INTERNATIONAL
FIRE SPRINKLER ~ SMOKE & HEAT VENT ~ DRAFT CURTAIN
FIRE TEST PROJECT

Scoping Tests

TECHNICAL REPORT

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NATIONAL
FIRE PROTECTION
RESEARCH FOUNDATION

FIRE RESEARCH

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FOREWORD

The International Fire Sprinkler ~ Smoke & Heat Vent ~ Draft Curtain Fire Test Project was initiated in 1996 with the aim of documenting the fire protection performance relationships of sprinklers, vents, and curtains. Questions regarding the interactions of these measures have long been among the fundamental issues of fire protection.

This report - one of three from the project - documents the results of a test series to characterize the fire environment in the presence of sprinklers, vents, and draft curtains. Two other reports on this project are also available.

This report is written by Underwriters Laboratories Inc. All information is the product of testing at UL's Northbrook laboratories.

The Research Foundation expresses its gratitude to David Sheppard and Daniel Steppan for the thorough preparation of this report, and Underwriters Laboratories Inc. for its professional conduct of the fire tests and presentation of the data. The Foundation and its authors thank the project's technical director Kevin McGrattan of National Institute of Standards & Technology, and the Technical Advisory Committee for their contributions of expertise and the financial resources required to complete this first phase of the project.

A Technical Advisory Committee, such as the one for this project, is generally made up of individuals and groups who have expertise or interest related to the subject of a Research Foundation project, some of whom are also sponsors who provide financial support for the project. A Technical Advisory Committee provides review and advice regarding a project. The content and conclusions contained in the Research Foundation report, however, are solely those of the authors of the report, and participation on a Technical Advisory Committee does not necessarily imply agreement with those contents and conclusions.

Sprinkler, Heat/Smoke Vent, Draft Curtain Project
National Fire Protection Research Foundation

Scoping Tests

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Abstract

This report presents the results of a series of 22 tests conducted to characterize the fire environment in the presence of sprinklers, vents, and draft curtains. The tests consisted of Air Flow Characterization Tests and Sprinkler Characterization Tests.

The tests were conducted in Underwriters Laboratories large scale fire test facility in the 120 by 120 ft. test room. The 100 by 100 ft. movable ceiling was positioned at 25 ft., and a 6 ft. draft curtain was attached to the ceiling to enclose a nominal area of 5000 ft^2. A 4 by 8 ft. ceiling vent was mounted in the ceiling. Upright sprinklers on a 10 by 10 ft. spacing were used for 22 tests. A heptane spray burner with a growing fire at a controlled rate was used for each test.

The results of the test series include data with respect to the fire environment in the presence of sprinklers, vents, and draft curtains. The data also includes information on carbon monoxide, carbon dioxide, and oxygen concentrations.

Contents

Table of Figures

List of Tables

Abbreviations

ADD	actual delivered density
BTU	British thermal unit
cal	calorie
°C	Centigrade
CO	carbon monoxide
CO_2	carbon dioxide
ft.	foot
°F	Fahrenheit
gpm	gallons per minute
h	hours
in.	Inch
kg	kilogram
kW	kiloWatts
m	meter
NFPRF	National Fire Protection Research Foundation
NIST	National Institute for Standards and Technology
O_2	oxygen
psi	pounds per square inch
psig	pounds per square inch gage pressure
RDD	required delivered density
RTI	response time index
SCFM	standard cubic feet per minute
UL	Underwriters Laboratories Inc.
W	Watt
'	feet
"	inches

Introduction

This investigation represents the first part of a three part effort by the National Fire Protection Research Foundation, NFPRF, to study the effects of ceiling vents in warehouses. The three parts of this project are defined as follows:

1. Scoping Tests
2. Preliminary Full Scale Commodity Fires
3. Final Full Scale Commodity Fires

The tests described by this report represent the *Scoping Tests* portion of the NFPRF's efforts. The scoping tests consisted of the following:

- **Air Flow Characterization Tests** - Growing fire tests were performed below a flat ceiling bounded by a draft curtain. The tests were conducted with a 4 by 8 ft. ceiling vent centered among sprinklers.
- **Sprinkler Characterization Tests-** Tests were performed to determine the discharge area density of the sprinklers used in the air flow characterization tests.

A detailed description of the two test series is provided herein.

PURPOSE

The purpose of this test program was to conduct tests to characterize the fire environment in the presence of sprinklers, vents, and draft curtains. The information obtained by this investigation is to be submitted to the National Fire Protection Research Foundation for their consideration only.

GENERAL

In no event shall UL be responsible to anyone for whatever use or nonuse is made of the information contained in this Report and in no event shall UL, its employees or its agents incur any obligations or liability for damages, including, but not limited to, consequential damage, arising out of or in connection with the use or inability to use the information contained in this Report.

Information conveyed by this Report applies only to the specimens actually involved in these tests. UL has not established a factory Follow Up Service Program to determine the conformance of subsequently produced material nor has any provision been established to apply any registered mark of UL to such material.

The issuance of this Report in no way implies Listing, Classification or Recognition by UL and does not authorize the use of UL Listing, Classification or Recognition Marks or other reference to UL on or in connection with the product or system.

Test Facility

The fire tests were conducted in Underwriters Laboratories large scale fire test facility located in Northbrook Illinois. The large-scale fire test building used for this investigation houses four fire test areas which are used to develop data on the fire growth and fire suppression characteristics of commodities, as well as the fire suppression characteristics of automatic water sprinkler systems.

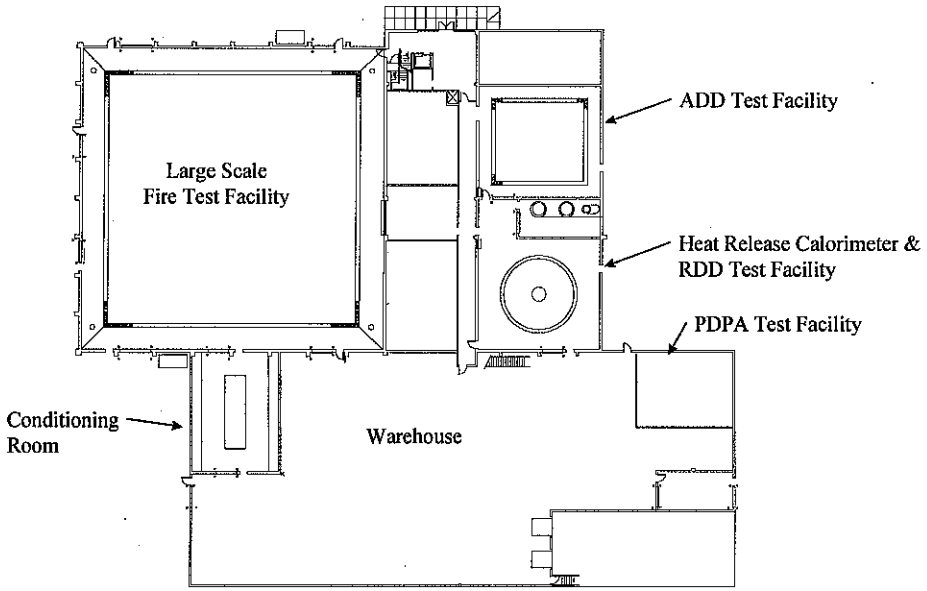


Figure 1. Test Facility

LARGE-SCALE FIRE TEST FACILITY

This unique fire test facility consists of a 120 x 120 ft. main fire test cell which is equipped with a 100 x 100 ft. adjustable height ceiling. The height of the ceiling may be adjusted by 4 hydraulic rams up to a maximum height of 48 feet. The ceiling has a load capacity of 250 tons. A flexible design sprinkler piping is available at the ceiling to permit any arrangement of sprinkler spacing with minimum pressure losses. Further the sprinkler deflector can be adjusted to be a specified distance from the ceiling. The sprinklers are provided with water during a fire test from a 200,000 gallon water reservoir using two 3,000 gpm water pumps rated at 150 psi. The water pumps are computer controlled to provide the required water demand during a fire test. The facility also has the capability to induce fire suppression foam when fighting a hydrocarbon fuel fire.

The exhaust flow rate in the fire test facility can be adjusted to provide a maximum of 60,000 SCFM. Four, 5 ft. diameter, inlet ducts provide make up air in the test facility and are located at the walls 10 ft. above the test floor to minimize any induced drafts during the fire tests. The combustion products from the fire test are exhausted through a regenerative smoke abatement system.

The facility has grated floor drains connected to a water treatment facility to separate debris, other effluents, and water released during the fire test.

The main fire test cell may be used for investigating the performance of sprinkler systems using standard (e.g., Group A, Class II) or non-standard (e.g., combustible liquids) commodity. It may also be used for evaluating new storage methodologies, or fire protection schemes.

Air Flow Characterization Tests

OBJECTIVE

The objective of the air flow characterization tests was to develop data with respect to fire environments in the presence of sprinklers, draft curtains and ceiling vents for use by NIST to calibrate and validate their computer model.

TEST PLAN

The investigation consisted of conducting a series of fire tests under a flat ceiling and measuring the resulting environment. During the tests fire location, maximum fire size, ceiling vent opening times, and use of draft curtains were varied to determine their effect on sprinkler operation and the fire environment. Ceiling height and sprinkler locations were unchanged for all air flow characterization tests.

Test Set Up

The tests were conducted in Underwriters Laboratories Building #11 large scale fire test facility in the 120 by 120 ft. test room. The 100 by 100 ft. movable ceiling was positioned at a 25 ft. elevation for the tests. A 6 ft. high draft curtain was attached to the ceiling to enclose a nominal area of 5000 ft². Upright sprinklers on a 10 by 10 ft. spacing were used for 21 tests. The 22nd test had no operative sprinklers. A 4 by 8 ft. ceiling vent was mounted in the ceiling. A schematic of the test set-up is provided in Figure 2.

A heptane spray burner was placed in various positions on the floor, and a growing fire was used for each test.

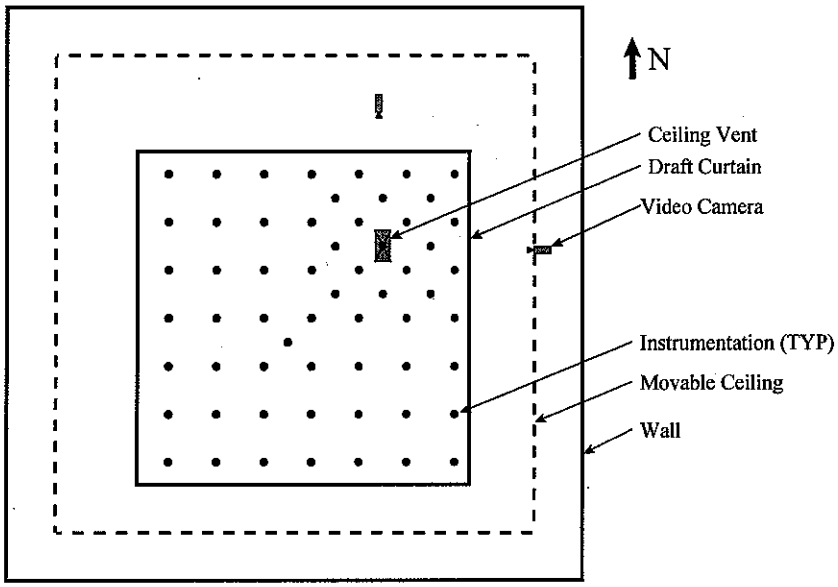


Figure 2. Reflected Plan View - Test Set-Up

The dimensions of the test set-up are provided in Figure 3.

