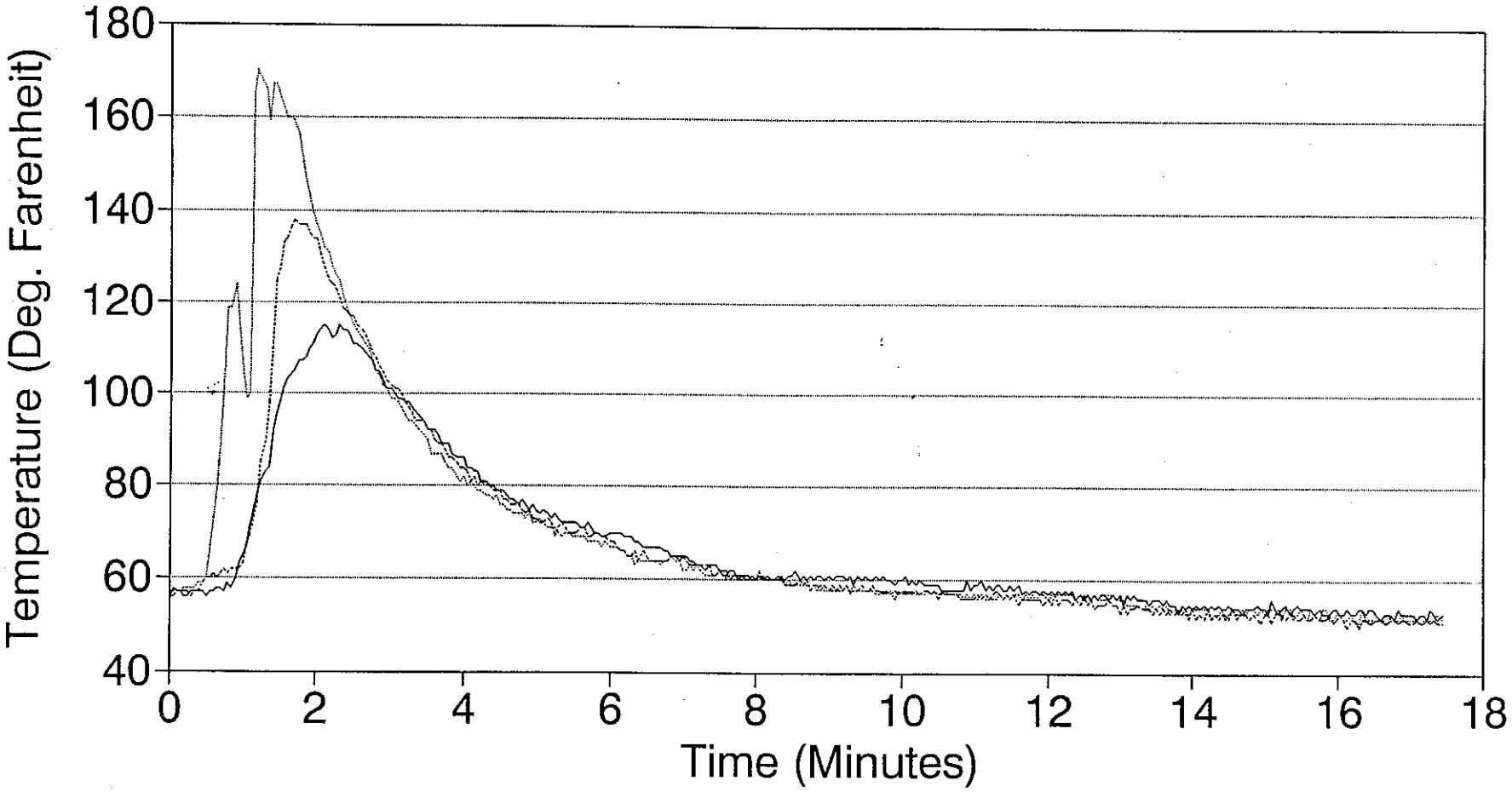
NFPRF RACK FIRE TEST NO.8

Perimeter Temperatures



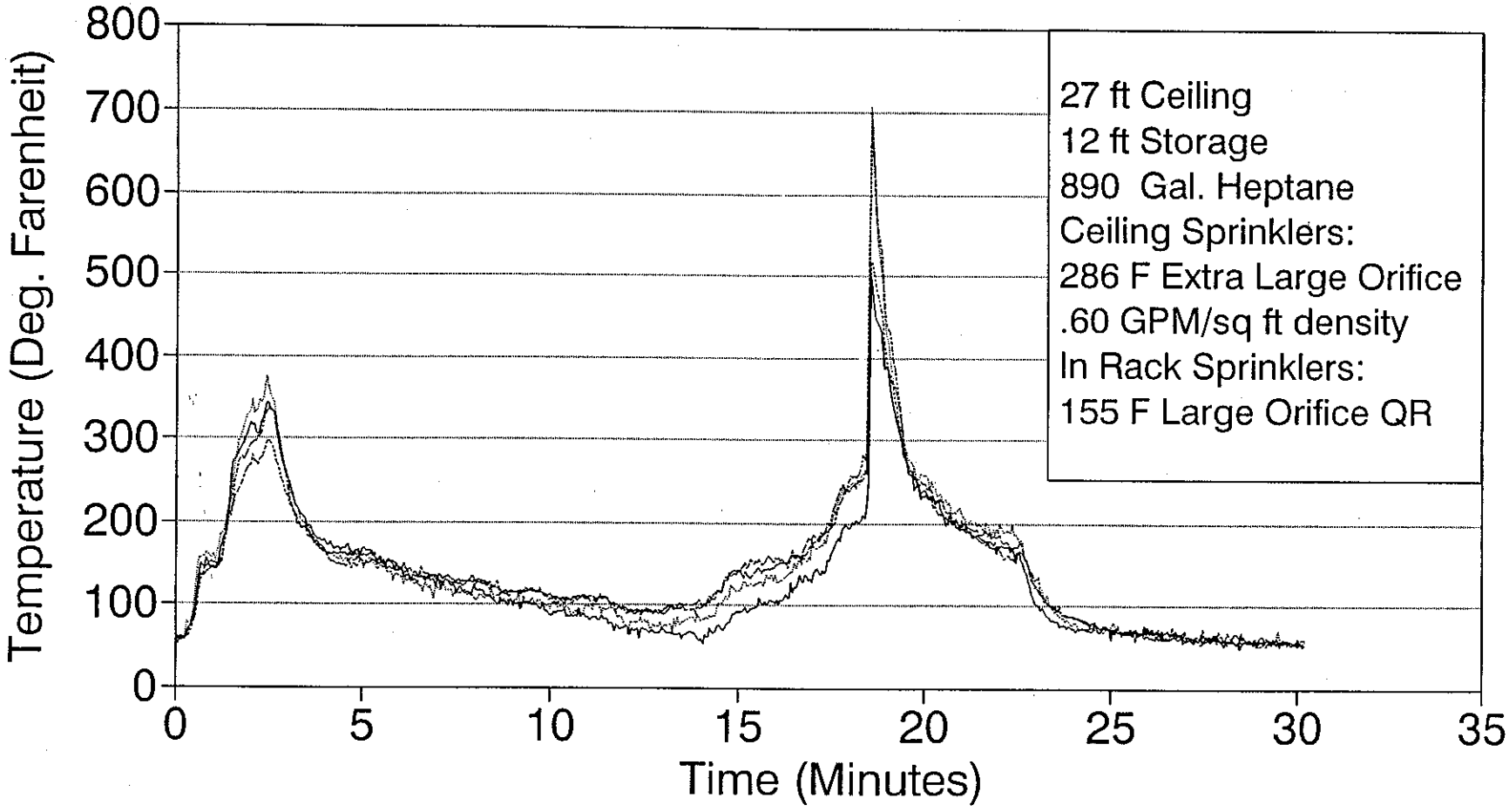
NFPRF RACK FIRE TEST NO.8

Perimeter Temperatures



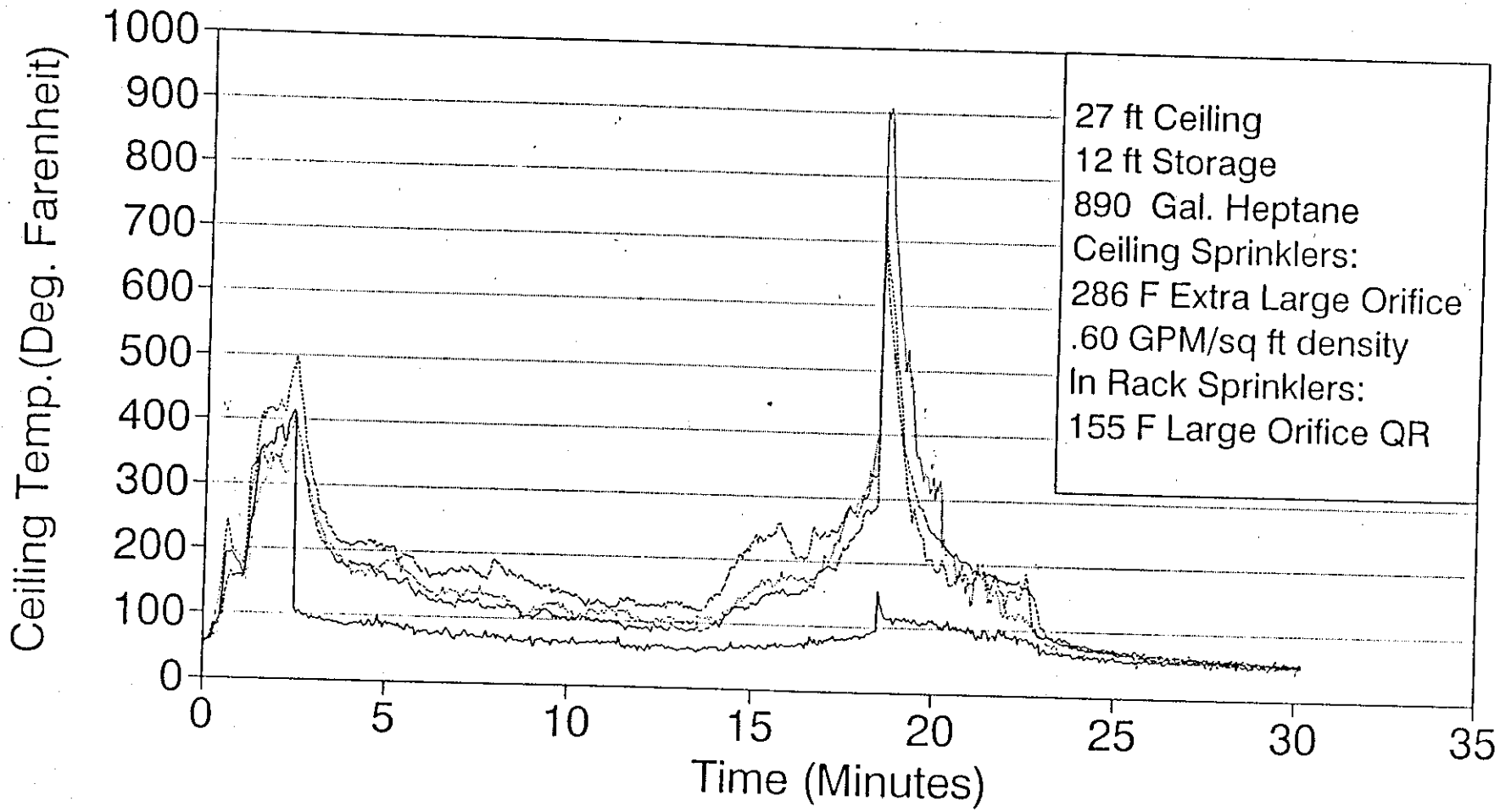
NFPRF RACK FIRE TEST NO. 9

Ceiling Temperatures



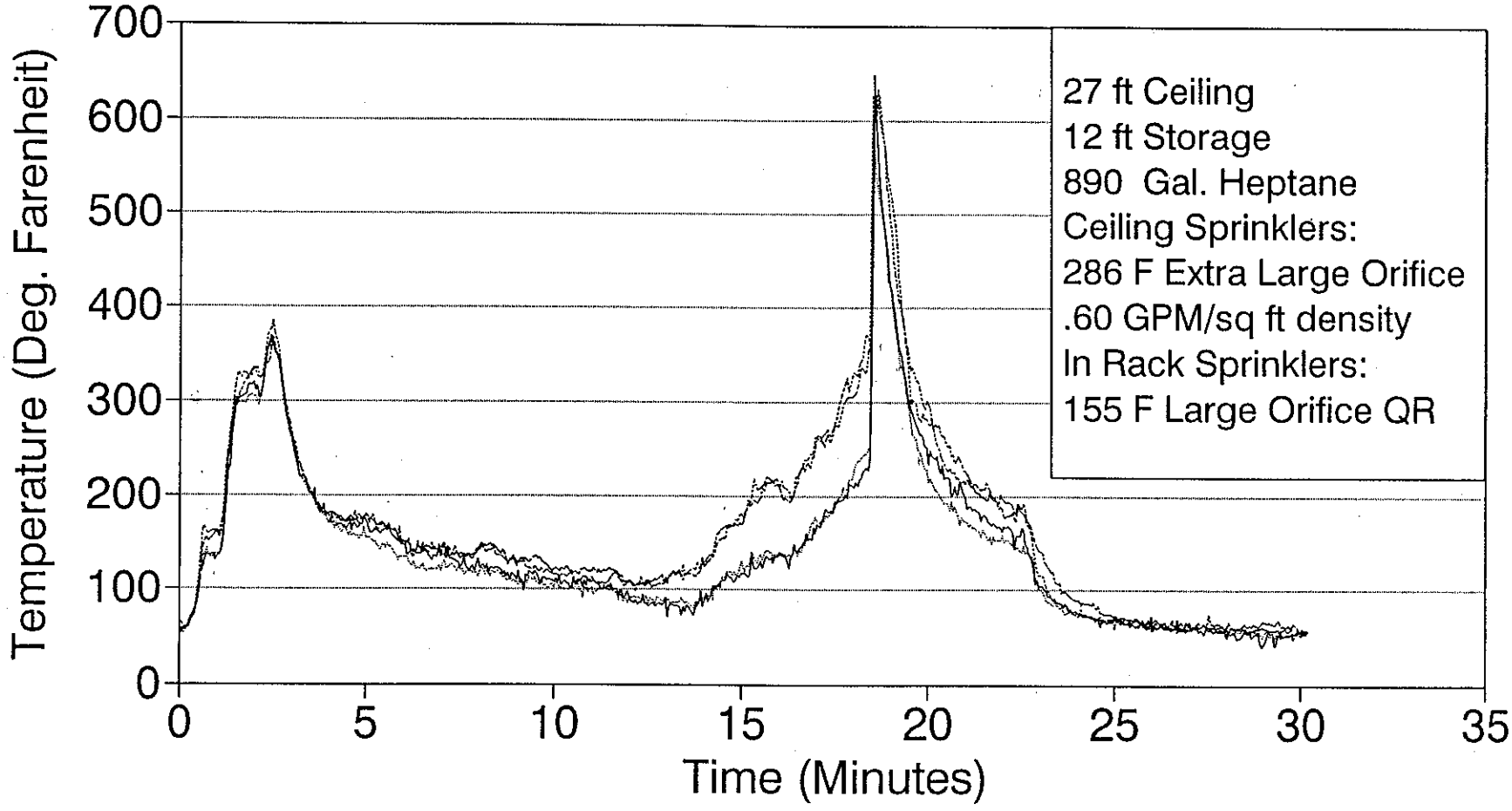
NFPRF RACK FIRE TEST NO. 9

27'Ceiling, 12'Storage, 73" In Racks



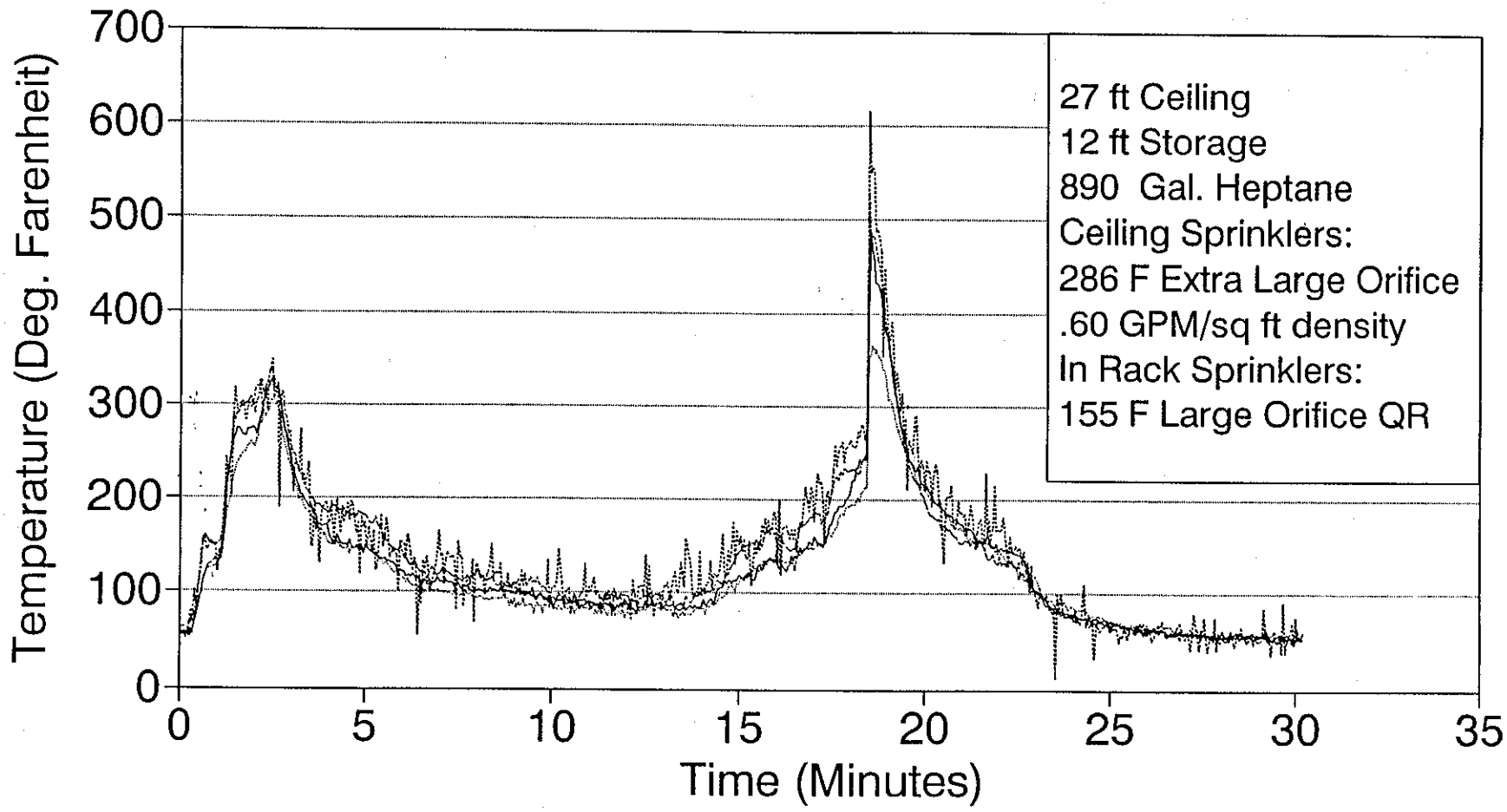
NFPRF RACK FIRE TEST NO. 9

Ceiling Temperatures



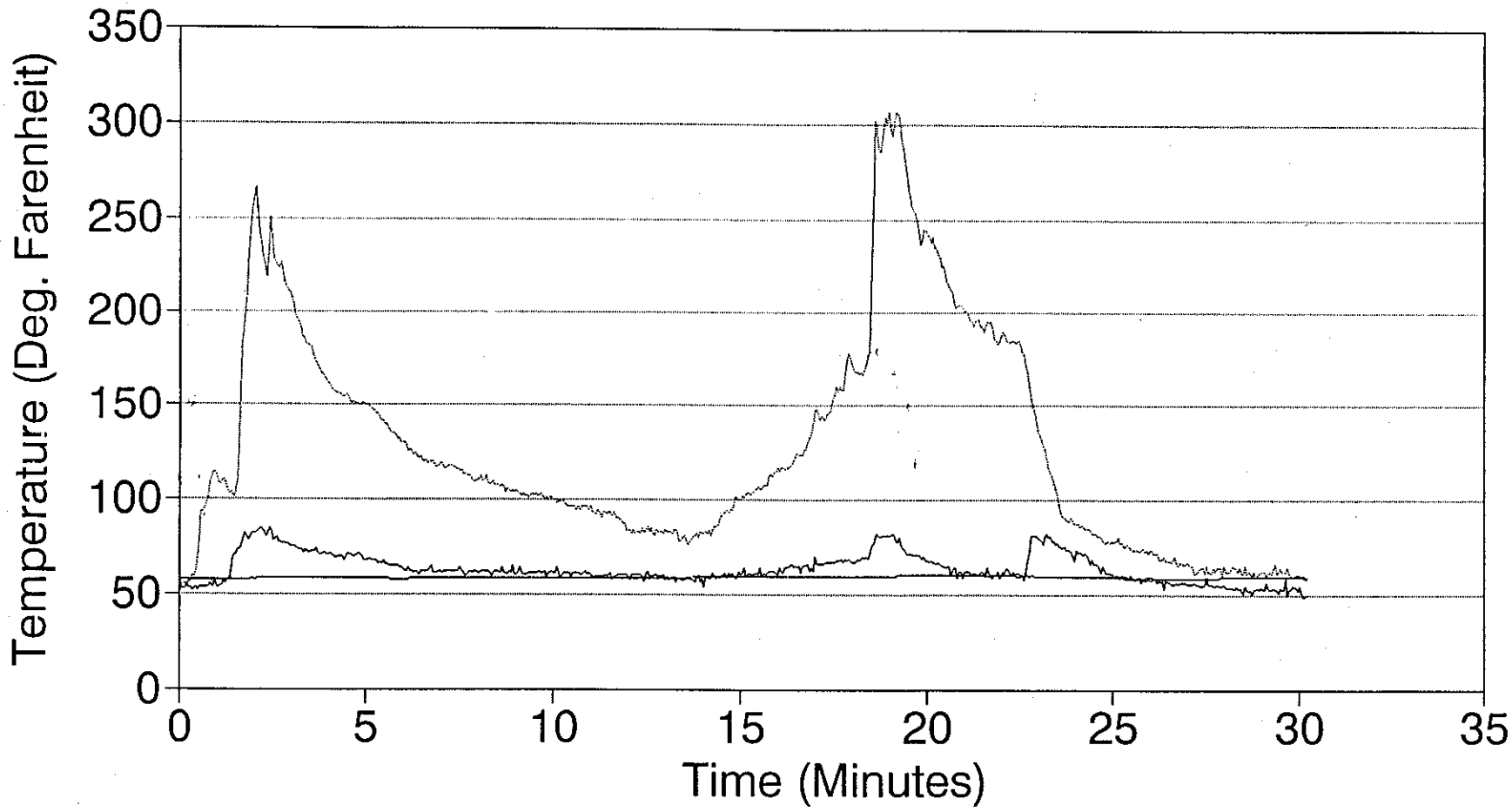
NFPRF RACK FIRE TEST NO. 9

Ceiling Temperatures



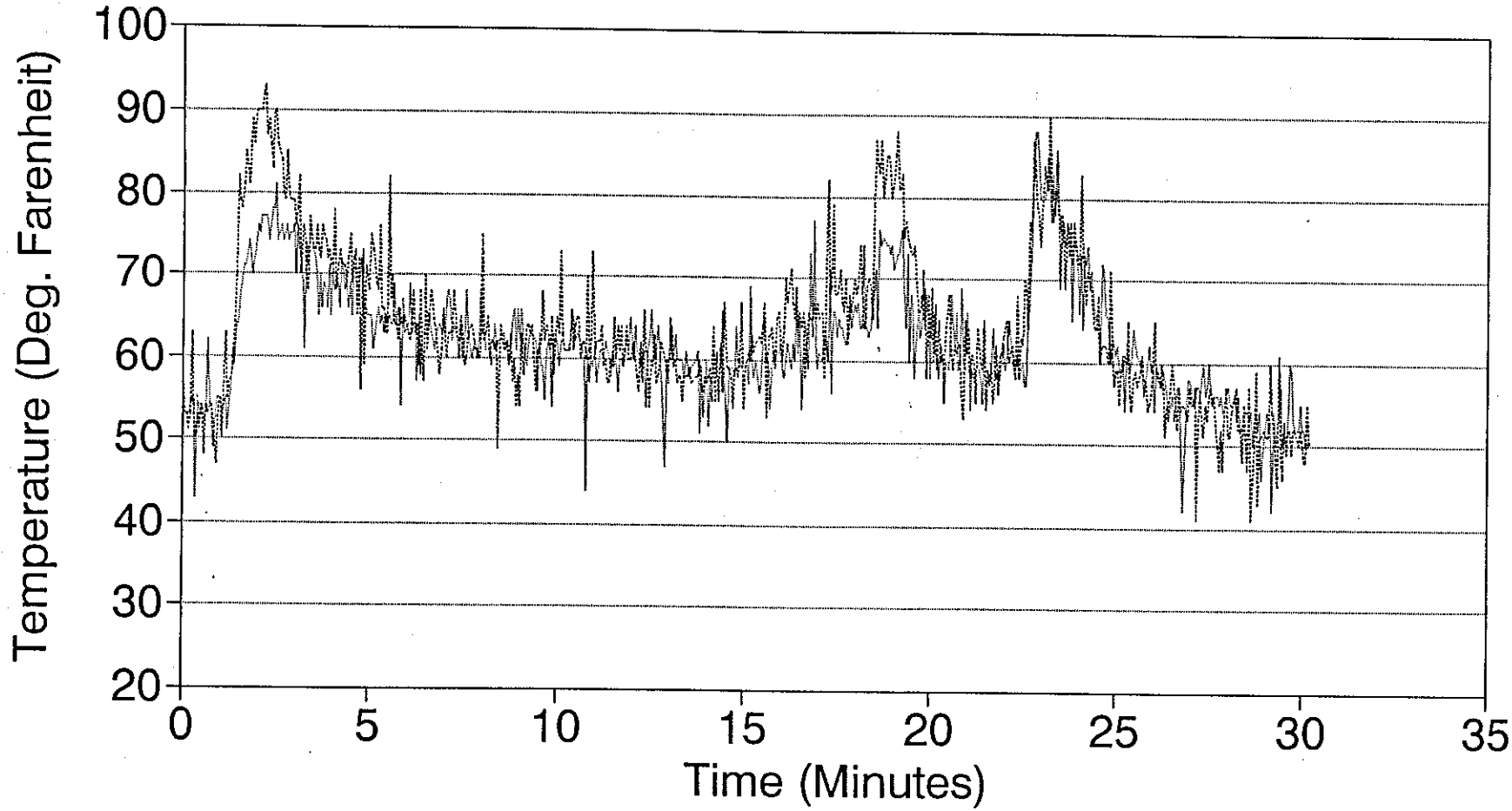
NFPRF RACK FIRE TEST NO. 9

Perimeter Temperatures



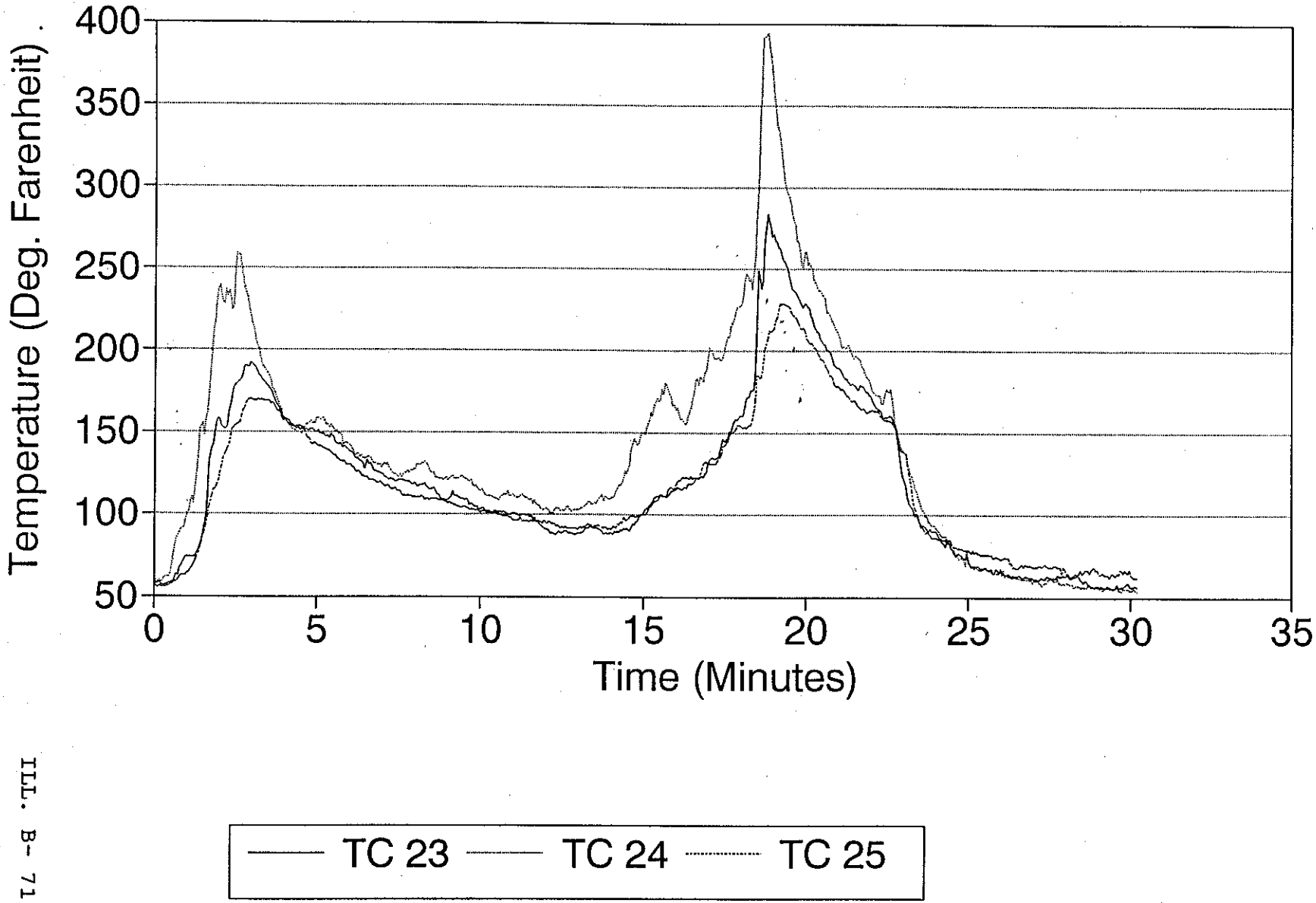
NFPRF RACK FIRE TEST NO. 9

Perimeter Temperatures



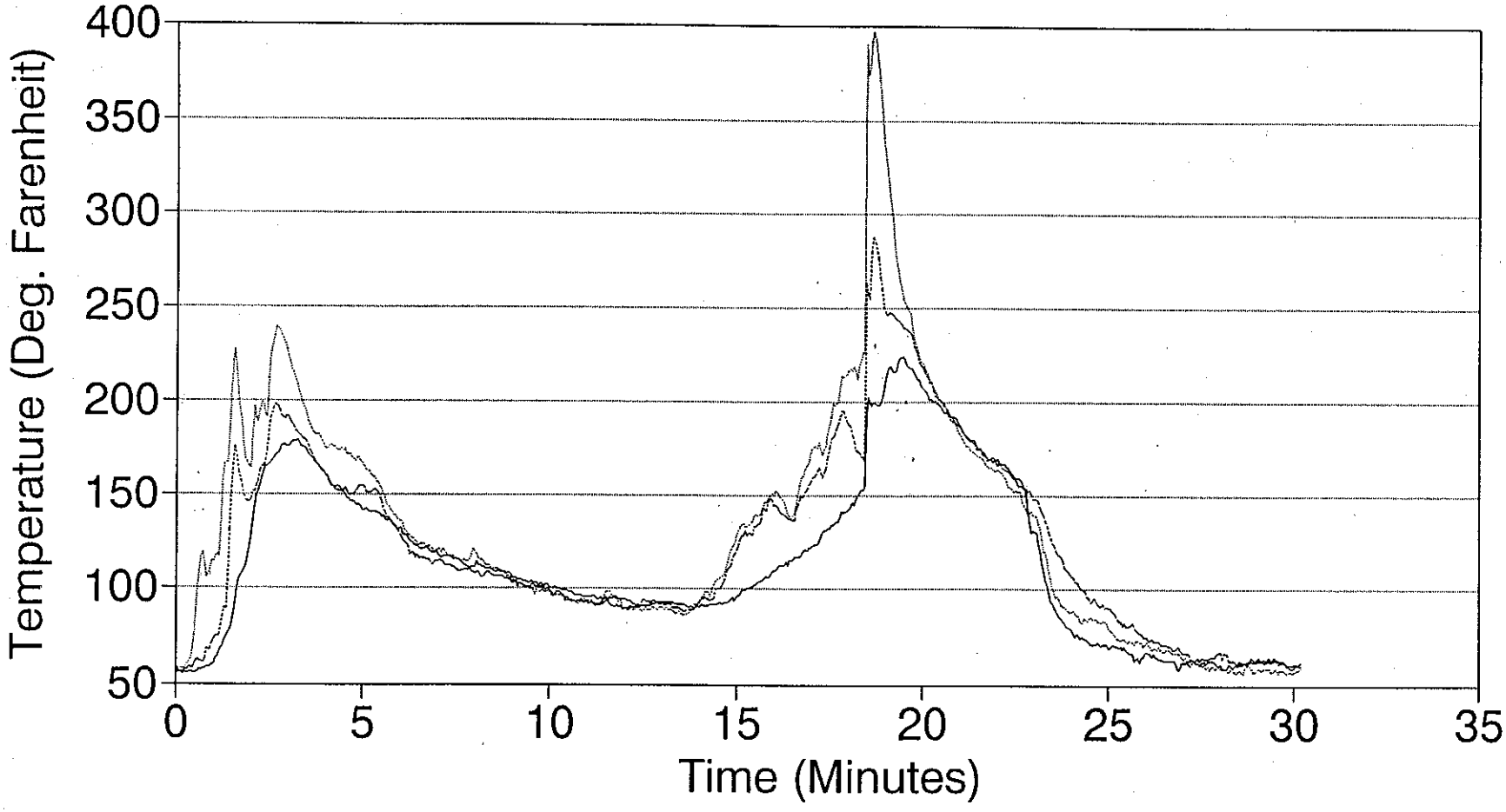
NFPRF RACK FIRE TEST NO. 9

Perimeter Temperatures



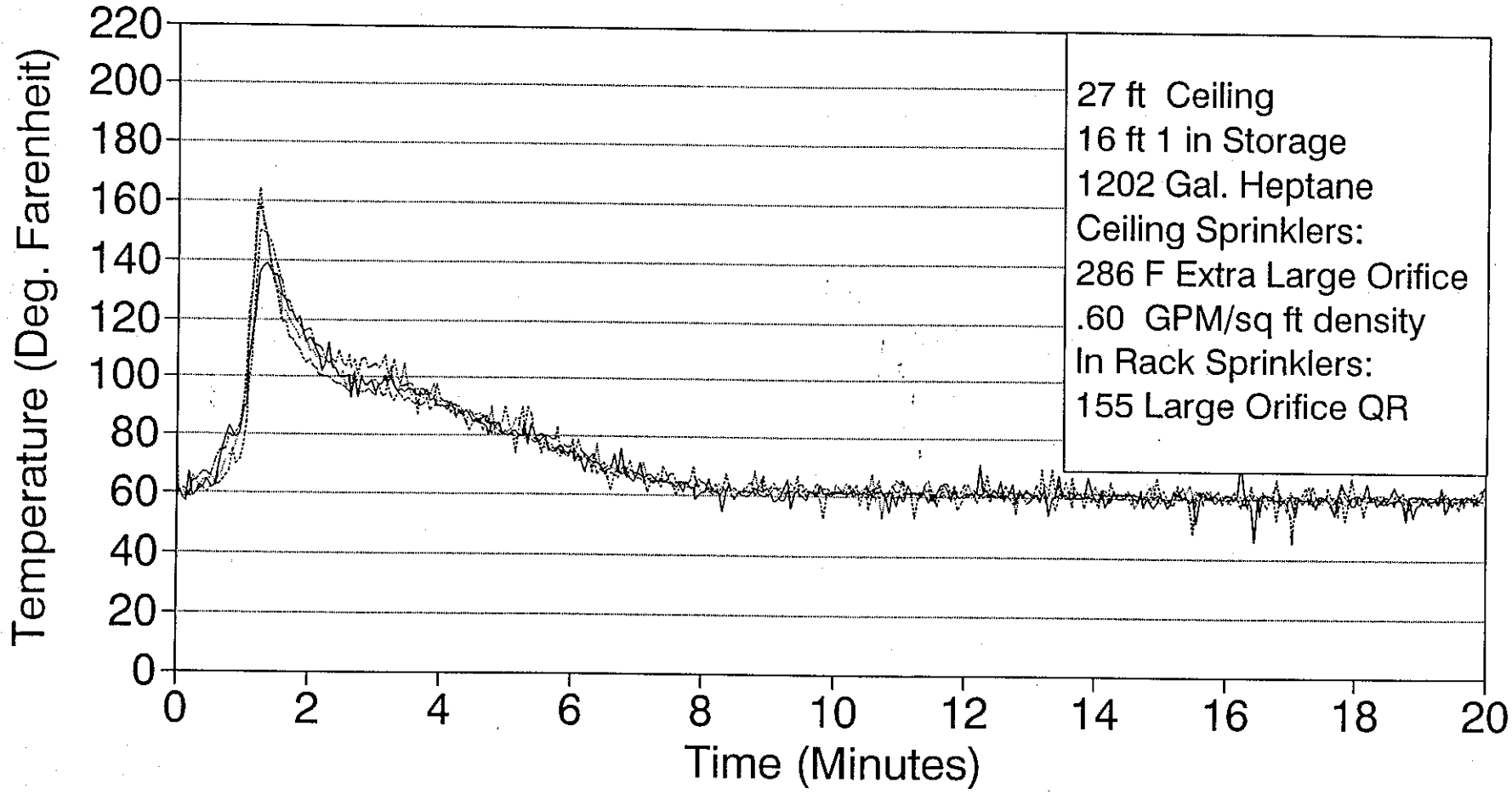