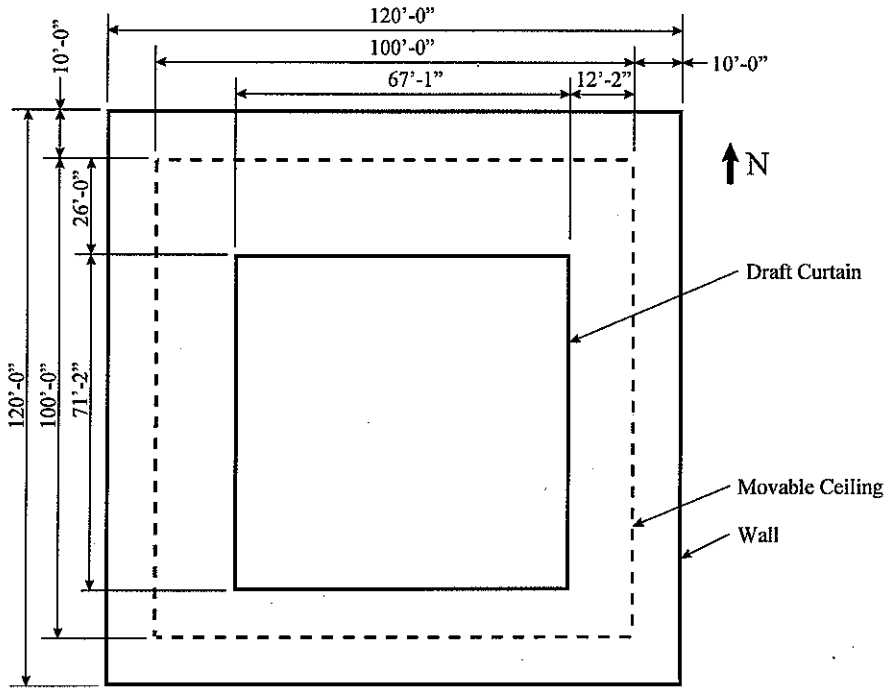


Figure 3. Reflected Plan View - Set-Up Dimensions

CEILING

The ceiling was constructed of 24 by 48 by 5/8 inch thick UL fire rated ceiling tiles suspended from 1.5 inch wide steel angle brackets.

The ceiling tiles had the following reference thermal properties: density of 27 lb/ft^3 (313 kg/m^3); thermal resistance of 1.4°F h/BTU (2.65 °C/W); thermal conductivity of 0.424 BTU-in/h-ft^2-°F (0.0611 W/m°C); specific heat of 0.18 cal/gm°C (753 J/kg°C); thermal diffusivity of 2.6 x 10^{-7} m^2/s.

The ceiling height was adjusted to be 25 ft. above the floor for these tests.

DRAFT CURTAIN

A 6 ft. high draft curtain was suspended from the ceiling. The draft curtain was constructed of 54 inch wide pieces of 18 gage sheet metal. The seams in the draft curtain were connected with aluminum tape. The draft curtain enclosed an area 67'-1" wide by 71'-2" long.

SPRINKLER PIPING

The sprinkler piping consisted of seven branch lines and two manifolds suspended from the ceiling within the draft curtains.

The branch lines were mounted at a 10 ft. spacing. The branch lines were 2 inch Schedule 40 pipe. The branch lines had a 2.375 inch outer diameter and were mounted with a 8.5 inch nominal clearance from the centerline of the pipe to the ceiling.

The manifolds were mounted below the branch lines and were used to plumb the water to the branch lines. The manifolds were 2.5 inch Schedule 40 pipe. The manifolds had a 2.875 inch outer diameter and were mounted with a 40.75 inch nominal clearance from the centerline of the pipe to the ceiling.

A schematic of the sprinkler piping is shown in Figure 4.

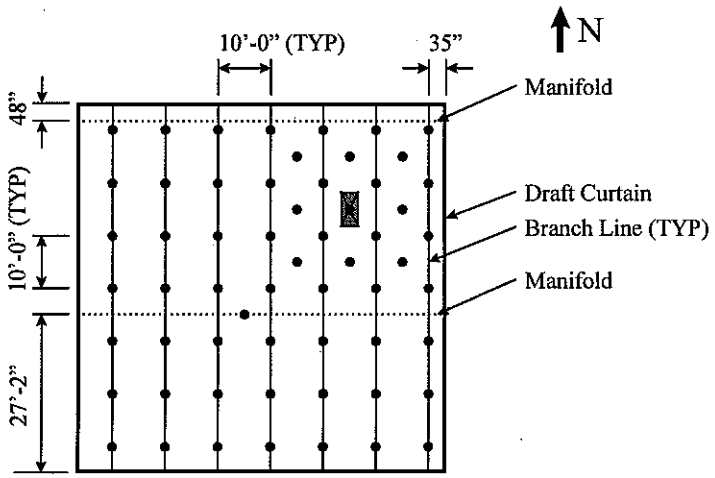


Figure 4. Reflected Plan View - Sprinkler Piping

The branch lines and manifolds were filled with water during all tests.

SPRINKLERS & WATER FLOW

The sprinklers were 0.625 inch nominal orifice size. The sprinklers had a reference actuation temperature of 165°F and a response time index, RTI, of 268 (ft·sec)½ [148 (m·s)½]. The conductivity factor for the sprinklers was 1.3 (ft/s)½ [0.7 (m/s)½]. The sprinklers were attached to the branch lines. There was a 3 inch distance from the top of the deflector to the bottom of the ceiling. There was a 4.25 inch spacing from the center of the link to the bottom of the ceiling. The sprinklers were installed on the branch lines to provide a 10 by 10 ft. spacing.

The pump system was set to provide a flow of 50 gallons per minute to each sprinkler, which in turn provided a 0.50 gpm/ft² density based on the sprinkler spacing. The pressure at each sprinkler was approximately 19 psig to provide the proper flow rate.

FIRE SOURCE AND LOCATION

The fire source in these tests consisted of a heptane burner constructed from a 1/2 inch pipe manifold as shown in Figure 5. Atomizing spray nozzles were used to provide a free spray of heptane which was then ignited to provide the fire source. The number and locations of atomizing nozzles used depended on the maximum heptane flow expected during the test. The two configurations used were nozzles in positions A,B,D,G for fires less than 5 MW, and A,B,C,D,E,F,G for fires greater than 5 MW. The pipe manifold was mounted on four cinder-blocks for the tests.

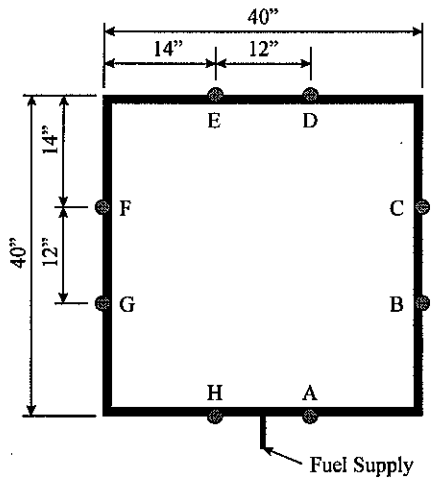


Figure 5. Heptane Burner

The heptane flow rate was controlled to create a growing fire following the equation shown in Eq. 1.

$$\dot{q} = 10000\left(\frac{t}{\tau}\right)^2 \qquad \text{Eq. 1}$$

Where $\dot{q}$ is the heat release rate of the fire in kW, t is the time in seconds, and τ is a fire growth constant, 75 seconds.

The flow of heptane to the burner was manually controlled using two float type flow meters. The two flow meters were connected in parallel. The first flow meter had a resolution of 0.02 gpm and a range from 0.18 gpm to 2.4 gpm. The second flow meter had a resolution of 0.3 gpm and a range from 0.24 gpm to 3.0 gpm.

The accuracy of the fire growth curves used in the tests was determined by comparing the fire sizes to the theoretical fire sizes. This was accomplished by placing the heptane burner under a product calorimeter, and creating growing fires similar to the fires developed for the air flow characterization tests. The results of these tests including total chemical heat release rate and convective heat release rate are provided in Figure 6. The measured convective fraction was found to be approximately 65%. The tabulated data are provided on the attached diskette. The data file is named FIRE1.CSV.

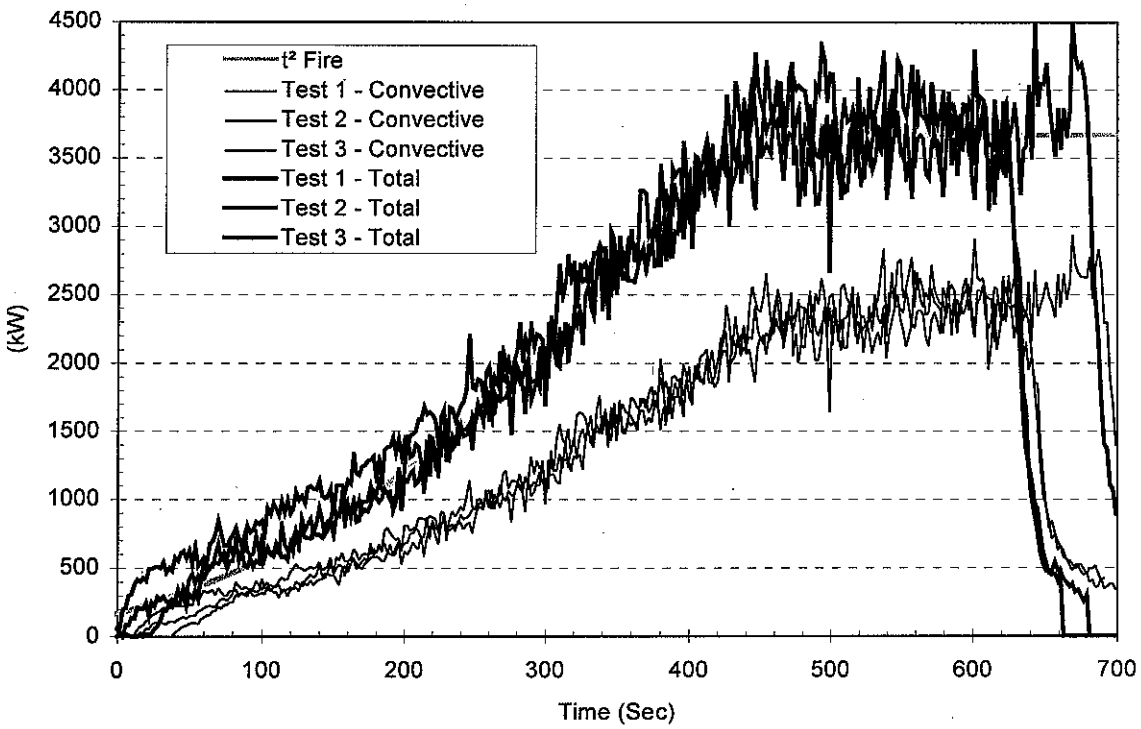


Figure 6. Fire Growth Curve

The fire was positioned in one of four locations during this test series. For each location the fire was centered between four sprinklers as shown in Figure 7.

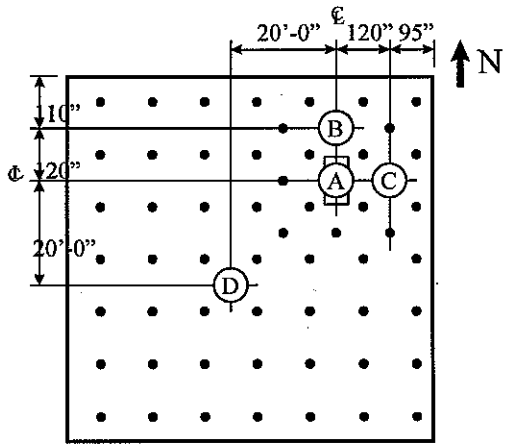


Figure 7. Reflected Plan View - Fire Locations

CEILING VENT

A ceiling vent was mounted in the ceiling. The vent was designed to be opened manually or with a fusible link. The inside dimensions of the vent were 4 by 8 ft. The bottom of the vent was mounted flush with the bottom of the ceiling as shown in Figure 10.

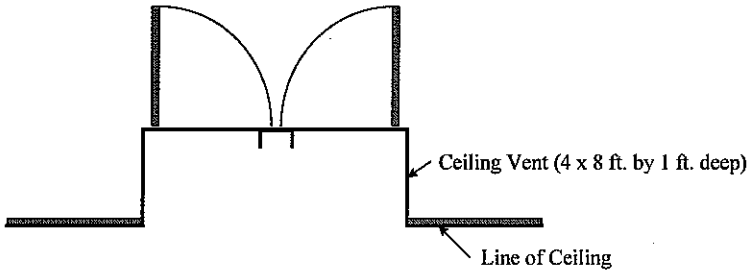


Figure 10. Vertical Section View - Ceiling Vent

Instrumentation

The instrumentation for the tests consisted of thermocouples, gas analysis equipment, and pressure transducers.

The locations of the ceiling instrumentation are shown in Figure 11.

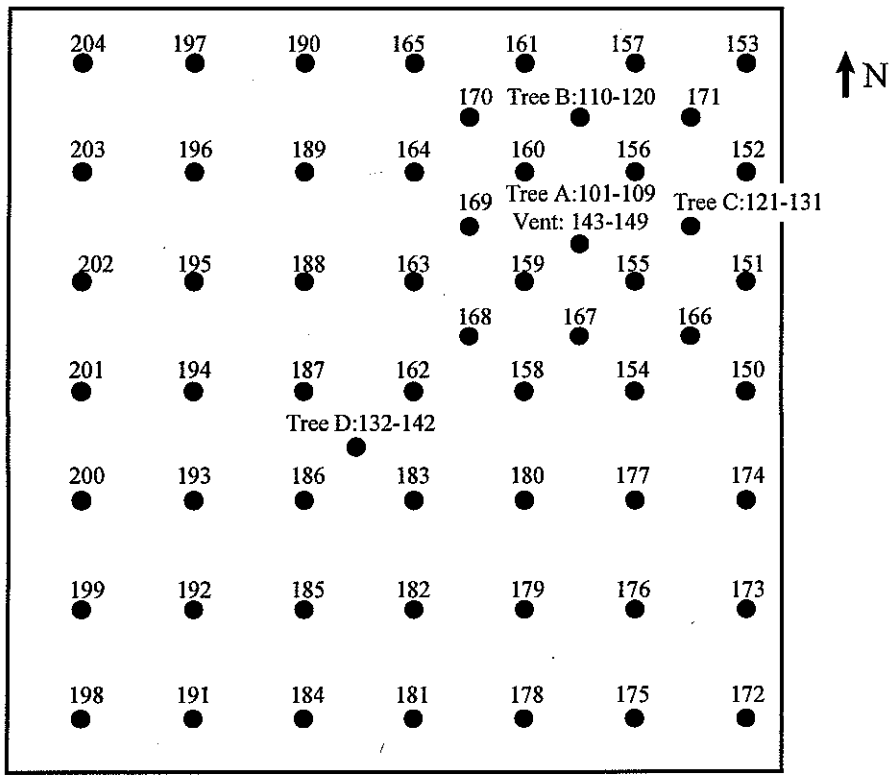


Figure 11. Reflected Plan View - Ceiling Instrumentation

TEMPERATURE MEASUREMENTS

Temperature measurements were recorded at 104 locations during the tests. Thermocouples were positioned to measure (i) temperatures near the ceiling, (ii) temperatures of the ceiling jet, and (iii) temperatures near the vent. The two types of thermocouples that were used were 0.0625 inch diameter inconel sheathed type K thermocouples and brass disk thermocouples. The placement of the thermocouples in each test are defined in Table 1 with respect to location numbers shown in Figure 11.

Table 1. Thermocouple Placement

Test	Inconel Thermocouples 2 inches below ceiling	Inconel Thermocouples 4 inches below ceiling	Brass Disk Thermocouples 4 inches below ceiling
1..16	166..204	150..165	
17..22	166..186, 189..195, 197..204	150..165	187, 188, 195, 196

TEMPERATURES - NEAR CEILING

Thermocouples were placed on a 10 ft. by 10 ft. grid within the draft curtain. Additional thermocouples were placed around the vent centered between the sprinkler locations. The thermocouples were positioned 2 or 4 inches below the ceiling. Figure 11 shows the thermocouple locations and the thermocouple designations.

TEMPERATURES - CEILING JET

Four (4) thermocouple trees were constructed from 0.0625 inch diameter inconel sheathed Type K thermocouples. The thermocouple trees were positioned directly above the four fire locations shown in Figure 7.

The thermocouple trees were constructed to hang below the ceiling. The thermocouple trees that were not located at the vent had two thermocouples positioned so that they were in contact with the top and bottom surface of the ceiling tile. The remaining nine thermocouples for all trees were positioned at 7", 22", 36", 50", 64", 78", 92", 106", and 120" below the ceiling. Figure 11 shows the thermocouple tree designations identified as 101-109, 110-120, 121-131 and 132-142 for fire locations A, B, C and D respectively. The thermocouples are numbered starting from the top.

TEMPERATURES - VENT

Seven thermocouples were positioned along the long centerline of the vent at the bottom level of the ceiling. The thermocouples were mounted on a 12 inch spacing. These thermocouples were numbered 143 to 149 from north to south, respectively.

TEMPERATURES - DISK THERMOCOUPLES

Brass disks were used to simulate the heat responsive element in a sprinkler. The brass disks, 0.384 inch diameter and 0.09 inch thick, were attached to 0.002 inch diameter chromel-alumel thermocouples. The RTI for the brass disks was measured by NIST as 32 $(ft{\cdot}s)^{1/2}$ (57.7 $(m{\cdot}s)^{1/2}$) using the plunge oven test. The RTI measurements were made normal to the flat face.

SPRINKLER ACTIVATION

Sprinklers at positions 50-65, 74, 77, 80 and 83 (see Figure 11) were instrumented to detect activation of the sprinklers. One thermocouple located 4 inches below the ceiling was positioned near each sprinkler to get wet when the sprinkler activated. An algorithm in the data acquisition system was used to indicate sprinkler activation based on a 86°F (30°C) drop in temperature over a 1 second time interval. For the other sprinkler

positions, the thermocouples were positioned approximately 1 inch above the sprinkler, so activation times were determined by reviewing the temperature data for each position.

GAS ANALYSIS

Oxygen, carbon monoxide, and carbon dioxide concentrations were monitored at two locations. The first location was six feet from the burner and nominally 3 inches above the floor. The second location was six inches below the ceiling and at the center of the vent.

The oxygen concentrations were measured with paramagnetic analyzers with a resolution of 100 ppm.

The carbon monoxide and carbon dioxide concentrations were measured with nondispersive infrared (NDIR) analyzers. The carbon monoxide meters have a resolution of 10 ppm. The carbon dioxide meters have a resolution of 100 ppm.

IR CAMERA

An infrared camera was used to measure ceiling temperatures during some tests. The infrared camera has a resolution of 0.2°F.

VENT PRESSURE

One differential pressure was measured across the vent. The static pressure taps were mounted 6 inches above the top of the vent and 6 inches below the ceiling. Both pressure taps were mounted at the center of the vent. The differential pressure was measured with a 0 to 1 TORR differential pressure transducer.

VIDEO

Two VHS video tapes were recorded for each test.

DATA ACQUISITION

All thermocouple, pressure transducer, and gas species data were collected electronically at a 2 second scan rate.

Test Parameters

The test parameters are listed in Table 2.

Table 2. Test Parameters

Test No.	Fire Location	Draft Curtain	Maximum Fire Size (kW)	Vent Status [1]	Installed Sprinklers
1	B	Yes	4400	Closed	20
2	B	Yes	4600	MO-40	21
3	B	Yes	4600	MO-90	21
4	C	Yes	4600	Closed	21
5	C	Yes	4600	MO-40	21
6	C	Yes	4600	MO-90	21
7	C	Yes	4600	L165	21
8	B	Yes	4600	L165	21
9	D	Yes	4600	L165	16
10	D	Yes	4600	MO-40	16
11	D	Yes	4600	L165	0
12	A	Yes	4600	Closed	16
13	A	Yes	6000	L165	16
14	A	Yes	5800	MO-40	16
15	A	Yes	5800	MO-90	16
16	A	Yes	4600	L165	16
17	B	No	4600	L212	20
18	C	No	4600	L212	20
19	A	No	4600	L212	20
20	A	No	4600	L165	20
21	C	No	4600	L165	20
22	D	No	4600	L212	16

Note [1] Closed Vent was kept closed for the duration of the test.
MO - XX The vent was manually opened at XX seconds.
L165 A 165°F link was installed in the vent.
L212 A 212°F link was installed in the vent.

Test Procedure

The following test procedure was used in conducting the fire tests:

1. The pumps were started and the sprinkler system was brought up to pressure. The pump system was set to provide a flow of 50 gallons a minute to each sprinkler, which in turn provided a 0.50 gpm/ft^2 density based on the sprinkler spacing. The pressure at the sprinkler was approximately 19 psig to provide the proper flow rate.
2. The room exhaust was adjusted to the lowest flow rate (approximately 24000 ft^3/min).
3. The data acquisition system was started.
4. The heptane burner was ignited and the growing fire was initiated.
5. The t^2 growing fire curve was followed until a specified fire size was obtained or the first sprinkler activated. After the first sprinkler activated, the fire size was held constant.
6. The steady fire size was maintained until the conditions from the test facility reached a steady state as determined by the temperatures at the ceiling (usually within 10 to 15 minutes).

Results

SUMMARY

A summary of the test variables and sprinkler operating times for the air flow characterization tests is presented in Table 3. Tabulated summaries of the measured values are presented in the following sections of the report. Charts are provided in the Appendices.

Table 3. Test Result Summary

Test No.	Fire Location	Draft Curtain	Maximum Fire Size (kW)	Vent Status [1]	Installed Sprinklers	Activated Sprinklers
1	B	Yes	4400	Closed	20	11
2	B	Yes	4600	MO-40	21	12
3	B	Yes	4600	MO-90	21	12
4	C	Yes	4600	Closed	21	10
5	C	Yes	4600	MO-40	21	9
6	C	Yes	4600	MO-90	21	8
7	C	Yes	4600	L165-NO	21	10
8	B	Yes	4600	L165-567	21	11
9	D	Yes	4600	L165-NO	16	13
10	D	Yes	4600	MO-40	16	13
11	D	Yes	4600	L165-168	0	0
12	A	Yes	4600	Closed	16	13
13	A	Yes	6000	L165-64	16	5
14	A	Yes	5800	MO-40	16	7
15	A	Yes	5800	MO-90	16	7
16	A	Yes	4600	L165-106	16	4
17	B	No	4600	L212-NO	20	6
18	C	No	4600	L212-NO	20	4
19	A	No	4600	L212-NO	20	10
20	A	No	4600	L165-80	20	4
21	C	No	4600	L165-420	20	10
22	D	No	4600	L212-NO	16	6

Note [1]

Closed	Vent was kept closed for the duration of the test.
MO - XX	The vent was manually opened at XX seconds.
L165 - XX	A 165°F link was installed in the vent. The vent opened at XX seconds.
L165 - NO	A 165°F link was installed in the vent. The vent did not operate.
L212 - XX	A 212°F link was installed in the vent. The vent opened at XX seconds.
L212 - NO	A 212°F link was installed in the vent. The vent did not operate.

SPRINKLER ACTIVATION

A summary of the sprinkler activation times for tests where the draft curtains were used is provided in Figure 12. The figure shows the fire locations versus the number of heads that opened. The bars at each fire location indicate the time that the vent was opened.