NFPRF RACK FIRE TEST NO. 9

Perimeter Temperatures



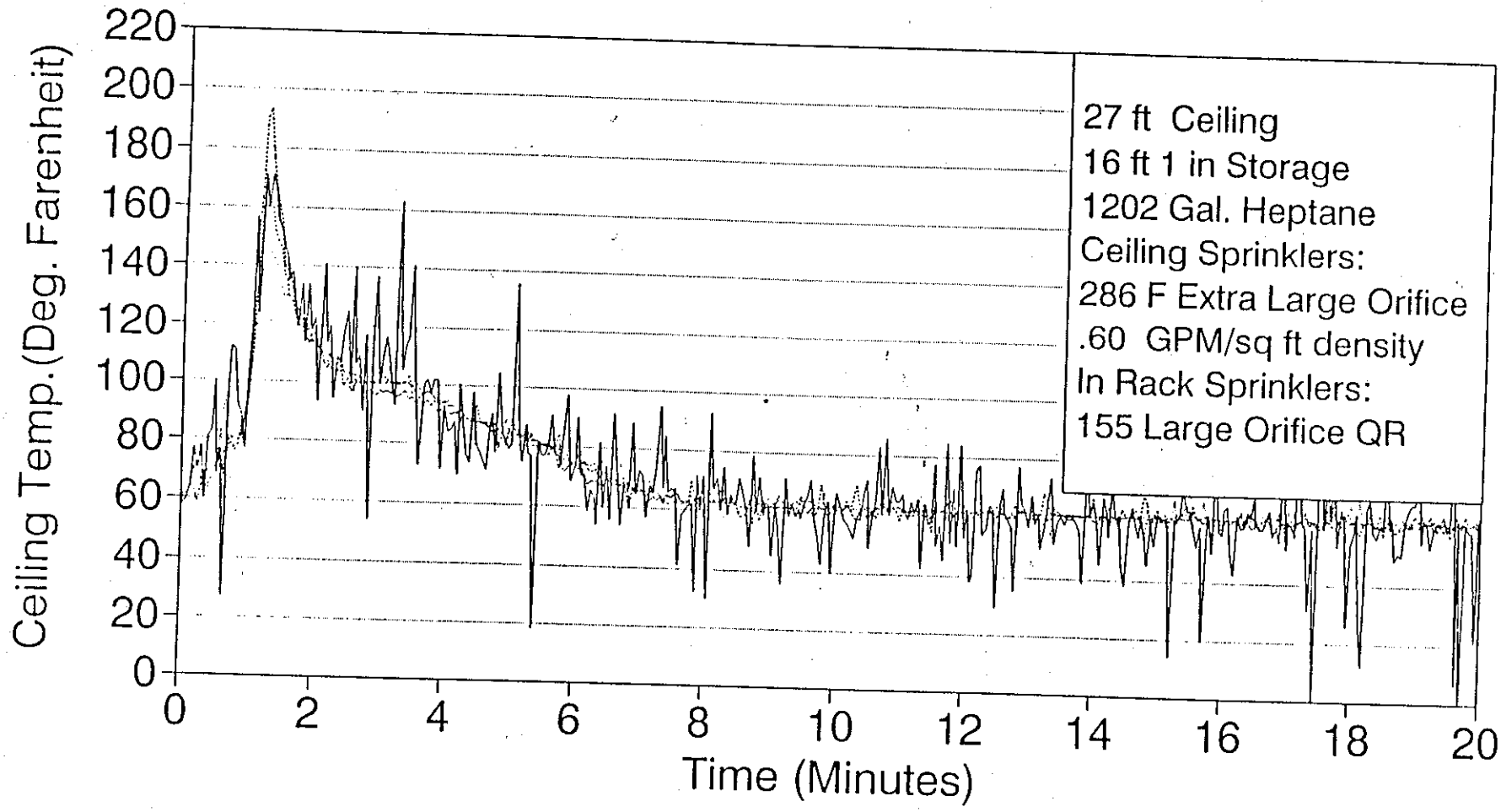
NFPRF RACK FIRE TEST NO. 10

Ceiling Temperatures



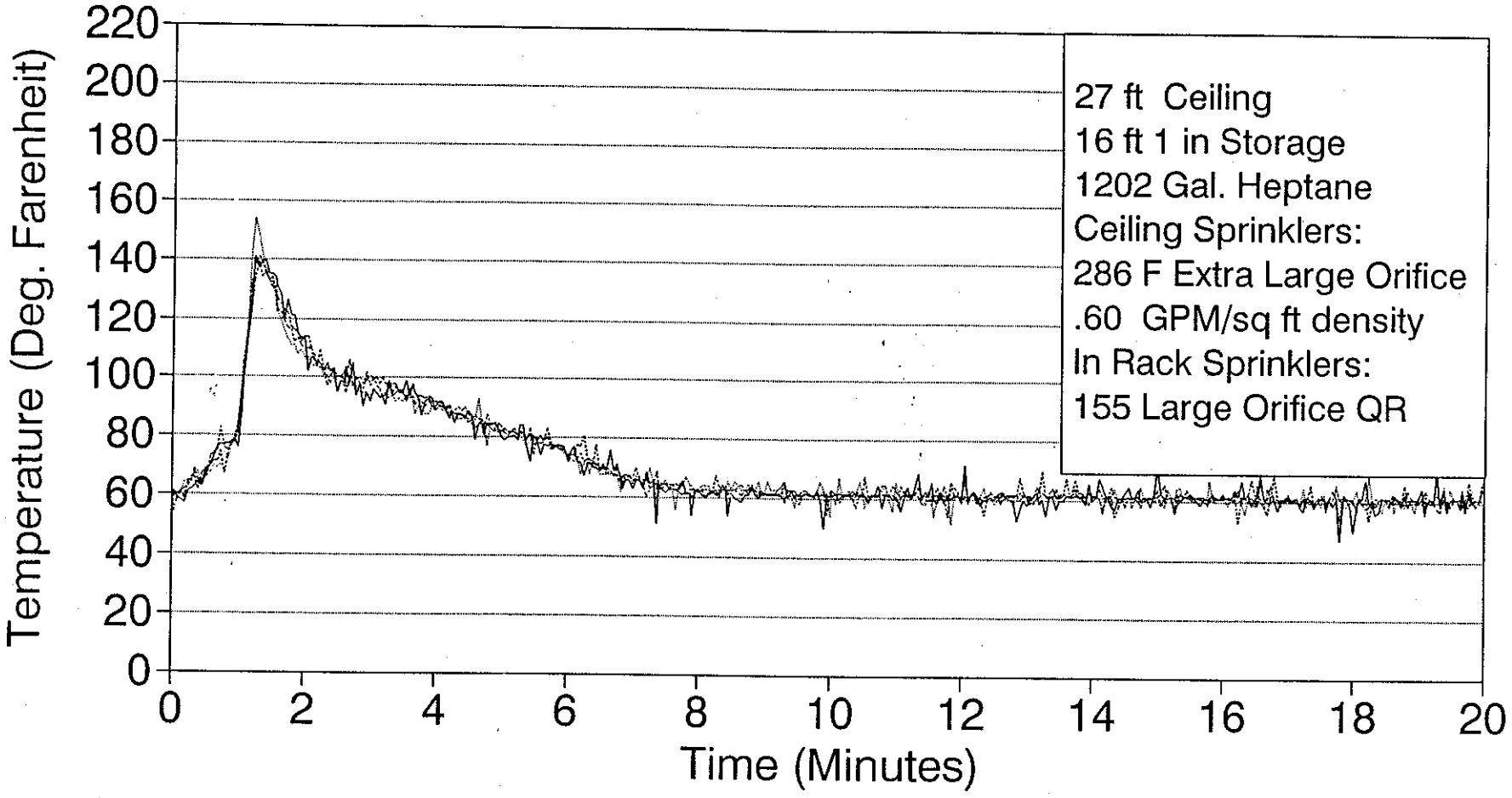
NFPRF RACK FIRE TEST NO. 10

27'Ceiling,16'Storage,73"& 138" InRacks



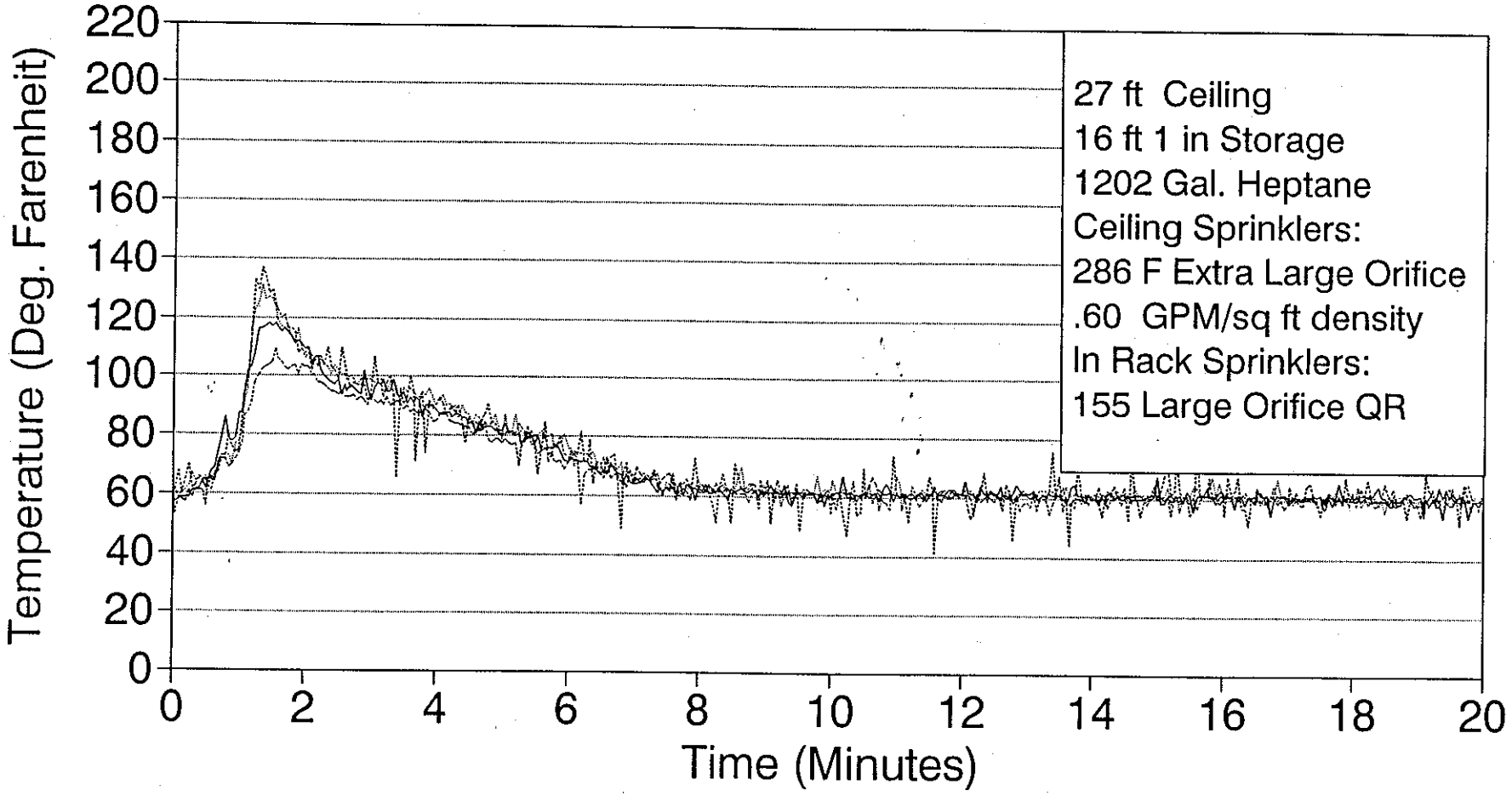
NFPRF RACK FIRE TEST NO. 10

Ceiling Temperatures



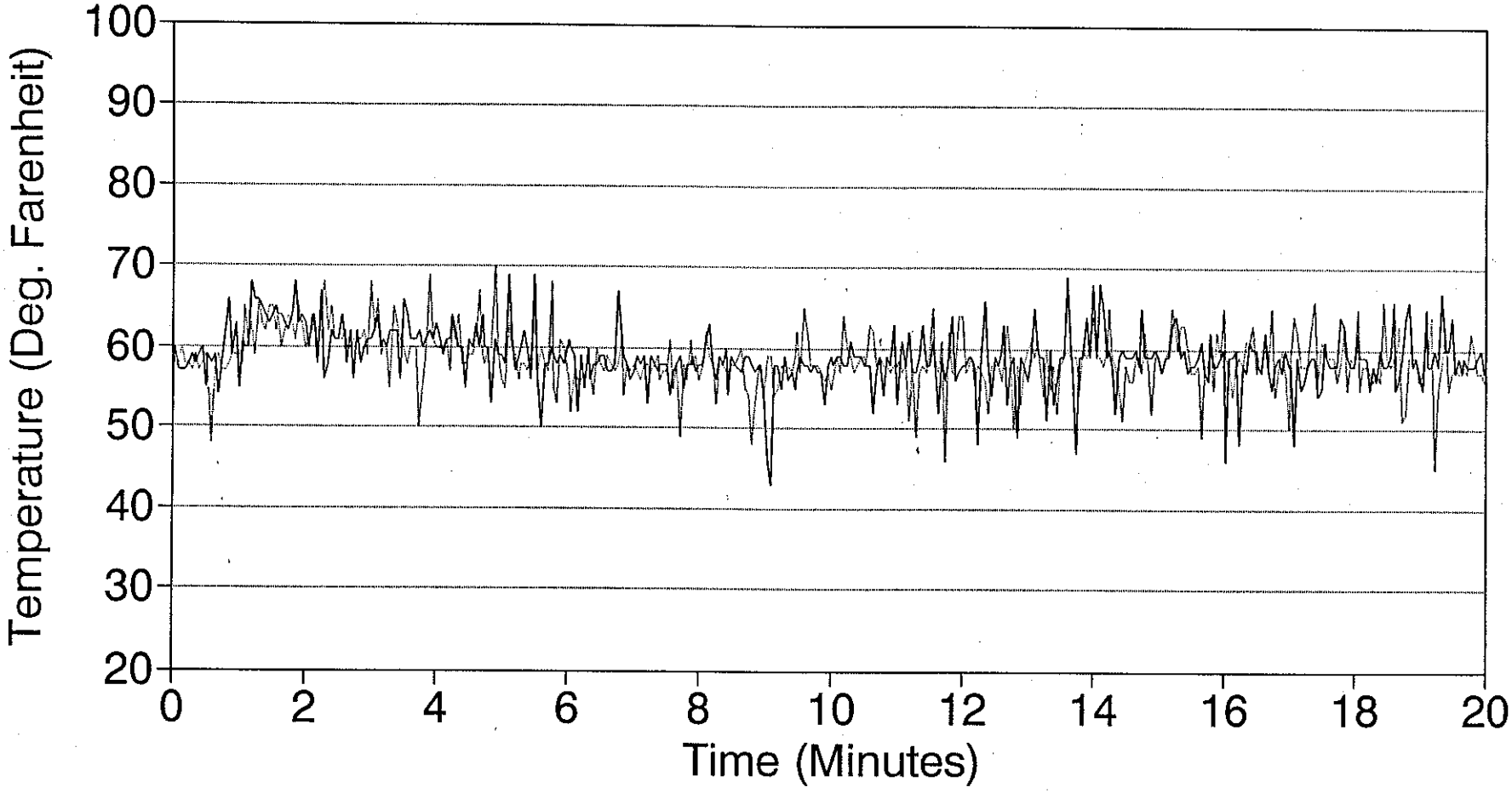
NFPRF RACK FIRE TEST NO. 10

Ceiling Temperatures