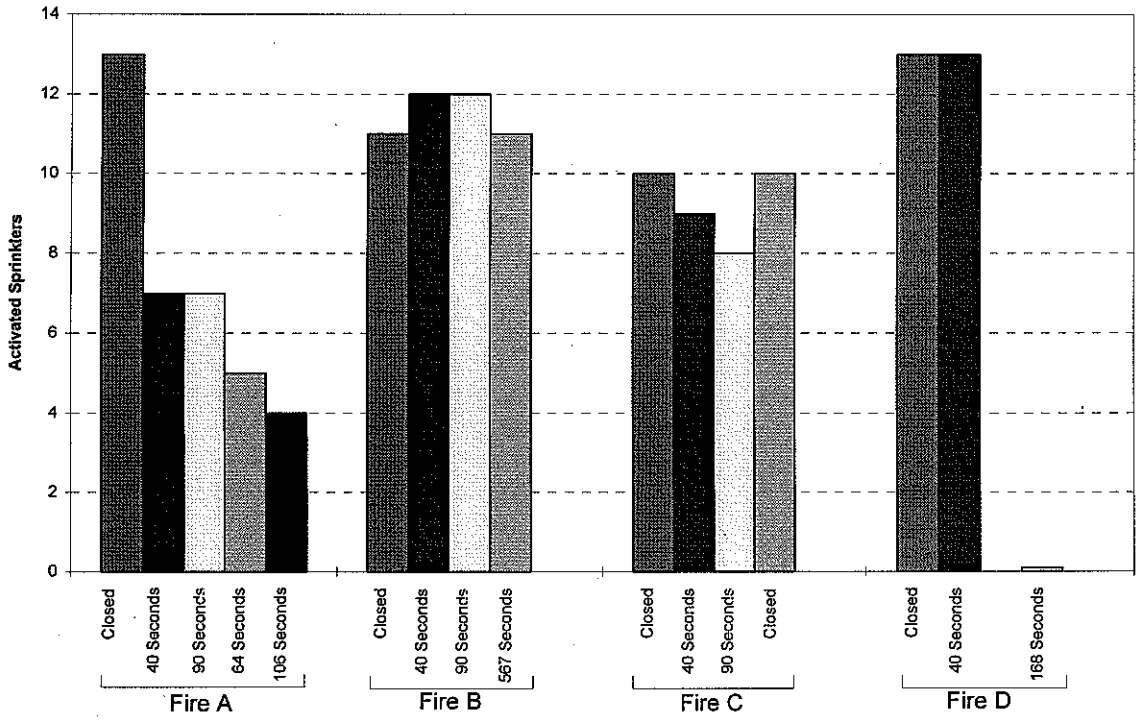


Figure 12. Sprinkler Activation

Sprinkler activation times are provided in Figure 13 through Figure 16 and in Appendix A. The figures show the sprinklers locations relative to the fire and the sprinkler activation times. The sprinkler locations are indicated by circles and the sprinkler location numbers are listed above each circle. The activation times for each test are listed under each sprinkler location. The sprinkler activation times are provided in the format AA-XX. Where AA is the test number and XX is the activation time in seconds. Sprinklers that experienced a malfunction (e.g. due to a lodgment) during activation are indicated with an "L".

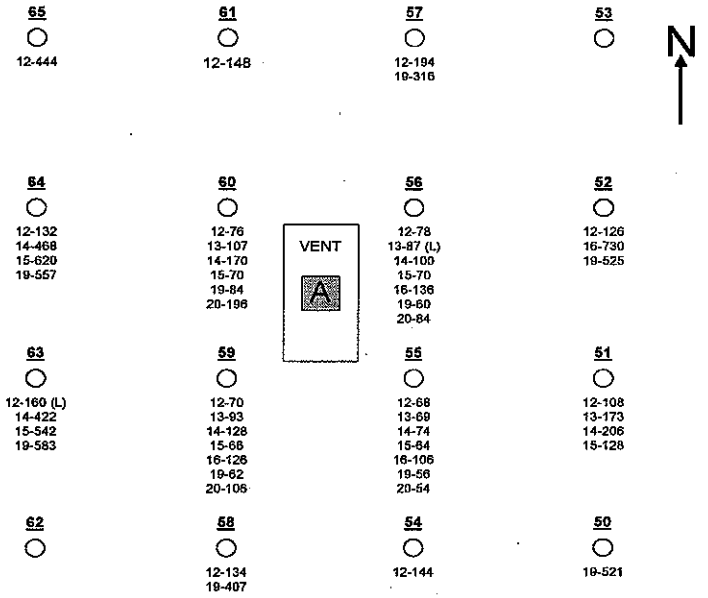


Figure 13. Sprinkler Activation Times for Tests with Fires at Position A

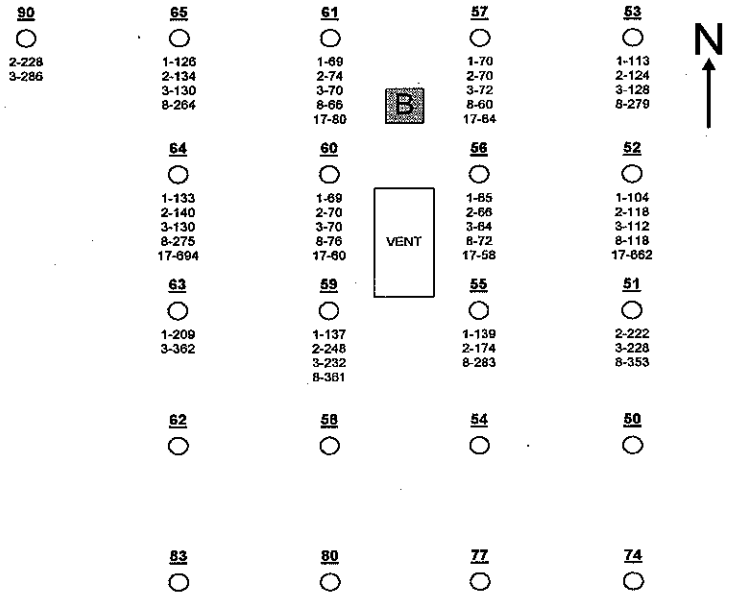


Figure 14. Sprinkler Activation Times for Tests with Fires at Position B

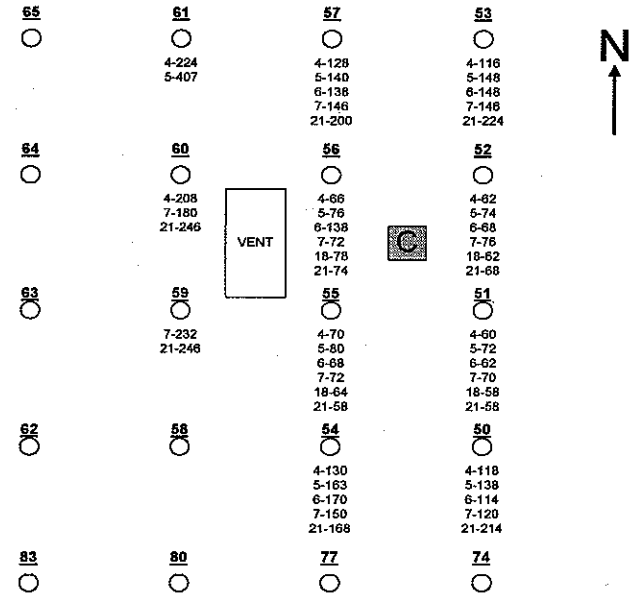


Figure 15. Sprinkler Activation Times for Tests with Fires at Position

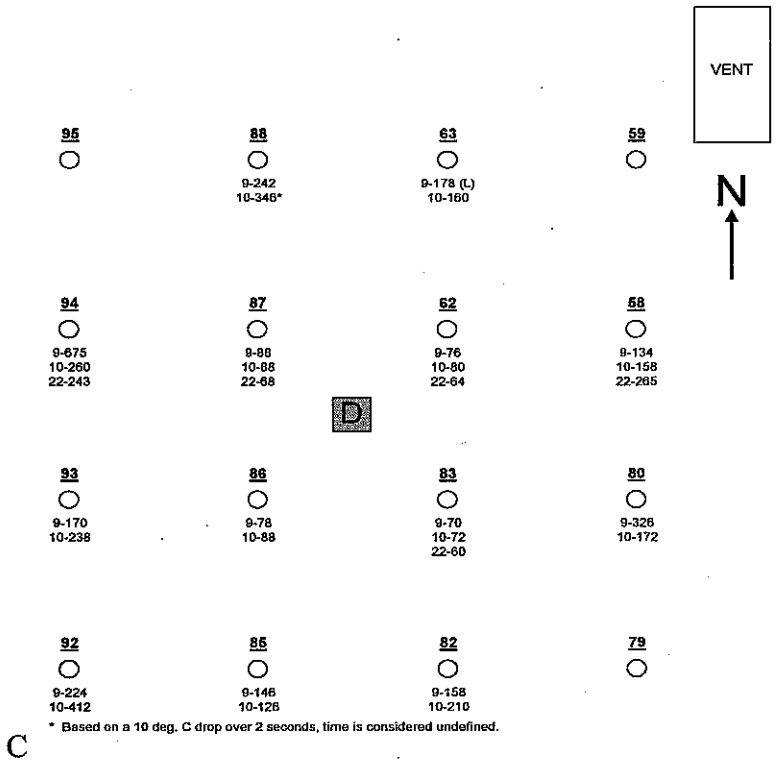


Figure 16. Sprinkler Activation Times for Tests with Fires at Position D

GAS ANALYSIS

A summary of the gas specie measurement results are presented in Table 4. Graphs of carbon dioxide and oxygen concentrations are provided in Appendix C. Table 4 displays the maximum measured concentrations of carbon monoxide, CO, and carbon dioxide, CO_2. The carbon monoxide and carbon dioxide values were 0% at the start of the tests. Table 4 also presents the minimum oxygen concentrations measured. The initial oxygen concentrations were 20.95% for all tests.

Table 4. Gas Specie Results

Test No.	Floor			Ceiling		
	Maximum CO (%)	Maximum CO_2 (%)	Minimum O_2 (%)	Maximum CO (%)	Maximum CO_2 (%)	Minimum O_2 (%)
1	0.01	1.09	19.40	0.10	1.80	17.78
2	0.01	0.06	20.40	0.10	1.35	18.76
3	0.02	0.87	19.54	0.04	1.55	18.61
4	0.00	0.56	19.82	0.00	1.24	18.87
5	0.00	0.41	19.79	0.00	1.00	19.24
6	0.00	0.64	20.11	0.01	1.33	19.10
7	0.00	1.22	19.16	0.00	1.37	18.95
8	0.01	1.32	19.52	0.00	1.72	18.91
9	0.00	1.14	19.44	0.03	1.07	19.45
10	0.00	0.71	18.08	0.00	0.17	19.95
11	0.00	0.00	20.83	0.00	0.28	19.73
12	0.02	1.16	19.29	0.02	2.23	17.89
13	0.02	0.61	20.23	0.01	1.85	18.62
14	0.01	0.53	20.11	0.06	1.68	18.43
15	0.02	0.72	20.01	0.04	1.92	18.38
16	0.00	0.01	20.84	0.01	0.89	19.38
17	0.00	0.45	20.31	0.00	0.91	19.50
18	0.00	0.43	20.31	0.00	0.62	19.97
19	0.00	0.74	19.95	0.00	1.67	18.72
20	0.00	0.51	20.32	0.00	1.45	18.99
21	0.01	0.57	20.05	0.00	0.93	19.58
22	0.01	0.55	20.15	0.00	0.59	19.88

VENT PRESSURES

The differential pressures measured across the vent were less than 1 Pascal for all tests. This pressure level is lower than the minimum resolution for the pressure transducer.