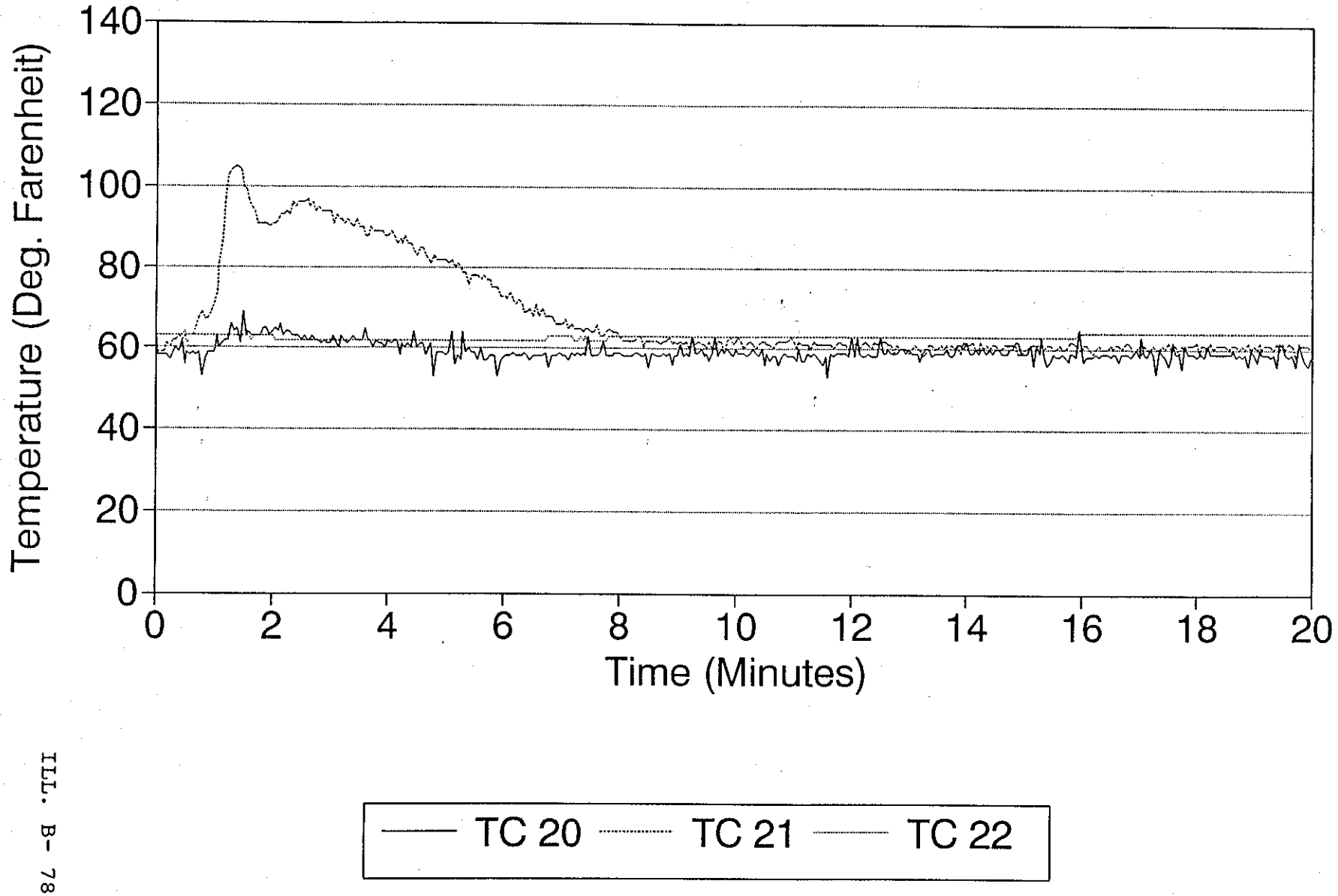
NFPRF RACK FIRE TEST NO. 10

Perimeter Temperatures



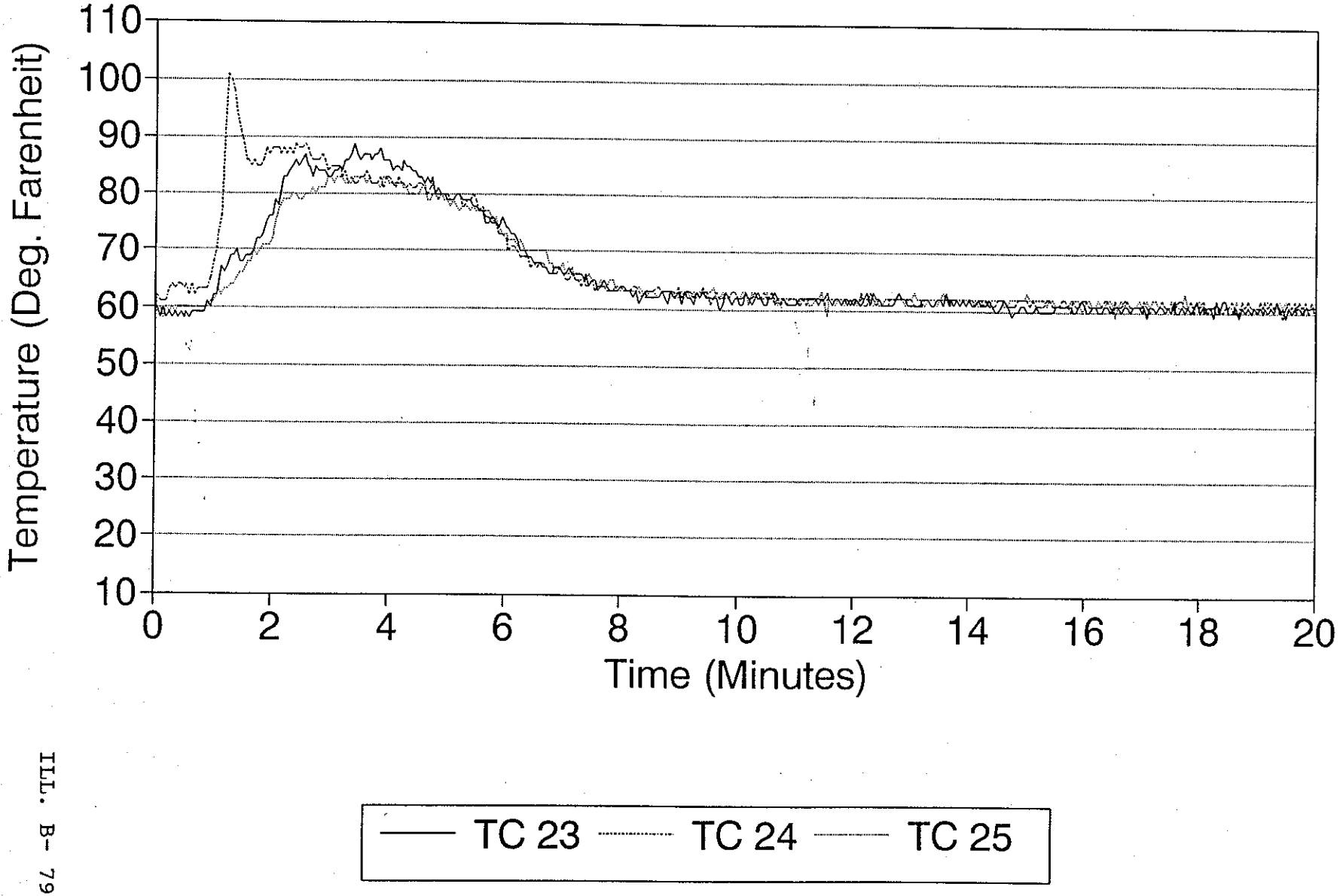
NFPRF RACK FIRE TEST NO. 10

Perimeter Temperatures



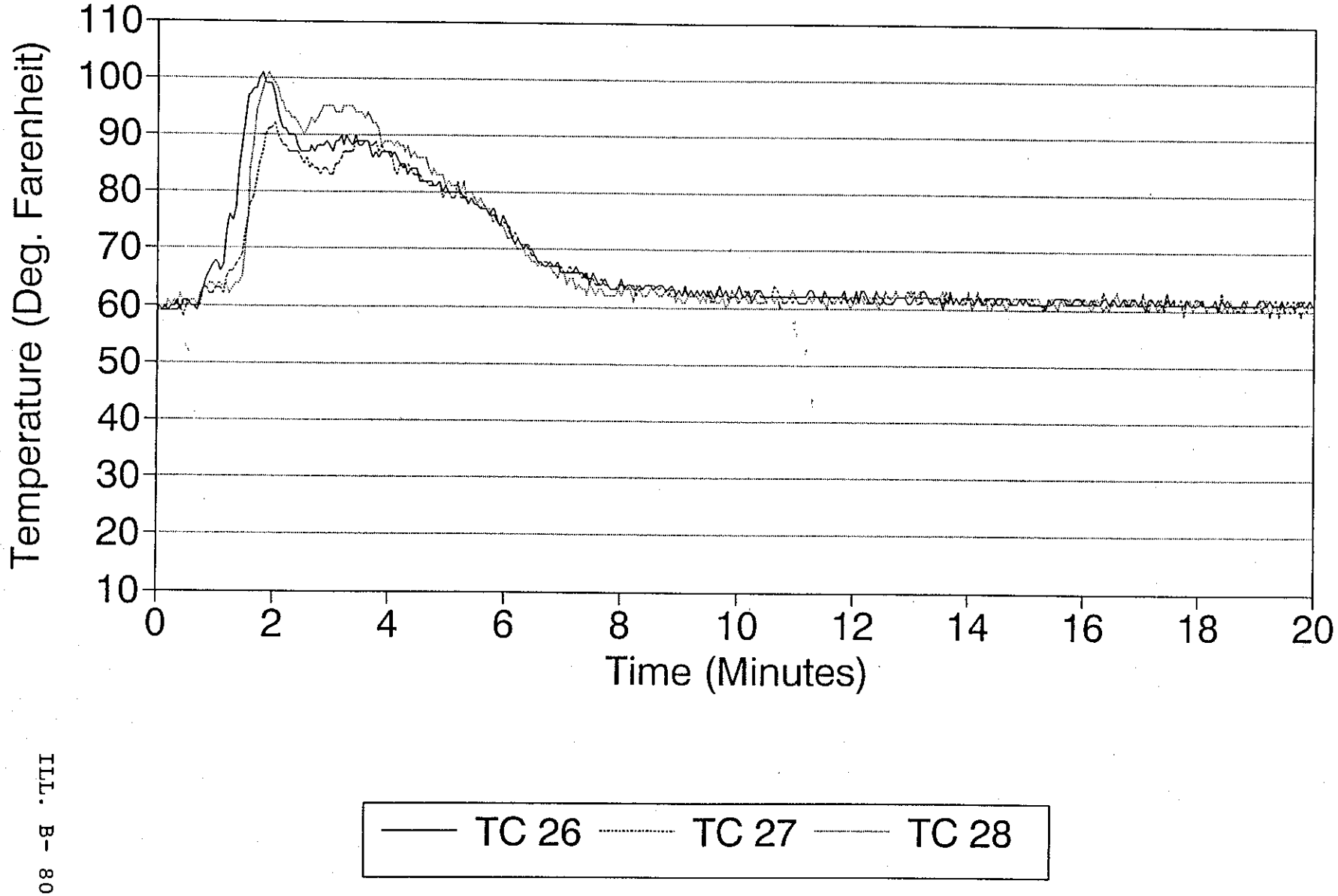
NFPRF RACK FIRE TEST NO. 10

Perimeter Temperatures



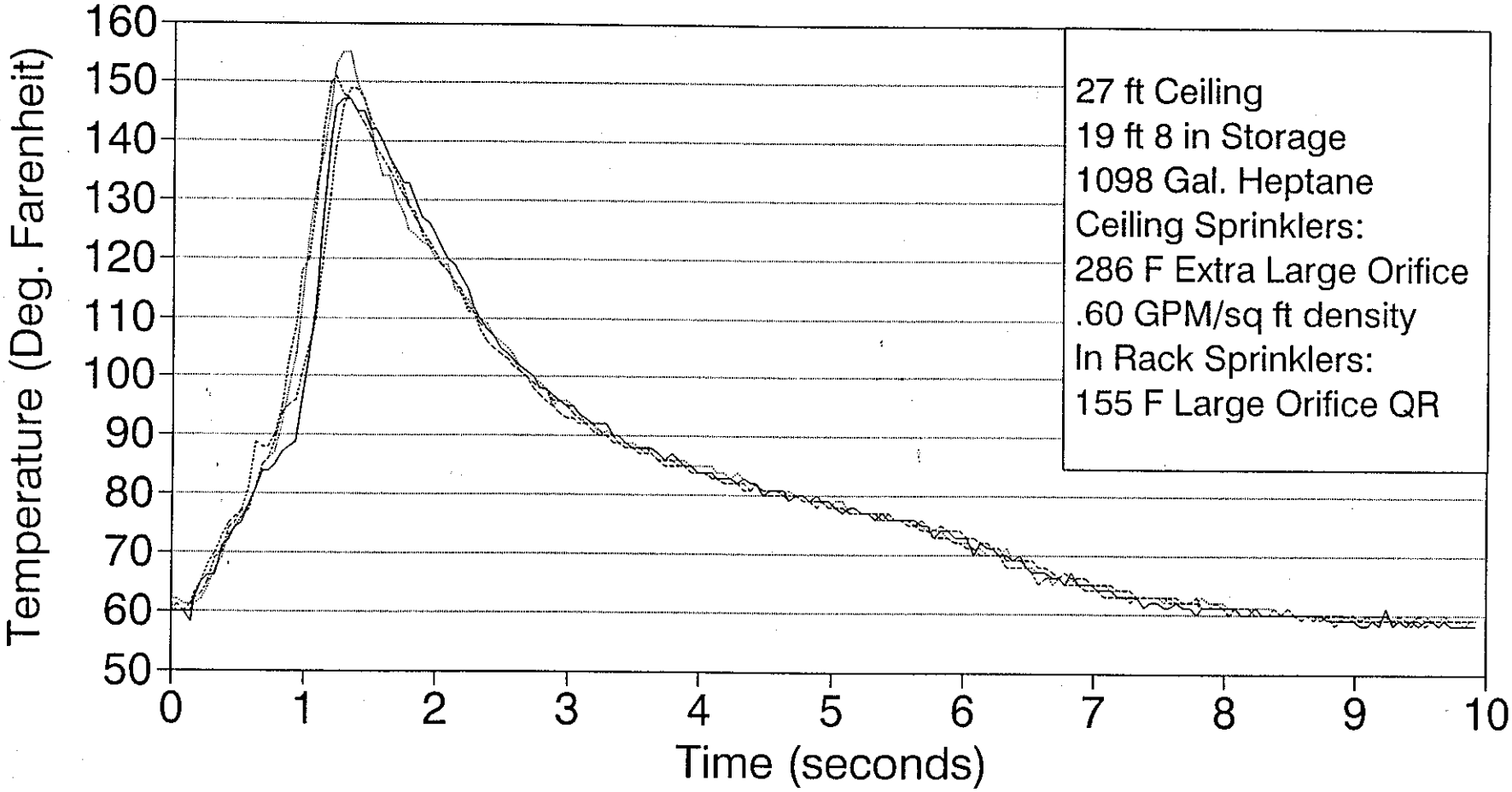
NFPRF RACK FIRE TEST NO. 10

Perimeter Temperatures



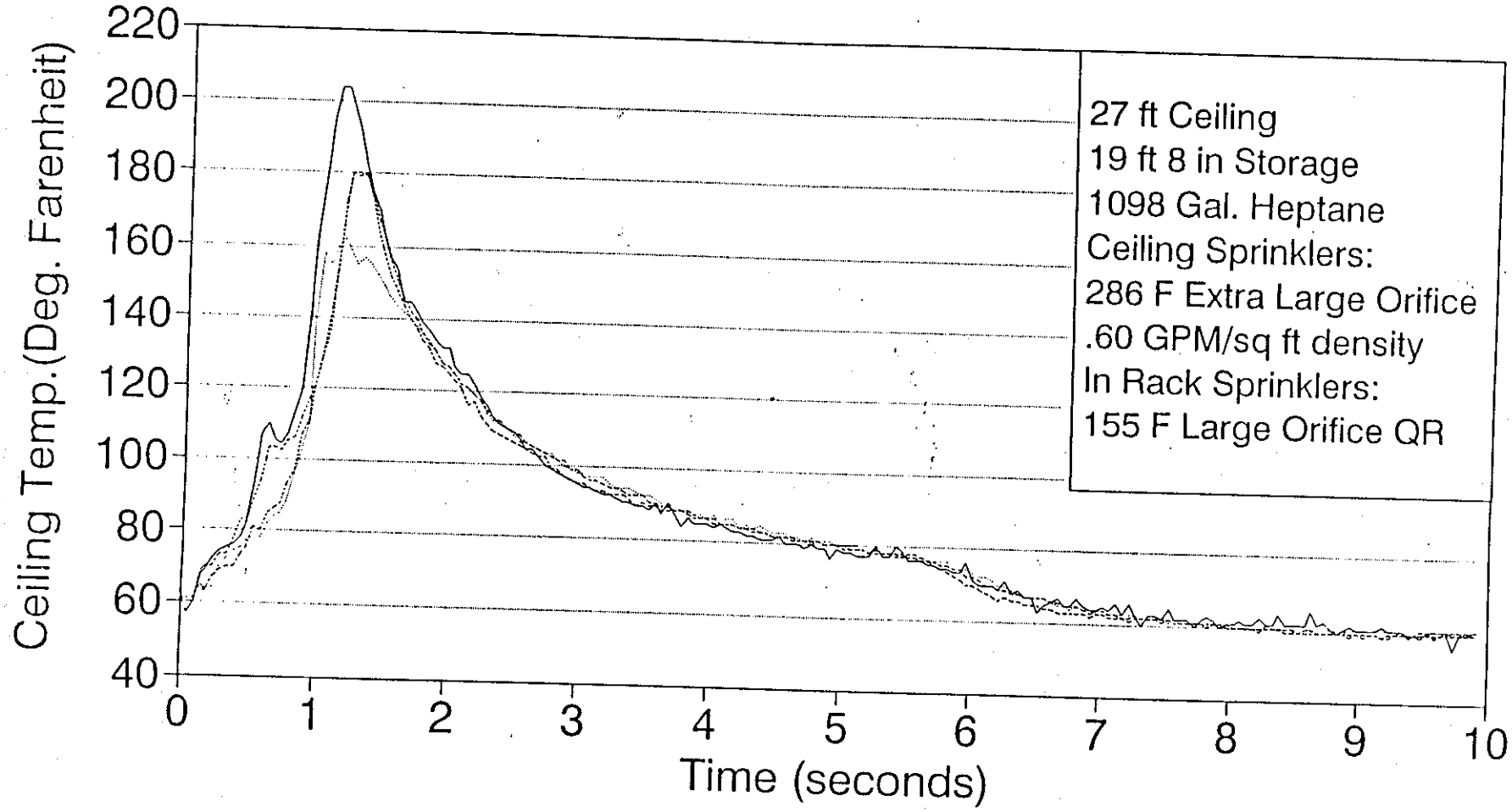
NFPRF RACK FIRE TEST NO. 11

Ceiling Temperatures



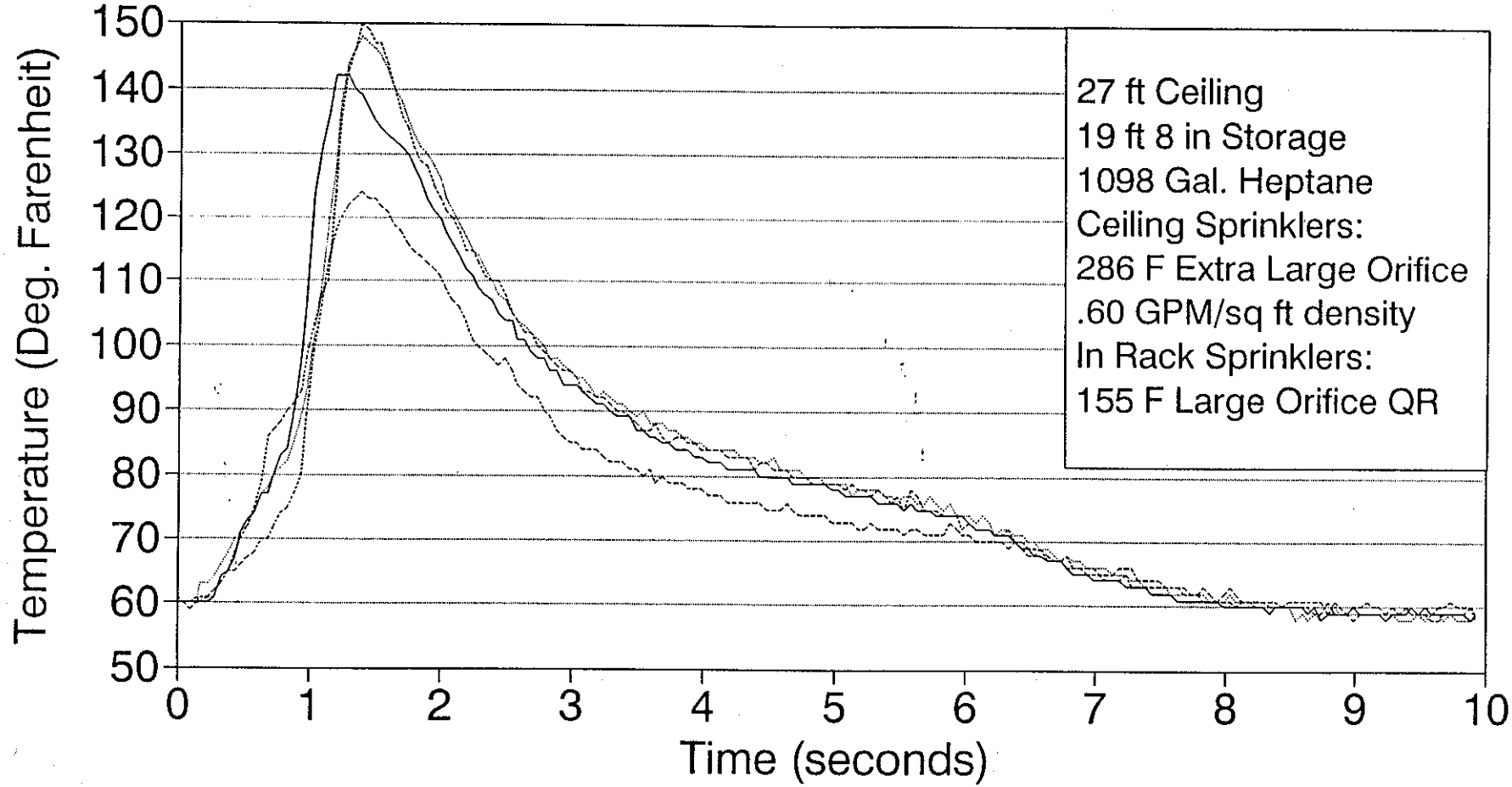
NFPRF RACK FIRE TEST NO. 11

27'Ceiling,20'Storage,73"& 138" InRacks



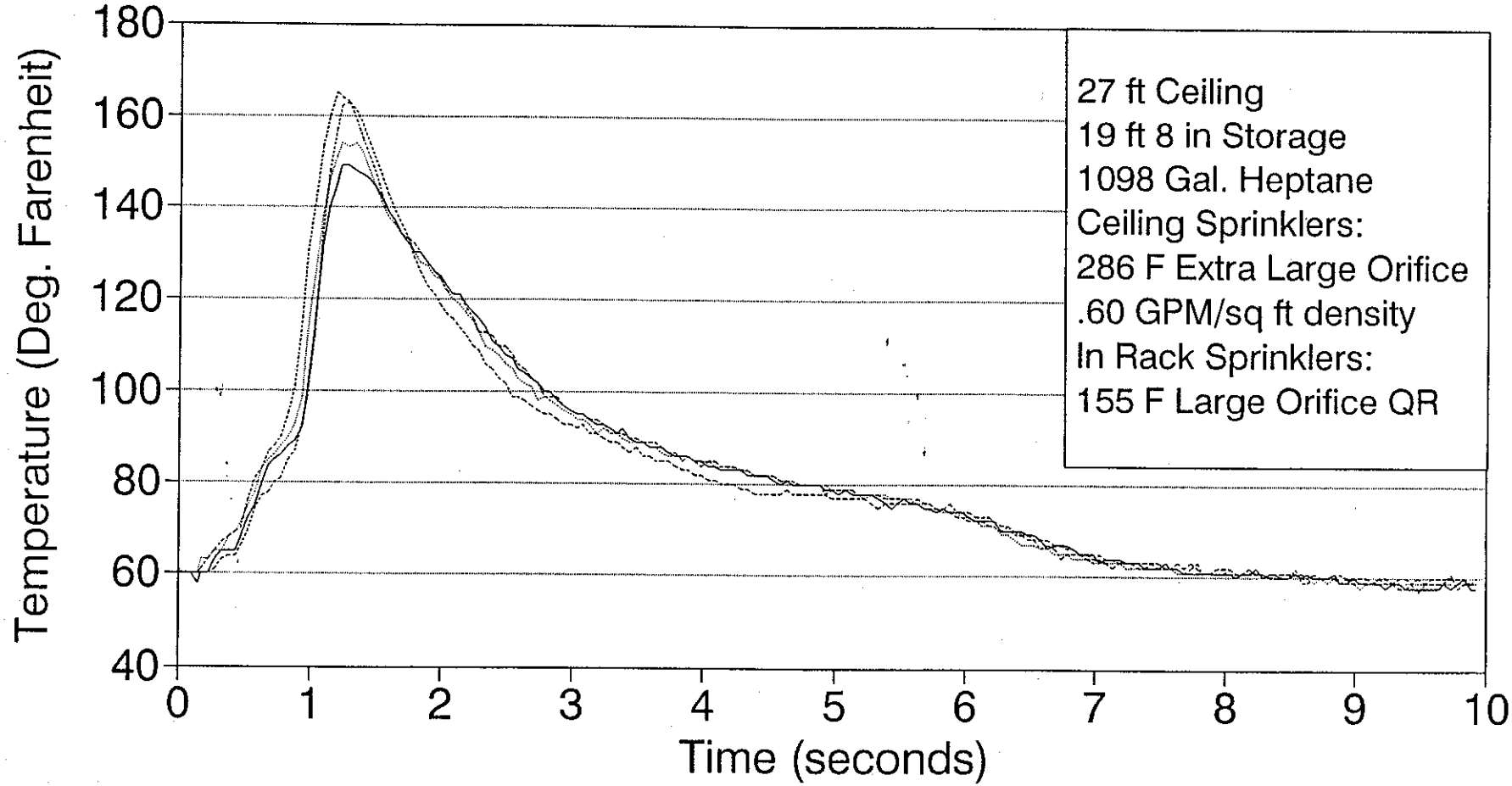
NFPRF RACK FIRE TEST NO. 11

Ceiling Temperatures



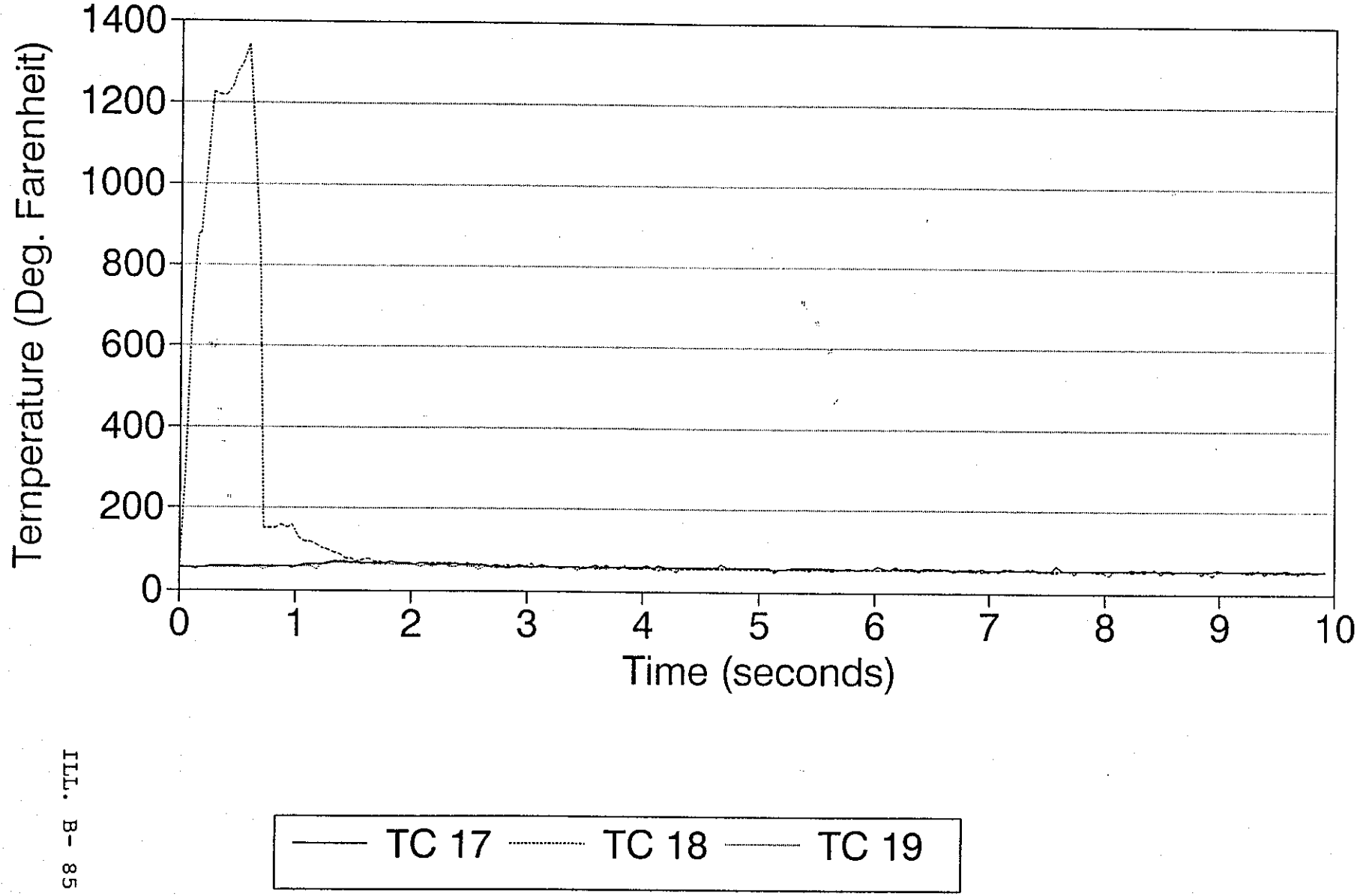
NFPRF RACK FIRE TEST NO. 11

Ceiling Temperatures



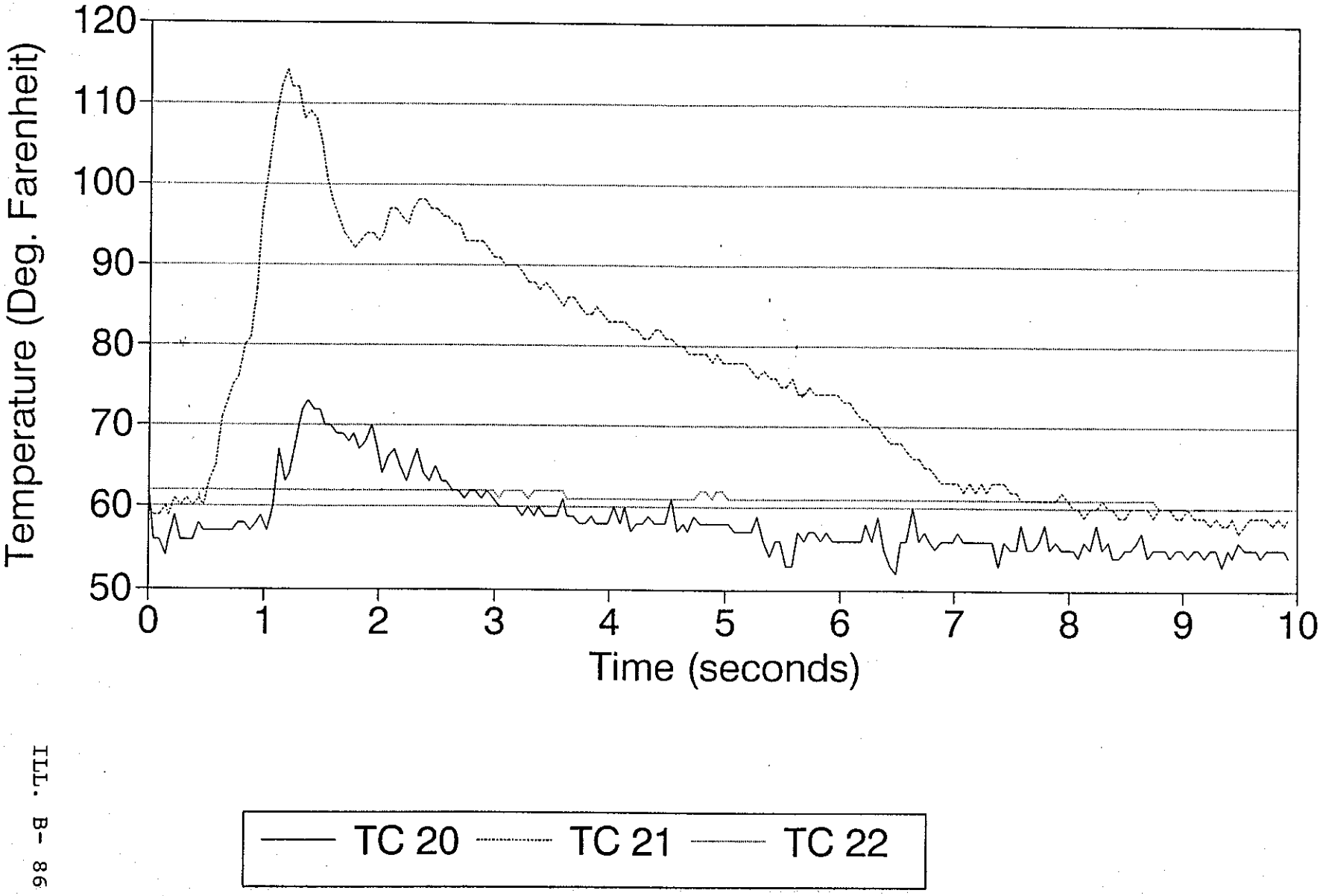
NFPRF RACK FIRE TEST NO. 11

Perimeter Temperatures



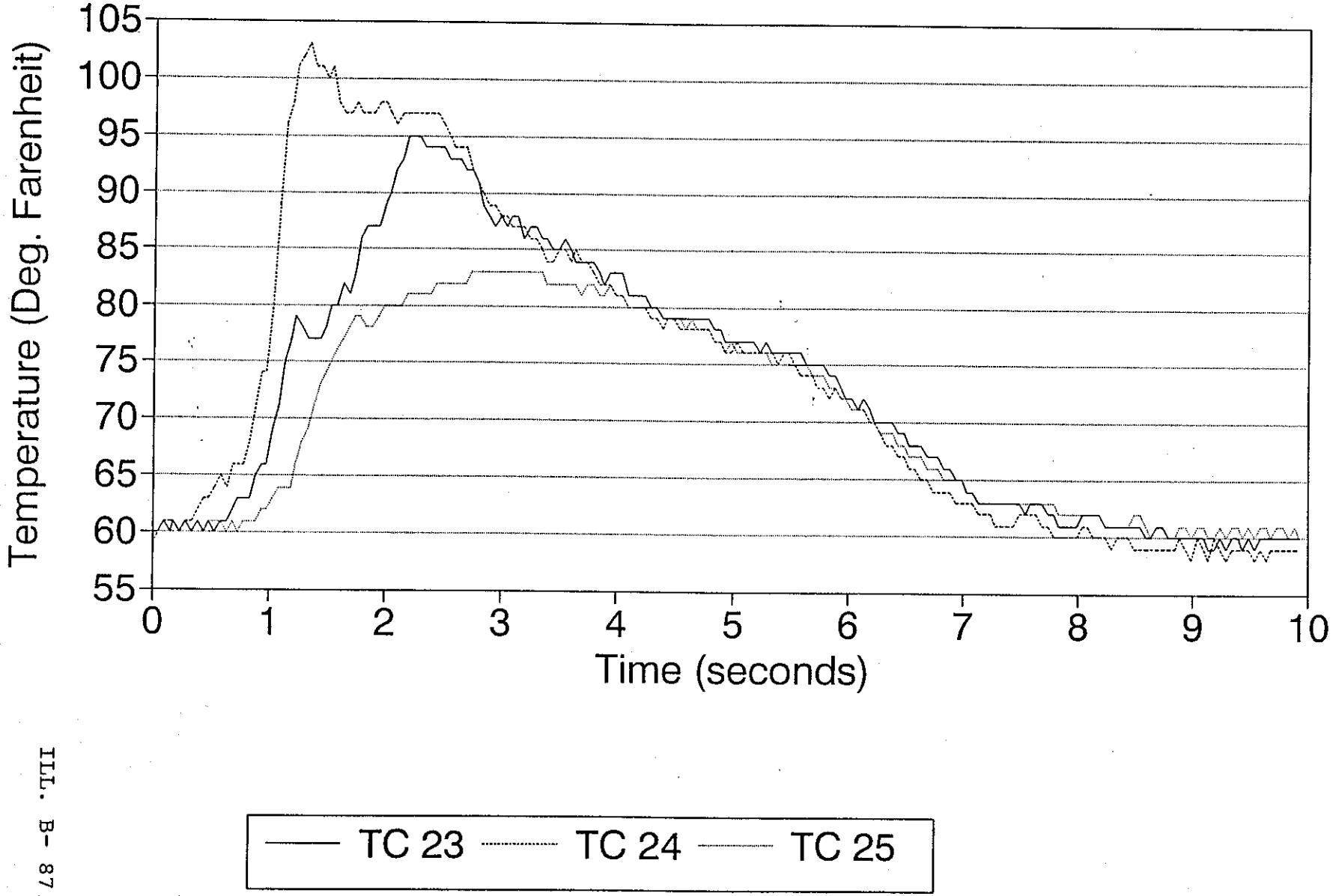