DATA FILES

The results for all tests have been saved in a standard data format as described herein. The data for each test has been saved in one file on the attached diskette. The test description with the data file name is provided in Table 5.

Table 5. Data Files

No.	Fire Location	Draft Curtain	Maximum Fire Size	Vent Status [1]	Data File Name
1	B	Yes	4400	Closed	Test01.CSV
2	B	Yes	4600	MO-40	Test02.CSV
3	B	Yes	4600	MO-90	Test03.CSV
4	C	Yes	4600	Closed	Test04.CSV
5	C	Yes	4600	MO-40	Test05.CSV
6	C	Yes	4600	MO-90	Test06.CSV
7	C	Yes	4600	L165-NO	Test07.CSV
8	B	Yes	4600	L165-567	Test08.CSV
9	D	Yes	4600	L165-NO	Test09.CSV
10	D	Yes	4600	MO-40	Test10.CSV
11	D	Yes	4600	L165-168	Test11.CSV
12	A	Yes	4600	Closed	Test12.CSV
13	A	Yes	6000	L165-64	Test13.CSV
14	A	Yes	5800	MO-40	Test14.CSV
15	A	Yes	5800	MO-90	Test15.CSV
16	A	Yes	4600	L165-106	Test16.CSV
17	B	No	4600	L212-NO	Test17.CSV
18	C	No	4600	L212-NO	Test18.CSV
19	A	No	4600	L212-NO	Test19.CSV
20	A	No	4600	L165-80	Test20.CSV
21	C	No	4600	L165-420	Test21.CSV
22	D	No	4600	L212-NO	Test22.CSV

The standard data format consists of a comma delimited ASCII text file. The file contains summary information of the test on the 1st line of the file. The next five lines contain information about the data channels. The remaining lines in the file contain the test data. An example of the data file format is provided in Table 6. A specific description of the data file is provided in Table 7 and Table 8.

Table 6. Data File Example

test=Air Flow Characterization, testnumber=8, ceilingheight=25ft,TestDate=1/23/97,MaxHRR=4600					
Time,	Time,	FLOOR CO,	VENT PRESSURE,	7" below ceiling,	22" below ceiling,
Hr:min:sec,	Sec,	%,	Pascals,	°C,	°C,
CHANNEL,	0,	2,	7,	101,	102,
FORMAT,	#.0,	#0.000,	#0,	#0.,	#0.,
0:00:00,	0,	0,	-0.2,	20.6,	20.7,
0:00:04,	4,	0,	-0.2,	20.6,	20.7,
0:00:08,	8,	0,	-0.04,	20.6,	20.7,

Table 7. Data Format

Row	Description
1	**Test Information** - Contains information about the project and the test. The format of the test information consists of a variable name followed by an equal sign followed by the variable information (example "ProjectNumber=97NK12345").
2	**Data Channel Descriptions** - Descriptions of the data channels separated by commas (example: "Ceiling Temperature, Oxygen Concentration")
3	**Data Units** - The units of the data channels (example: "°C,%")
4	**Data Channel** Number- A description of the data channel that refers to the location of the data in the data acquisition program (example: "16, 26").
5	**Format** - Description of the format used to present the data. The data format string is the same as used for Microsoft Excel (example: one decimal place is #0.0, four decimal places is #0.0000).
6...	**Test Data**

The first two columns of the data file are used to present time.

Table 8. Data Format

Column	Description
1	Text Test Time - Presents the test time in a hours : minutes : seconds format (example: a test time of 85 second would be listed as "00:01:25").
2	Decimal Test Time - Presents the test time in a decimal format (example: a test time of one minute twenty-five seconds would be listed as "85.0")
3..	Test data

VIDEO

Two VHS video cameras were used to record each test. The videos are on the attached twelve video tapes.

Sprinkler Characterization Tests

OBJECTIVE

The objective of these tests was to measure the sprinkler water distribution under a limited area for large and extra large orifice sprinklers from different manufacturers.

TEST PLAN

Single upright sprinkler distribution tests were conducted with a sprinkler centered over one hundred 1 by 1 ft. collection pans arranged in a 10 by 10 array to determine the water distribution. A single large orifice and a single extra large orifice upright sprinkler from three sprinkler manufacturers were tested at a flow rate of 30 and 50 gallons per minute.

A total of twelve distribution tests were conducted.

The sprinkler descriptions are as follows:

Table 9. Sprinkler Information

Sprinkler No.	Orifice Type / Thread (inch NPT)	Orifice Diameter (inch)
1	Large - 3/4"	0.5250
2	Extra Large - 3/4" (Pintle)	0.6255
3	Large - 1/2" (Pintle)	0.5250
4	Extra Large - 3/4" (Pintle)	0.6180
5	Large - 3/4"	0.5250
6	Extra Large - 3/4" (Pintle)	0.6275

SET-UP

The sprinklers were installed in a tee supplied by a 1.5 inch Schedule 40 steel pipe. The pipe was positioned below a smooth, flat horizontal ceiling. The sprinklers were installed such that the sprinkler's deflector was 7 foot 6 inches from the top of the nominal one foot tall collection pans. The distance from the center of the pipe to the sprinkler's deflector was measured. The sprinkler was positioned centered over the 10 by 10 array of collection pans.

METHOD

Water was discharged at a flow rate of 34 and 50 gallons a minute through the sprinkler under test. The amount of water collected in each pan was then measured and the individual pan's area density was determined. The distance of sprinkler over-spray (beyond the collection pan area) reaching the ground was also measured.

The test was terminated at 10 minutes or when the pans were filled to the top and were overflowing.

RESULTS

The results of the distribution tests are provided in Appendix E.

Note that tests 5, 8 and 10 were conducted for 7 minutes instead of 10 minutes due to overflowing of pans. The data was multiplied by a factor of 10 / 7 to correctly report the area densities.

Table A-1. Results For Fires in Position A

Test Number	**12**	**13**	**14**	**15**	**16**	**19**	**20**
Burner Pos.	A	A	A	A	A	A	A
Vent Open. Time	Closed	165 F Link	40 sec	90 sec	165 F Link	212 F Link	165 F Link
Fire Growth	fast	fast	fast	fast	slow	fast	fast
Scenario #	2	3	4	5	"18"	n/a	n/a
Test Date	17-Jan	17-Jan	17-Jan	17-Jan	17-Jan	21-Jan	21-Jan
Sprinkler Position	**Operating Time**						
50	DNO	DNO	DNO	DNO	DNO	8:41	DNO
51	1:48	2:53	3:26	2:08	DNO	DNO	DNO
52	2:06	DNO	DNO	DNO	12:10	8:45	DNO
53	DNO	DNO	DNO	DNO	DNO	DNO	DNO
54	2:24	DNO	DNO	DNO	DNO	DNO	DNO
55	1:08	1:09	1:14	1:04	1:46	0:56	0:54
56	1:18	1:27	1:40	1:10	2:16	1:00	1:24
57	3:14	DNO	DNO	DNO	DNO	5:16	DNO
58	2:14	DNO	DNO	DNO	DNO	6:47	DNO
59	1:10	1:33	2:08	1:06	2:06	1:02	1:46
60	1:16	1:47	2:50	1:10	DNO	1:24	3:16
61	2:28	DNO	DNO	DNO	DNO	DNO	DNO
62	DNO	DNO	DNO	DNO	DNO	DNO	DNO
63	2:40	DNO	7:02	9:02	DNO	9:43	DNO
64	2:12	DNO	7:48	10:20	DNO	9:17	DNO
65	7:24	DNO	DNO	DNO	DNO	DNO	DNO
73	-	-	-	-	-	-	-
74	-	-	-	-	-	DNO	DNO
76	-	-	-	-	-	-	-
77	-	-	-	-	-	DNO	DNO
79	-	-	-	-	-	-	-
80	-	-	-	-	-	DNO	DNO
82	-	-	-	-	-	-	-
83	-	-	-	-	-	DNO	DNO
VENT OPEN	N/A	1:04	0:40 PULL	0:90 PULL	1:46	DNO	1:20
# operating sprinklers	13\16	5\16	7\16	7\16	4\16	10\20	4\20

DNO : Did Not Operate
N/A: Not Applicable

Table A-2. Results For Fires in Position B

Test Number	**1**	**2**	**3**	**8**	**17**
Burner Pos.	B	B	B	B	B
Vent Open. Time	closed	40 sec	90 sec	165 F Link	212 F Link
Fire Growth	fast	fast	fast	fast	fast
Scenario #	6	8	9	"7"	n/a
Test Date	15-Jan	15-Jan	15-Jan	16-Jan	21-Jan
Sprinkler Position	**Operating Times**				
50	DNO	DNO	DNO	DNO	DNO
51	DNO	3:42	3:48	5:53	DNO
52	1:44	1:58	1:52	1:58	11:02
53	1:53	2:04	2:08	4:39	DNO
54	DNO	DNO	DNO	DNO	DNO
55	2:19	2:54	DNO	4:43	DNO
56	1:05	1:06	1:04	1:12	0:58
57	1:10	1:10	1:12	1:00	1:04
58	DNO	DNO	DNO	DNO	DNO
59	2:17	4:08	3:52	6:01	DNO
60	1:09	1:10	1:10	1:16	1:00
61	1:09	1:14	1:10	1:06	1:20
62	DNO	DNO	DNO	DNO	DNO
63	3:29	DNO	6:02	DNO	DNO
64	2:13	2:20	2:10	4:35	11:34
65	2:06	2:14	2:10	4:24	DNO
73	-	-	-	-	-
74	DNO	DNO	DNO	DNO	DNO
76	-	-	-	-	-
77	DNO	DNO	DNO	DNO	DNO
79	-	-	-	-	-
80	DNO	DNO	DNO	DNO	DNO
82	-	-	-	-	-
83	DNO	DNO	DNO	DNO	DNO
85	-	-	-	-	-
88	-	-	-	-	-
90	-	3:48	4:46	DNO	-
92	-	-	-	-	-
95	-	-	-	-	-
97	-	DNO	DNO	-	-
VENT OPEN	N/A	0:40 PULL	0:90 PULL	9:27	NO OPER.
# operating sprinklers	11\20	12\21	12\21	11\21	**6\20**

DNO : Did Not Operate
N/A: Not Applicable

Table A-3. Results For Fires in Position C

Test Number	**4**	**5**	**6**	**7**	**18**	**21**
Burner Pos.	C	C	C	C	C	C
Vent Open. Time	Closed	40 sec	90 sec	165 F Link	212 F Link	165 F Link
Fire Growth	fast	fast	fast	fast	fast	fast
Scenario #	10	12	13	"11"	n/a	n/a
Test Date	15-Jan	15-Jan	15-Jan	16-Jan	21-Jan	21-Jan
Sprinkler Position	**Operating Times**					
50	1:58	2:18	1:54	2:00	DNO	3:34
51	1:00	1:12	1:02	1:10	0:58	0:58
52	1:02	1:14	1:08	1:16	1:02	1:08
53	1:56	2:28	2:28	2:26	DNO	3:44
54	2:10	2:43	2:50	2:30	DNO	2:48
55	1:10	1:20	1:08	1:12	1:04	0:58
56	1:06	1:16	2:18	1:12	1:18	1:14
57	2:08	2:20	2:18	2:26	DNO	3:20
58	DNO	DNO	DNO	DNO	DNO	DNO
59	DNO	DNO	DNO	3:52	DNO	4;06
60	3:28	DNO	DNO	3:00	DNO	4:06
61	3:44	6:47	DNO	DNO	DNO	DNO
62	DNO	DNO	DNO	DNO	DNO	DNO
63	DNO	DNO	DNO	DNO	DNO	DNO
64	DNO	DNO	DNO	DNO	DNO	DNO
65	DNO	DNO	DNO	DNO	DNO	DNO
73	DNO	DNO	DNO	DNO	-	-
74	DNO	DNO	DNO	DNO	DNO	DNO
76	-	-	-	-	-	-
77	DNO	DNO	DNO	DNO	DNO	DNO
79	-	-	-	-	-	-
80	DNO	DNO	DNO	DNO	DNO	DNO
82	-	-	-	-	-	-
83	DNO	DNO	DNO	DNO	DNO	DNO
VENT OPEN	N\A	0:40 PULL	0:90 PULL	NO OPER.	NO OPER.	7:00
# operating sprinklers	10\21	9\21	8\21	10\21	4\20	10\20