NFPRF RACK FIRE TEST NO. 11

Perimeter Temperatures



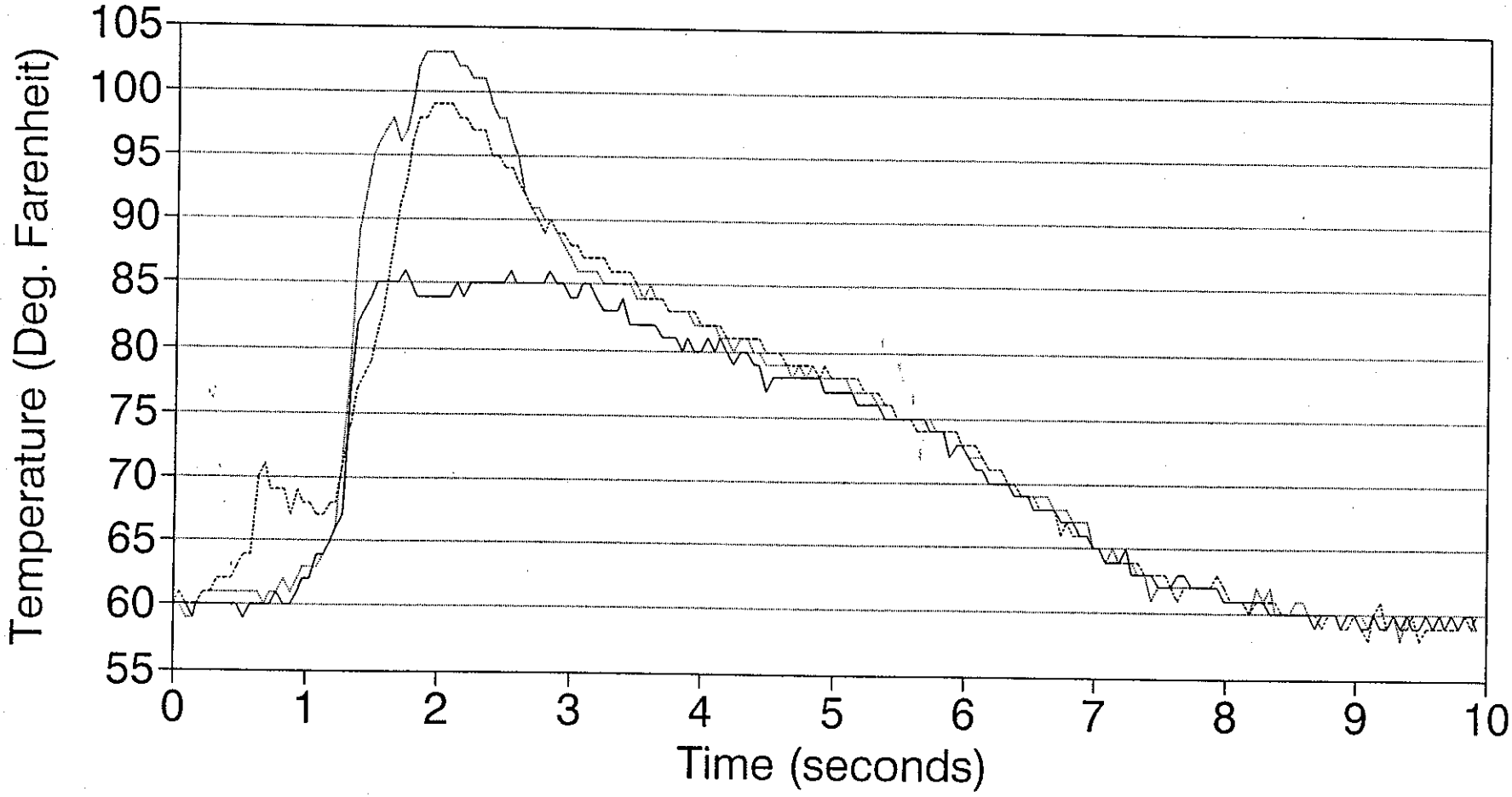
NFPRF RACK FIRE TEST NO. 11

Perimeter Temperatures



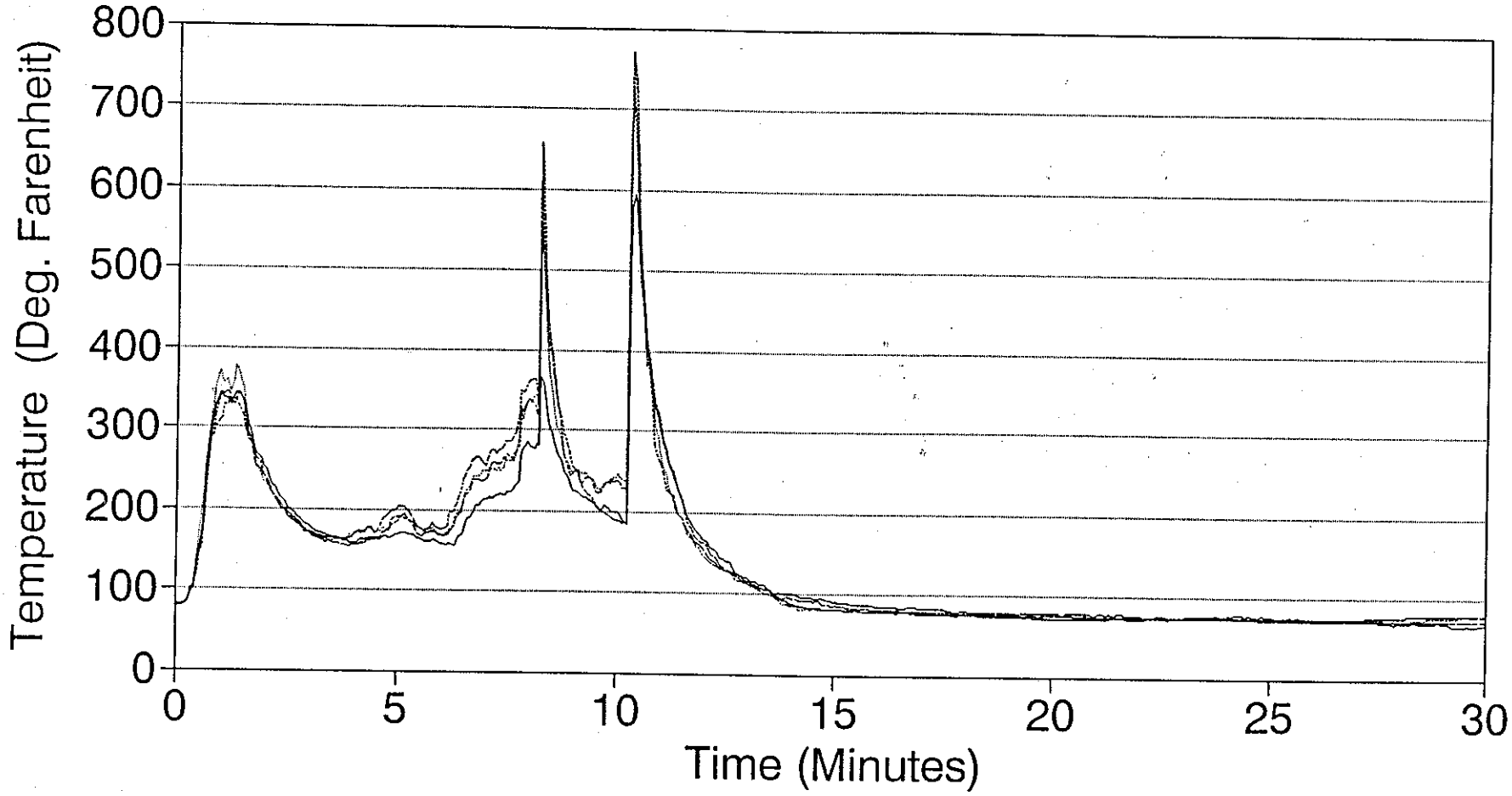
NFPRF RACK FIRE TEST NO. 11

Perimeter Temperatures



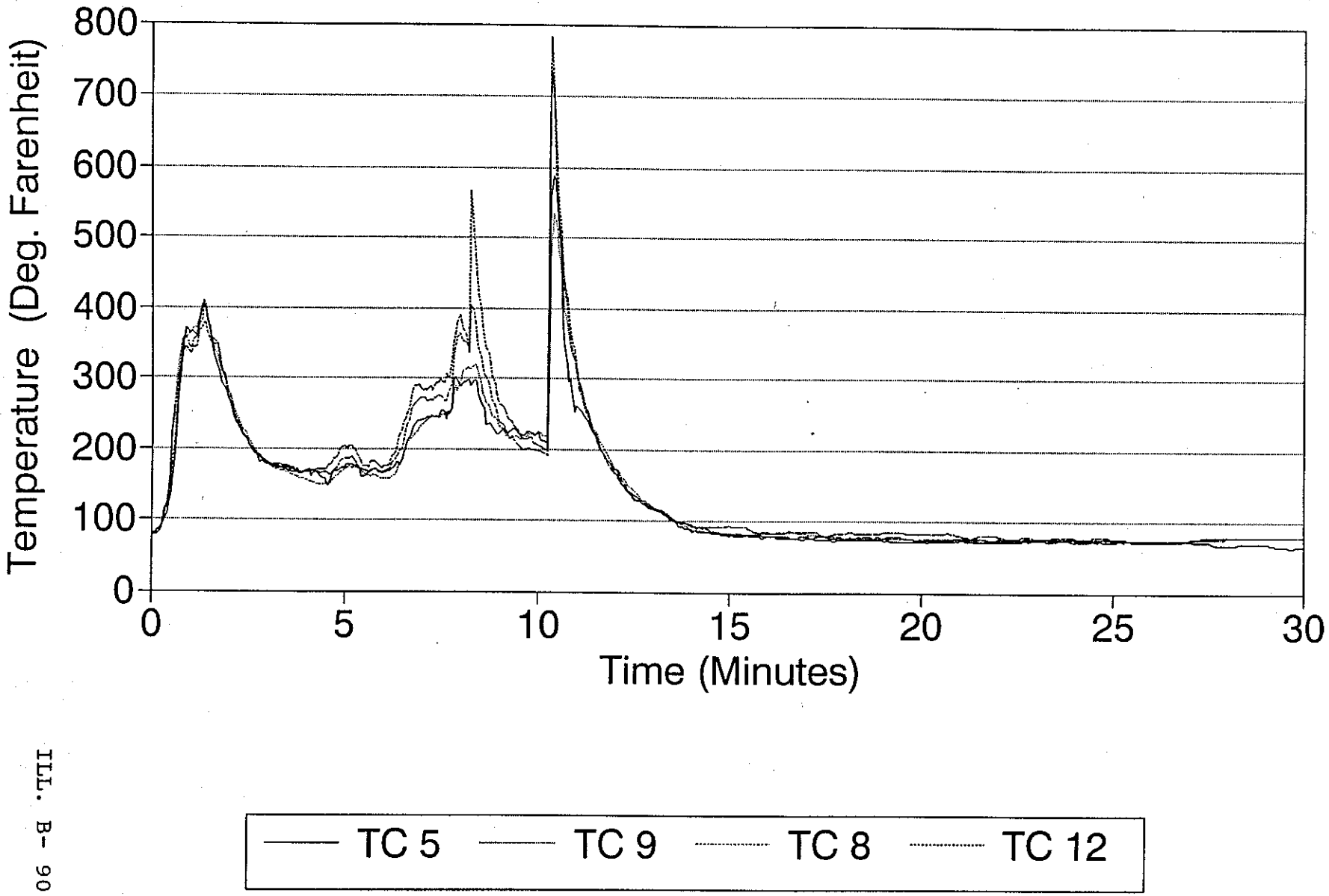
NFPRF RACK FIRE TEST NO.12

Ceiling Temperatures



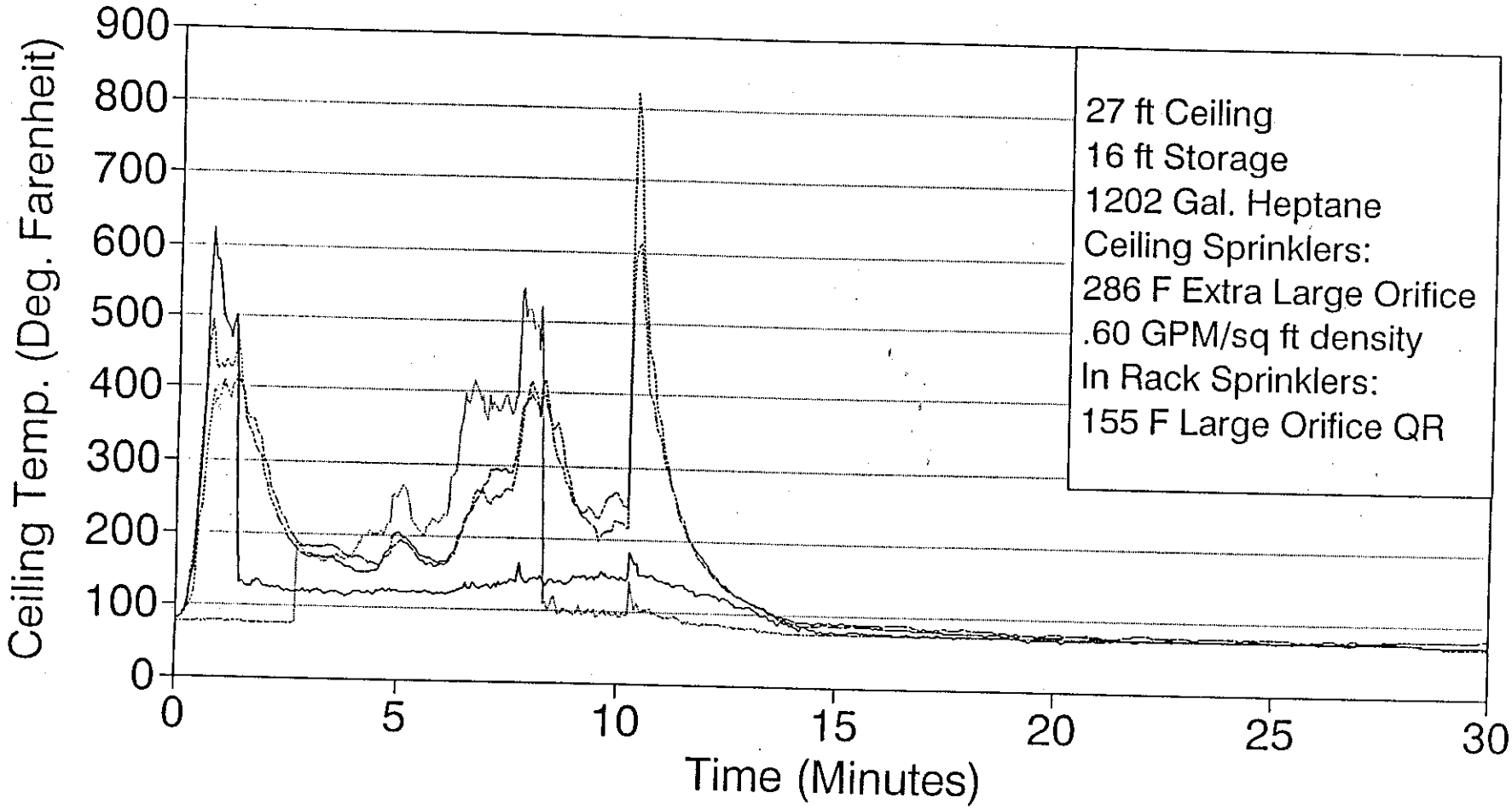
NFPRF RACK FIRE TEST NO.12

Ceiling Temperatures



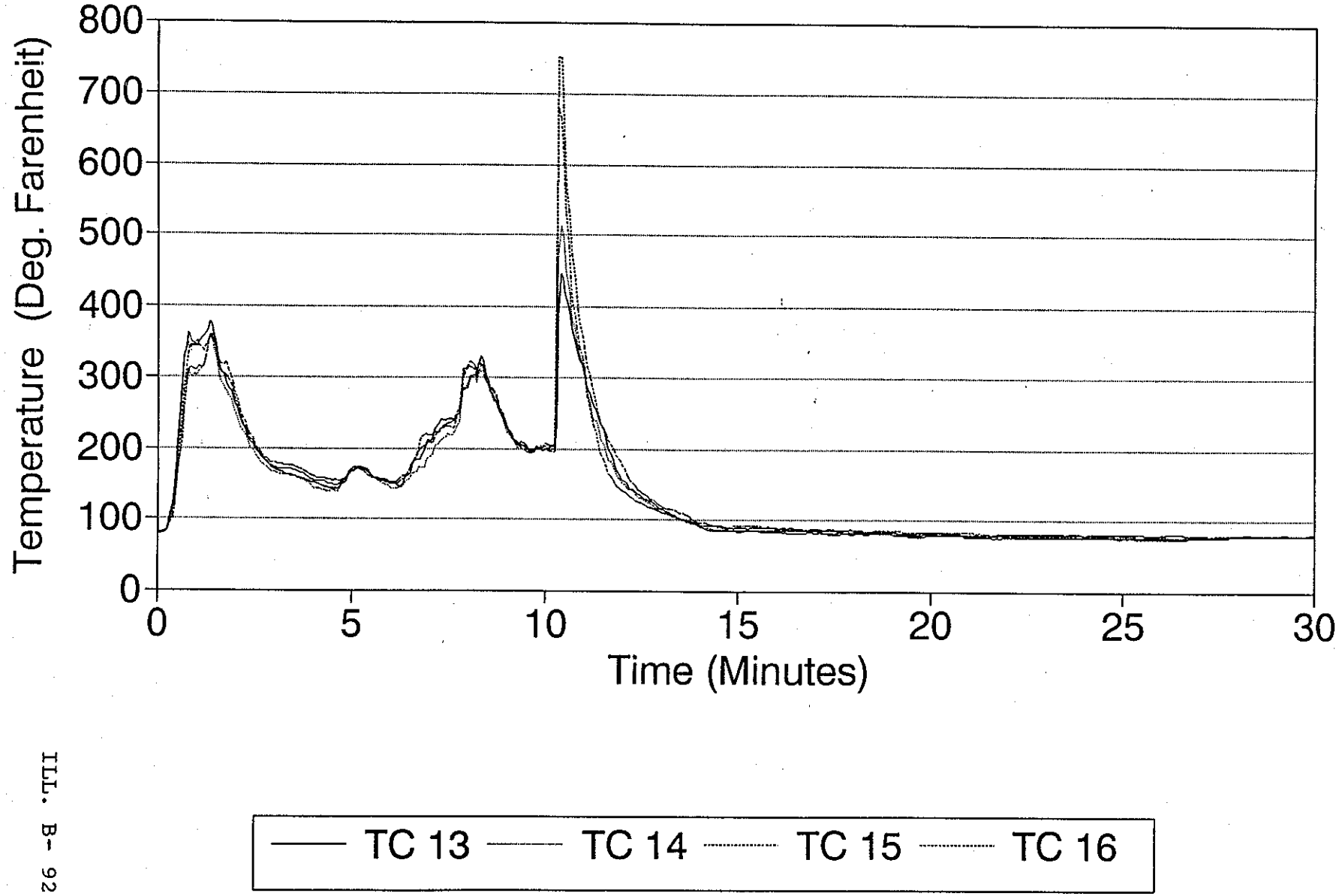
NFPRF RACK FIRE TEST NO.12

27'Ceiling, 16'Storage, 93" In-Racks



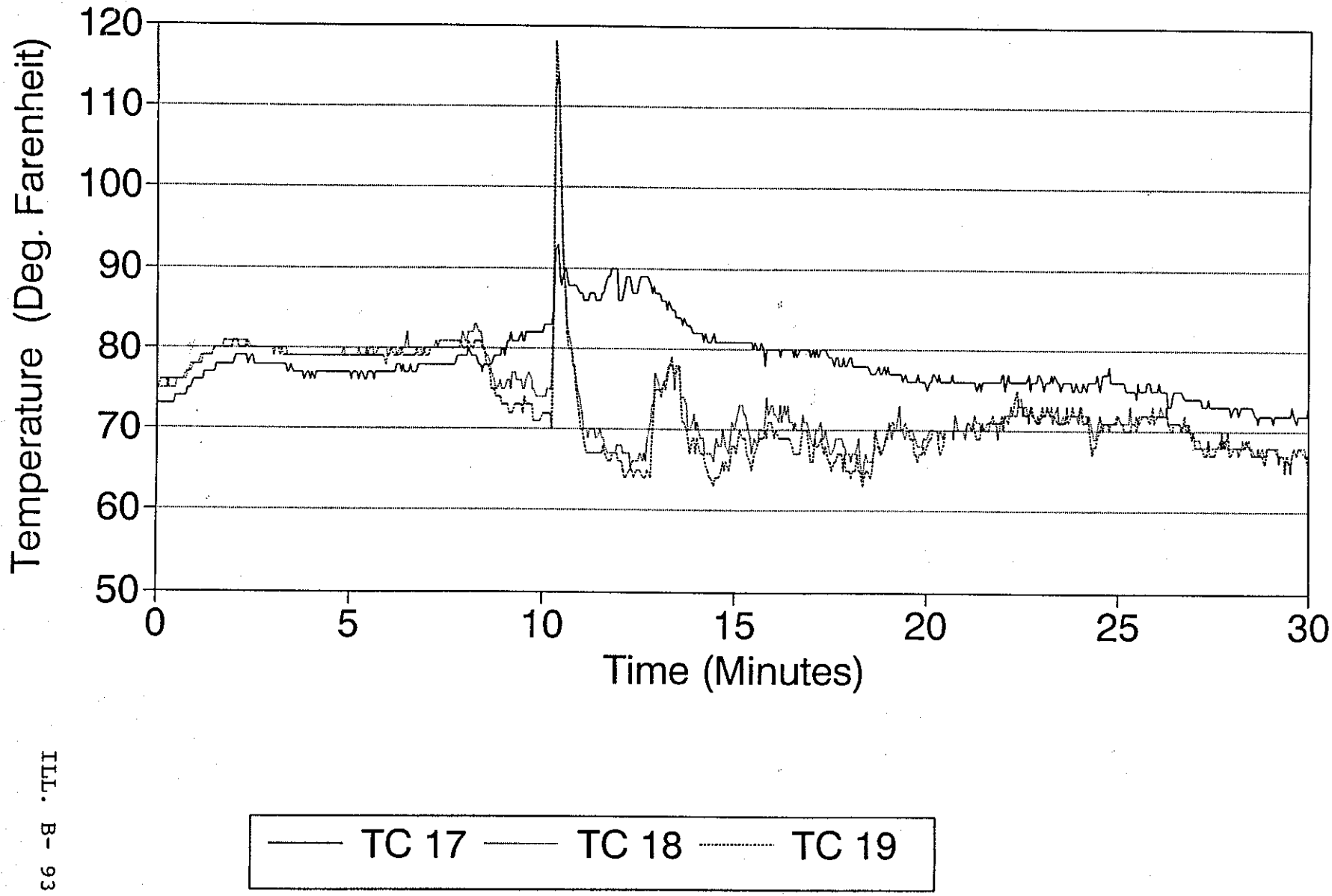
NFPRF RACK FIRE TEST NO.12

Ceiling Temperatures



NFPRF RACK FIRE TEST NO.12

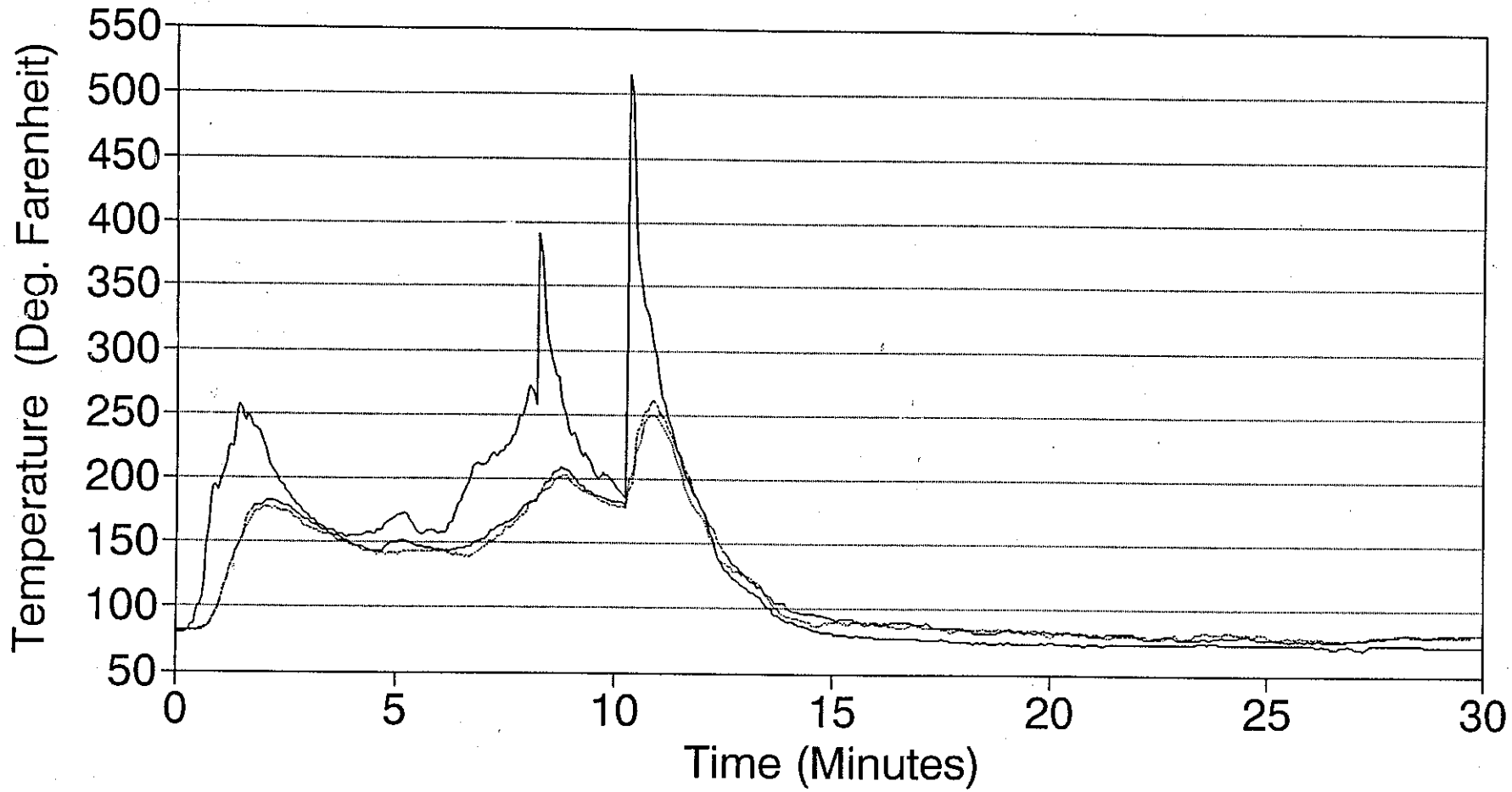
Perimeter Temperatures



ILL. B-93

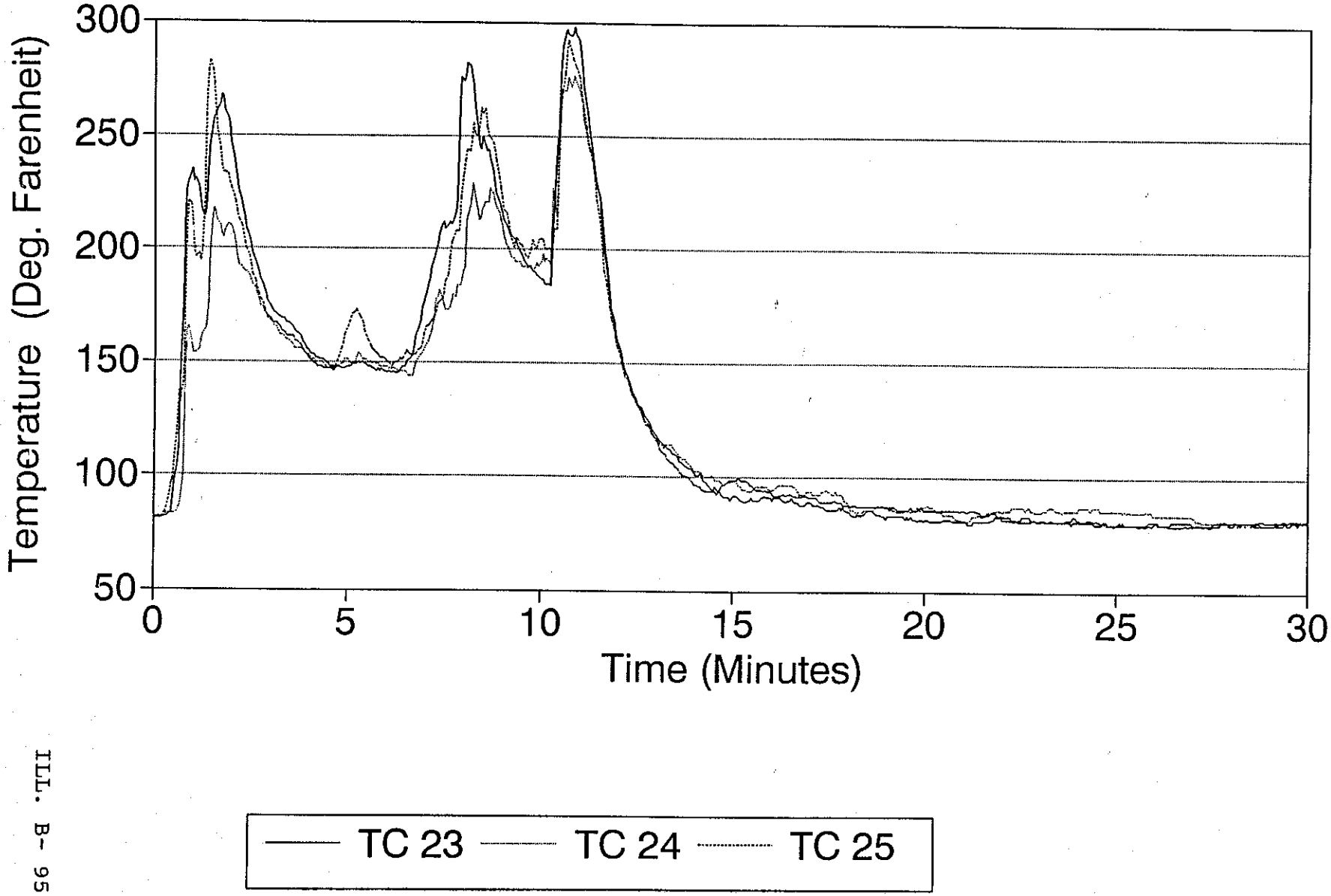
NFPRF RACK FIRE TEST NO.12

Perimeter Temperatures



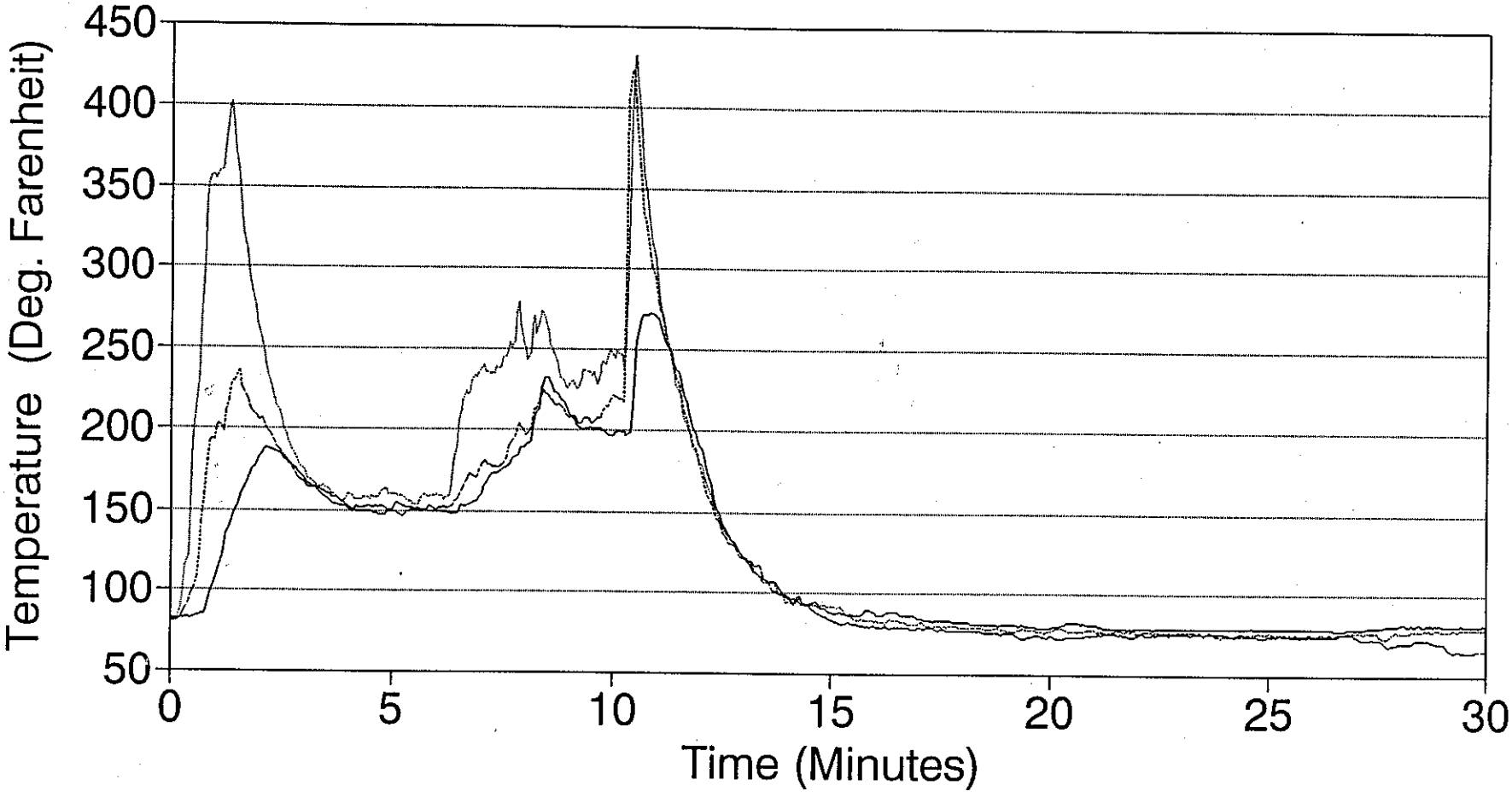
NFPRF RACK FIRE TEST NO.12