DNO : Did Not Operate
N/A: Not Applicable

Table A-4. Results For Fires in Position D

Test Number	**9**	**10**	**11**	**22**
Burner Pos.	D	D	D	D
Vent Open. Time	165 F Link	40 sec	165 F Link	212 F Link
Fire Growth	fast	fast	fast	fast
Scenario #	15	16	"27"	n/a
Test Date	16-Jan	16-Jan	17-Jan	22-Jan
Sprinkler Position	**Operating Time**			
58	2:14	2:38	-	4:25
59	DNO	DNO	-	DNO
60	-	-	-	-
61	-	-	-	-
62	1:16	1:20	-	1:04
63	2:58	2:40	-	DNO
64	-	-	-	-
79	DNO	DNO	-	DNO
80	5:26	2:52	-	DNO
82	2:38	3:30	-	DNO
83	1:10	1:12	-	1:00
85	2:26	2:06	-	DNO
86	1:18	1:28	-	1:02
87	1:28	1:28	-	1:08
88	4:02	5:46*	-	DNO
90	-	-	-	-
92	3:44	6:52	-	DNO
93	2:50	3:58	-	DNO
94	11:15	4:20	-	4:03
95	DNO	DNO	-	DNO
97	-	-	-	-
VENT OPEN	NO OPER.	0:40 PULL	2:48	NO OPER.
# operating sprinklers	13\16	13\16	N/A	6\16