Perimeter Temperatures



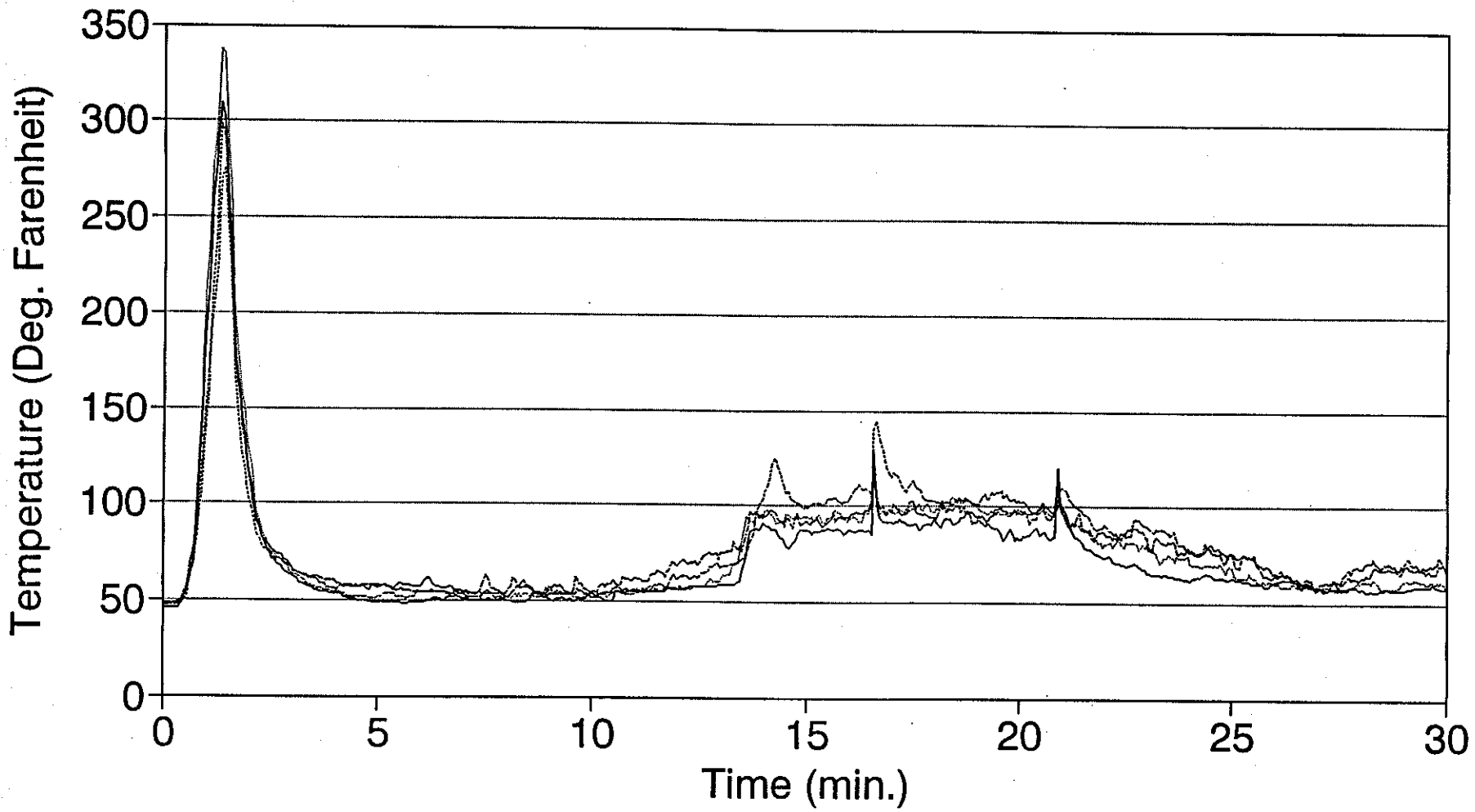
NFPRF RACK FIRE TEST NO.12

Perimeter Temperatures



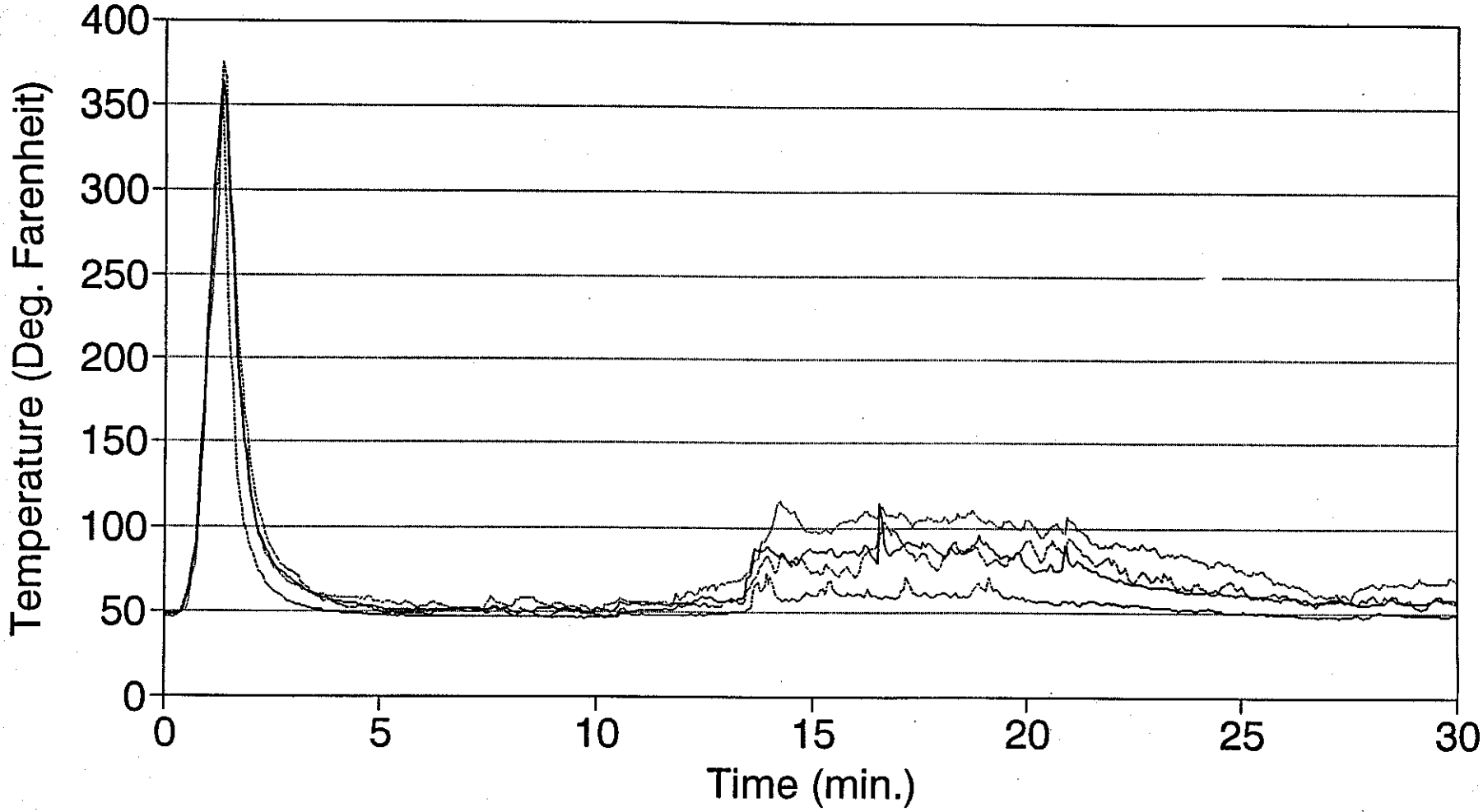
NFPRF RACK TEST NO. 16

Ceiling Temperatures



NFPRF RACK TEST NO. 16

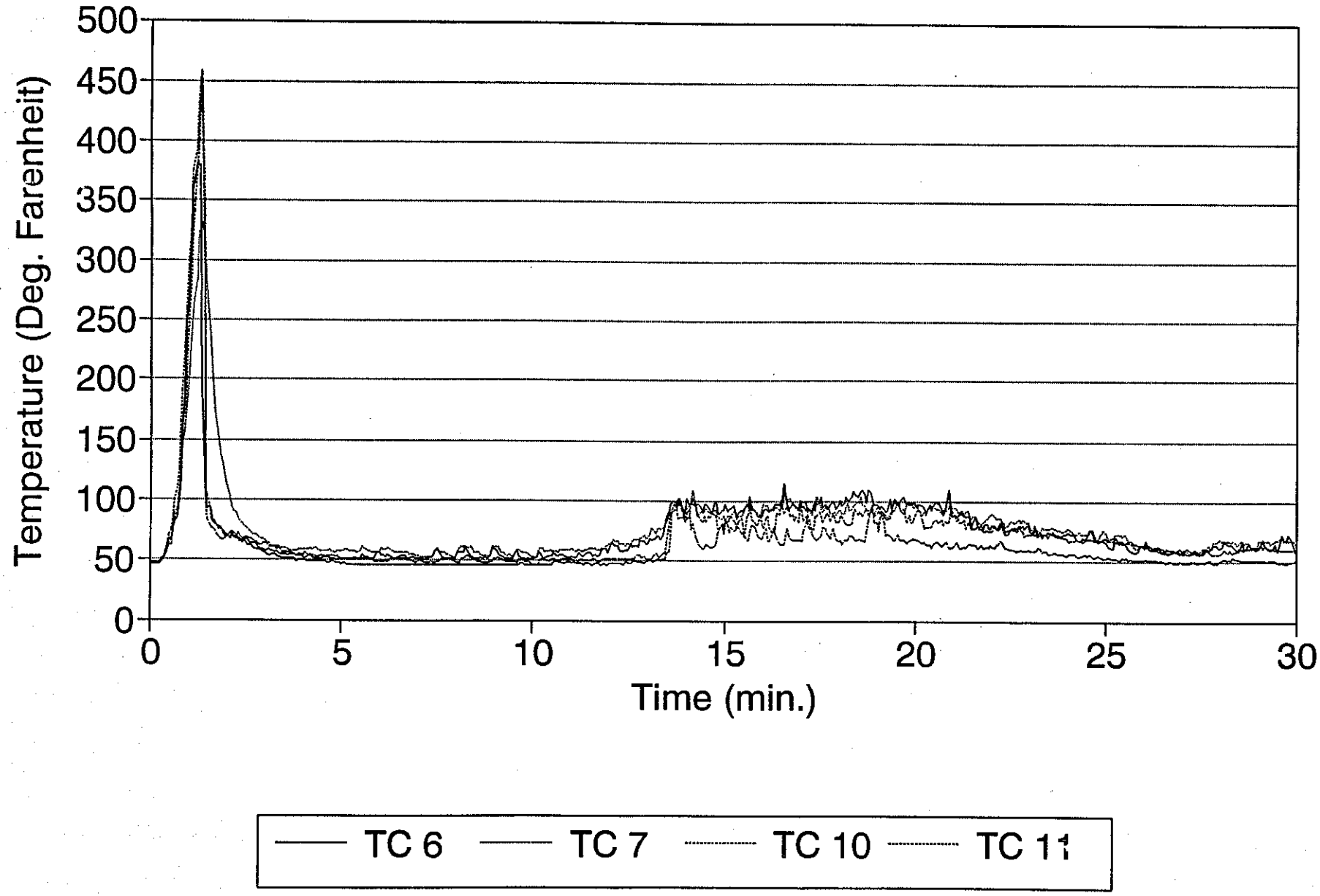
Ceiling Temperatures



TC 5 — TC 8 ····· TC 9 ····· TC 12

NFPRF RACK TEST NO. 16

Ceiling Temperatures



ILL. B-99

NFPRF RACK TEST NO. 16

Ceiling Temperatures