DNO : Did Not Operate
N/A: Not Applicable

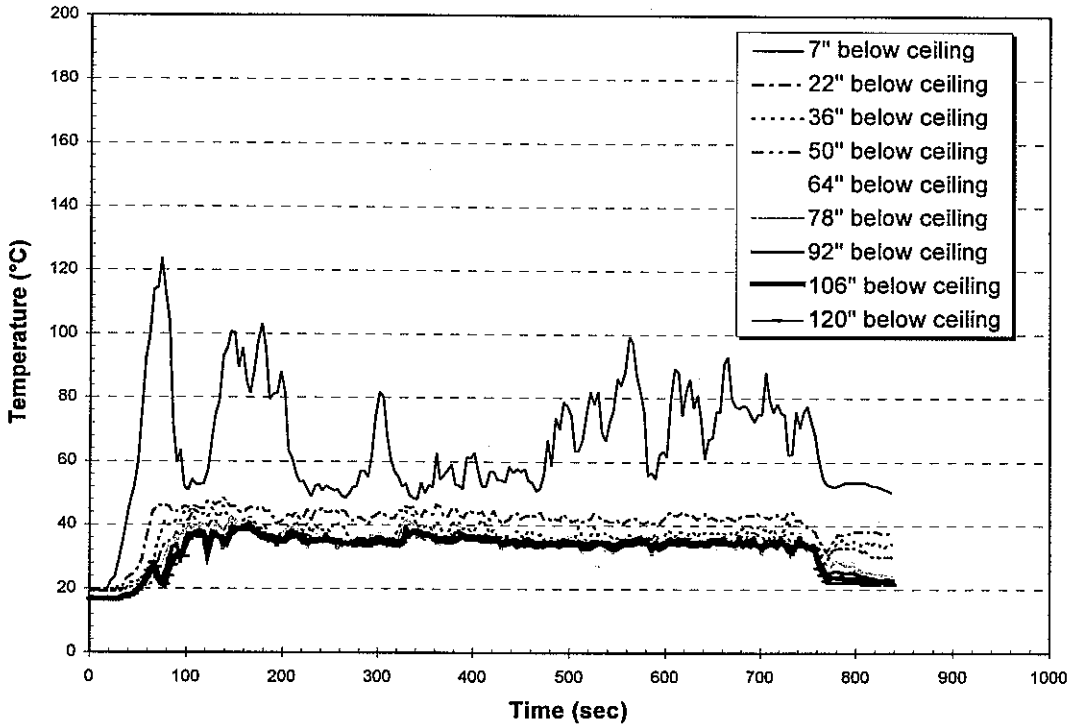


Figure B-1. Temperatures - Tree A : Test 1

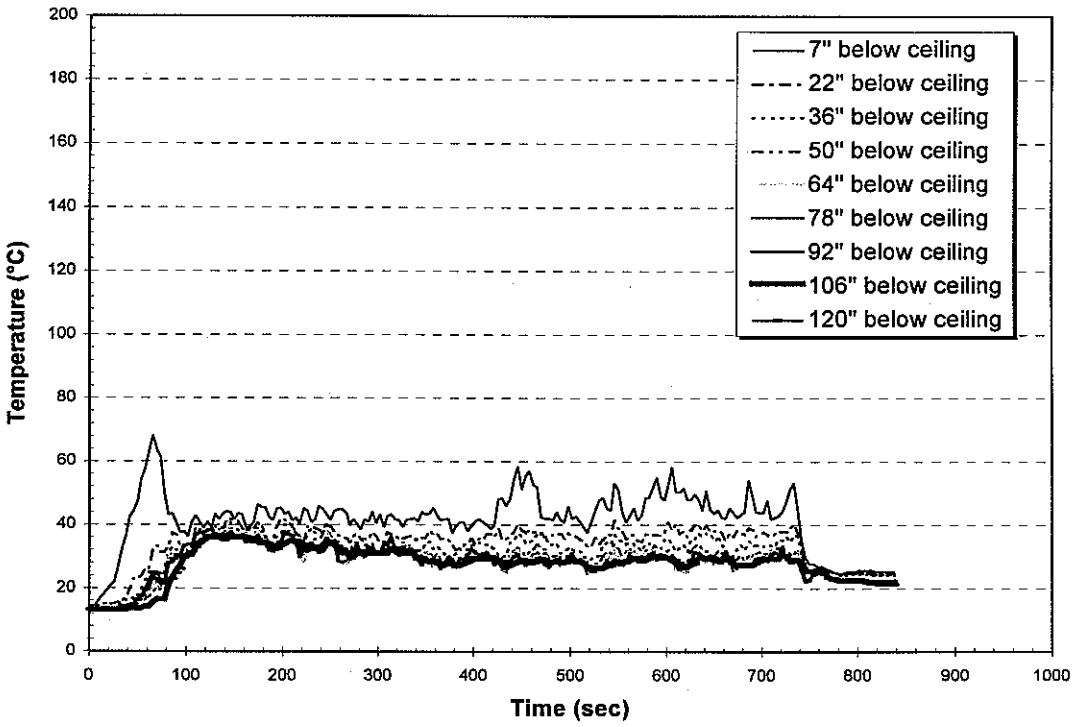


Figure B-2. Temperatures - Tree A : Test 2

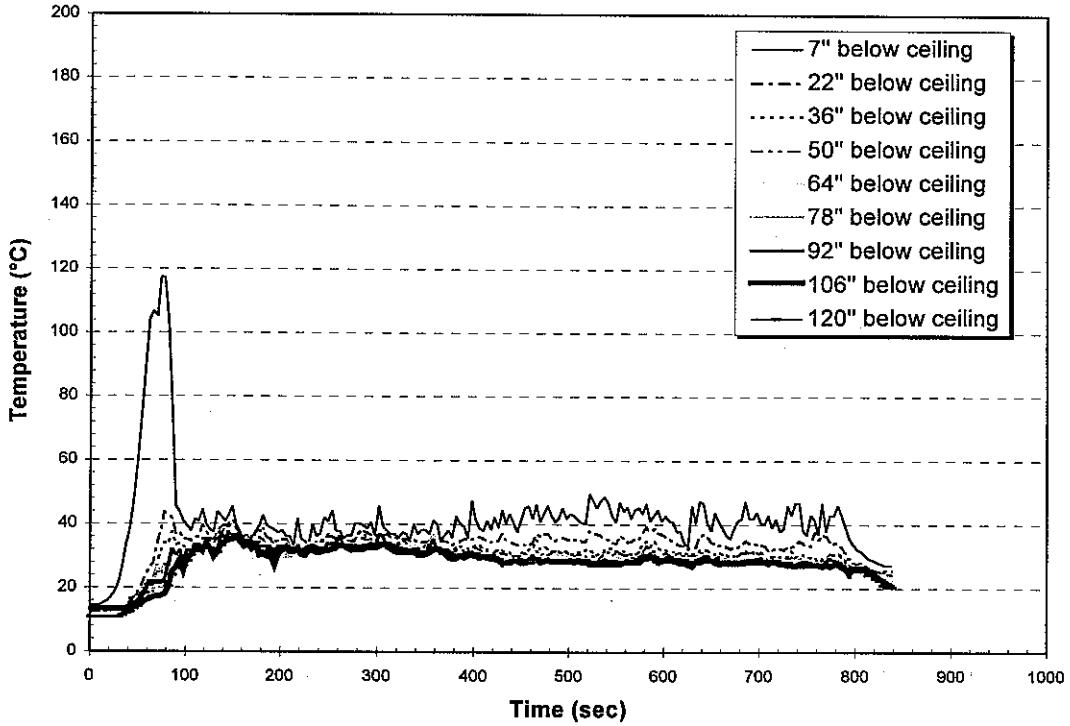


Figure B-3. Temperatures - Tree A : Test 3

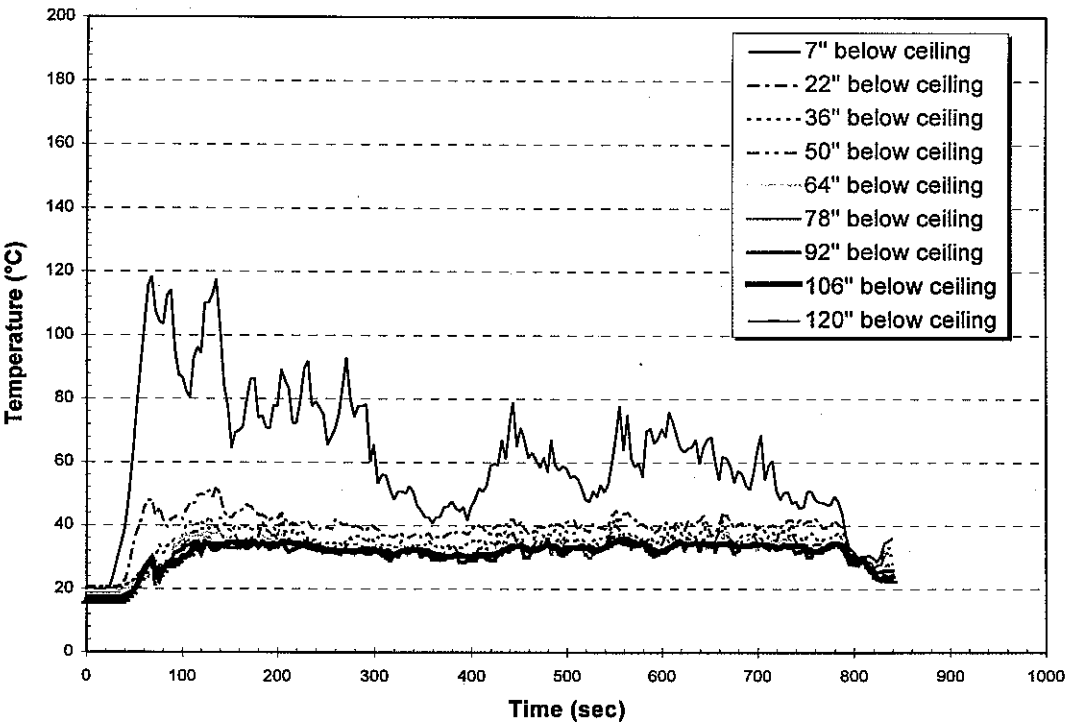


Figure B-4. Temperatures - Tree A : Test 4

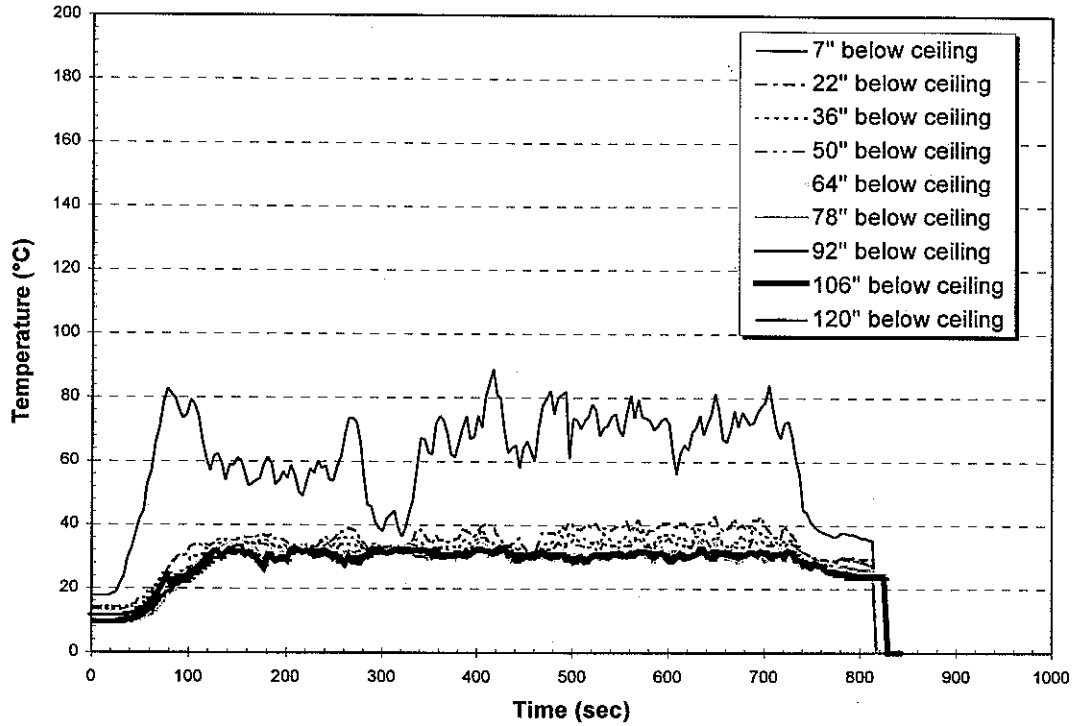


Figure B-5. Temperatures - Tree A : Test 5

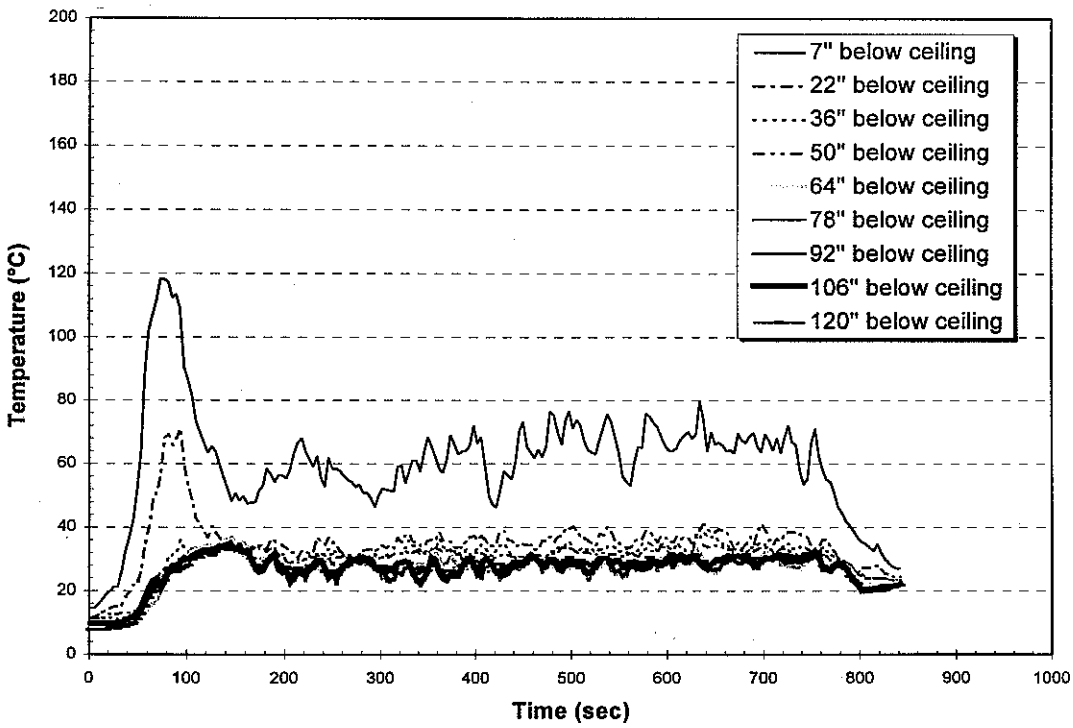


Figure B-6. Temperatures - Tree A : Test 6

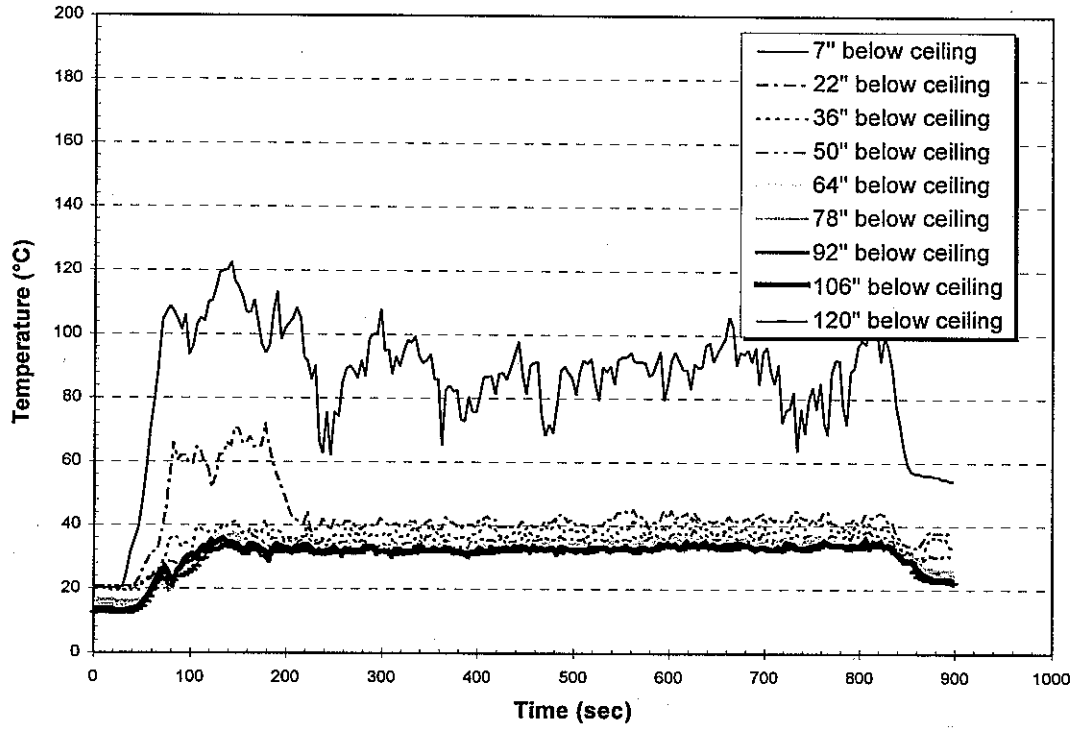


Figure B-7. Temperatures - Tree A : Test 7

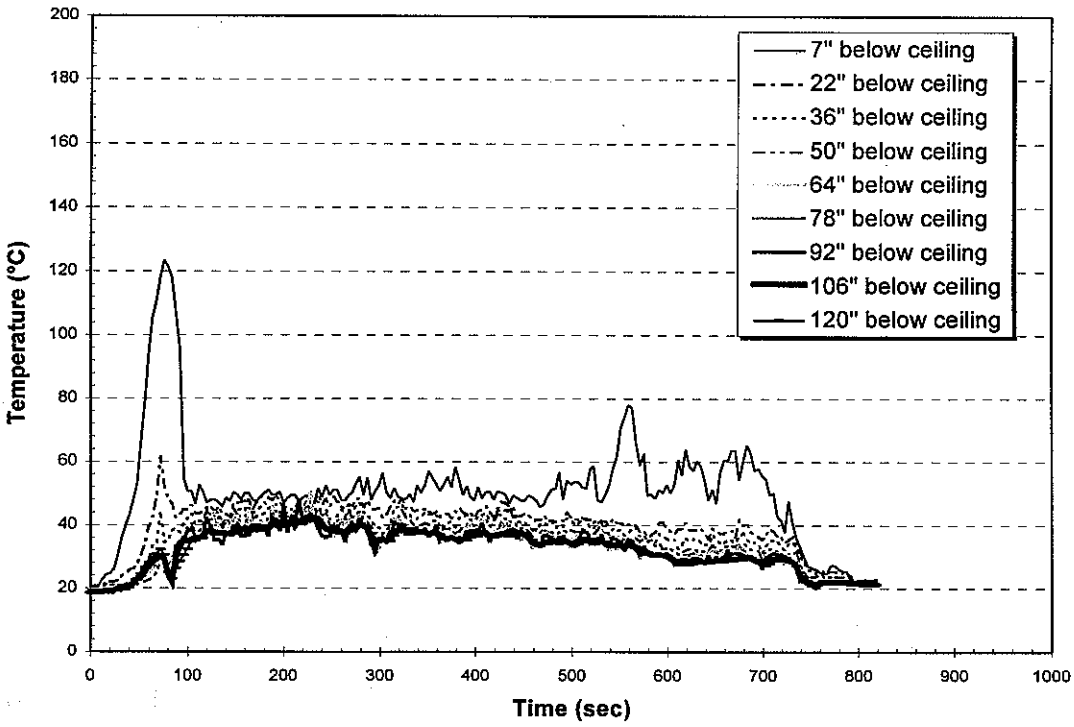


Figure B-8. Temperatures - Tree A : Test 8

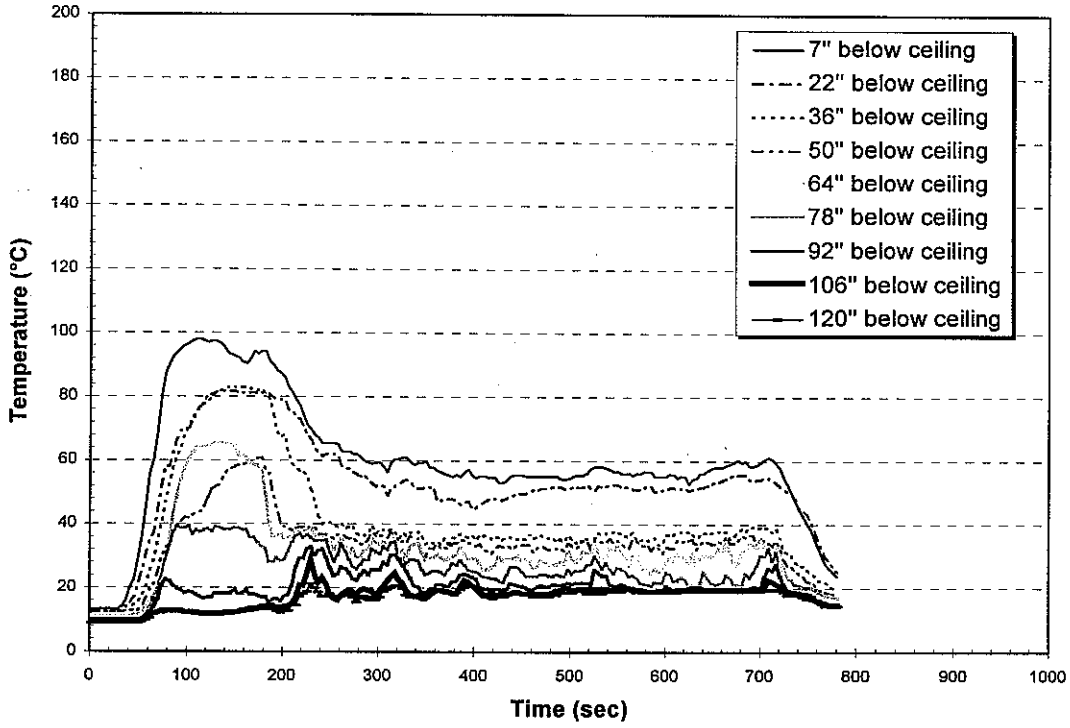


Figure B-9. Temperatures - Tree A : Test 9

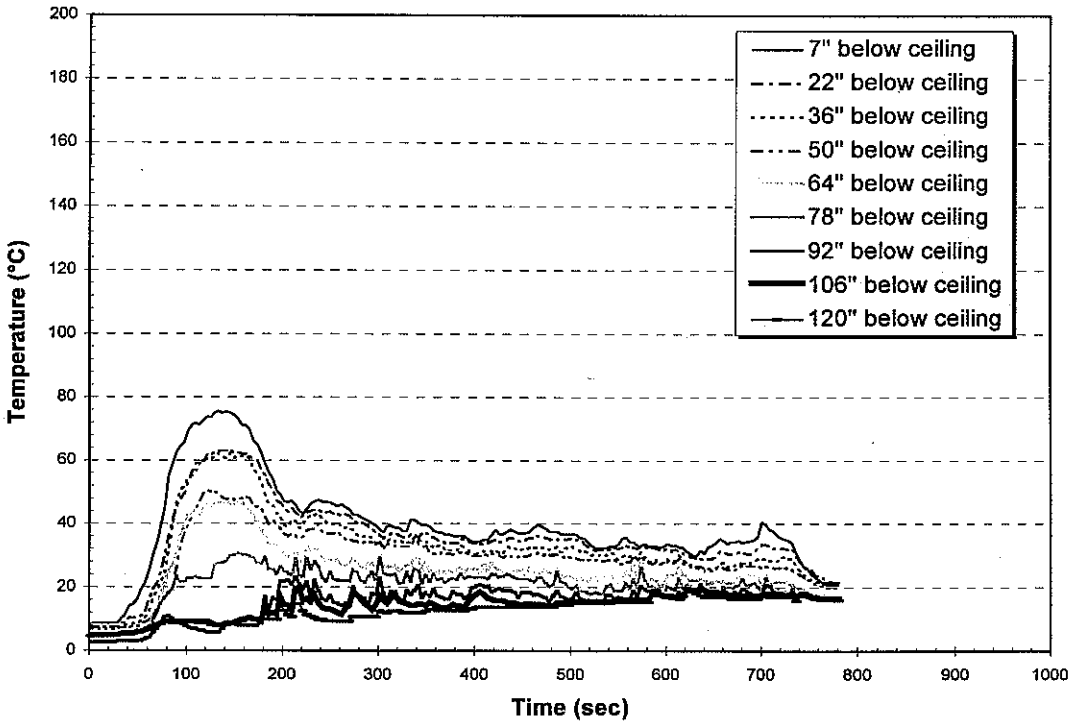


Figure B-10. Temperatures - Tree A : Test 10

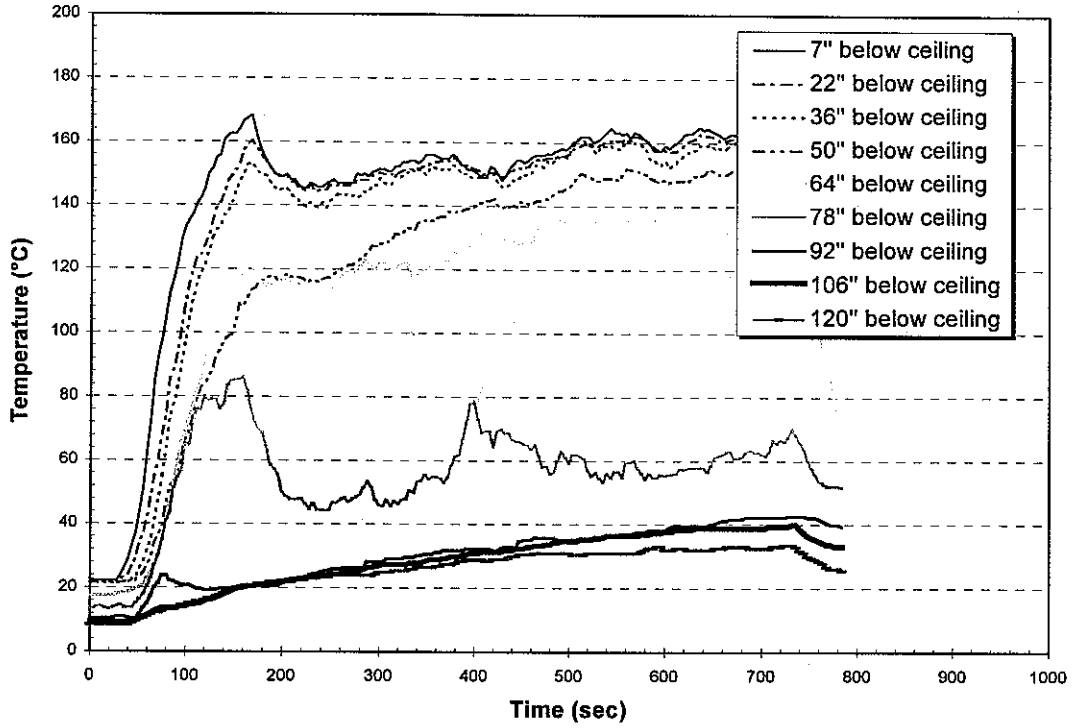


Figure B-11. Temperatures - Tree A : Test 11

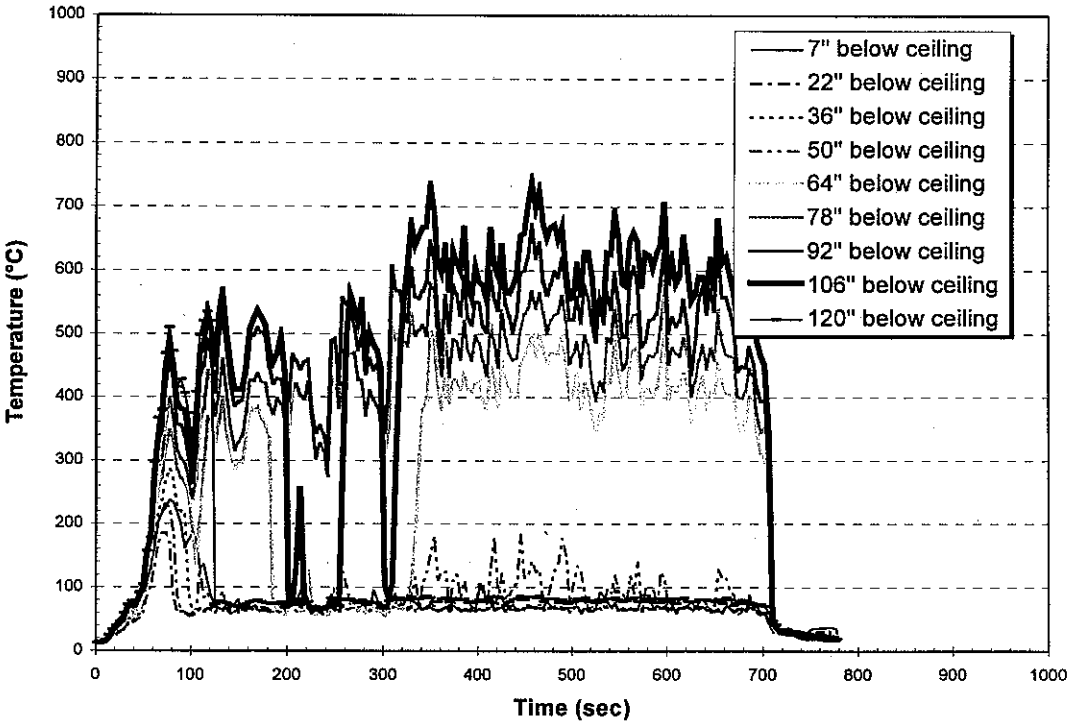


Figure B-12. Temperatures - Tree A : Test 12

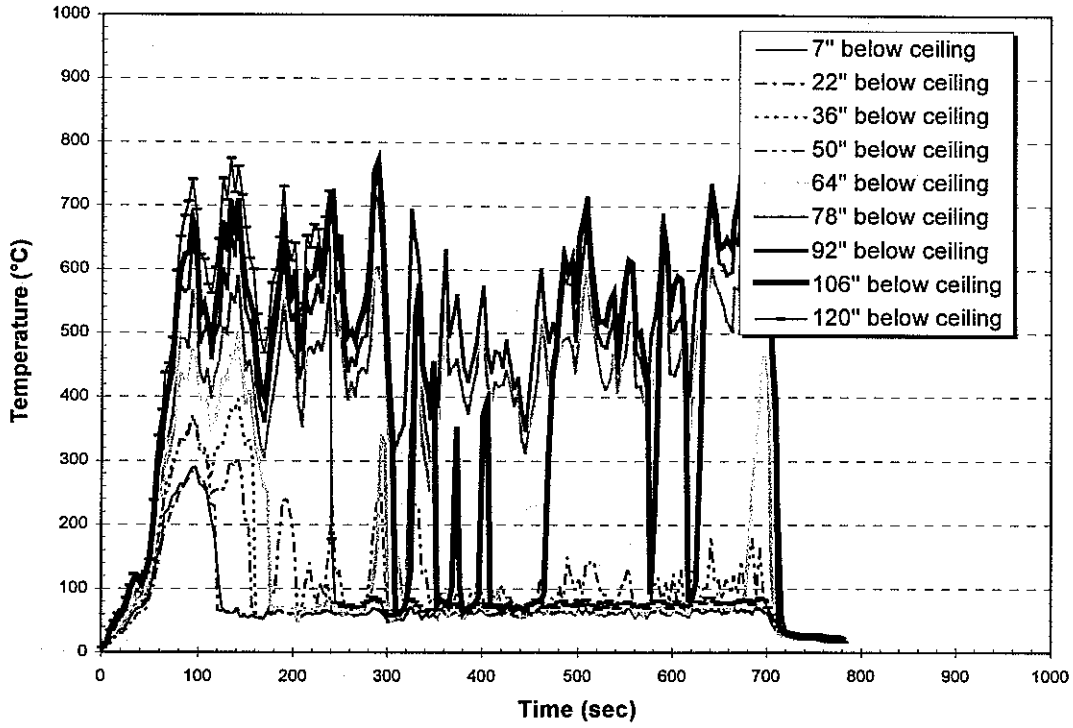


Figure B-13. Temperatures - Tree A : Test 13

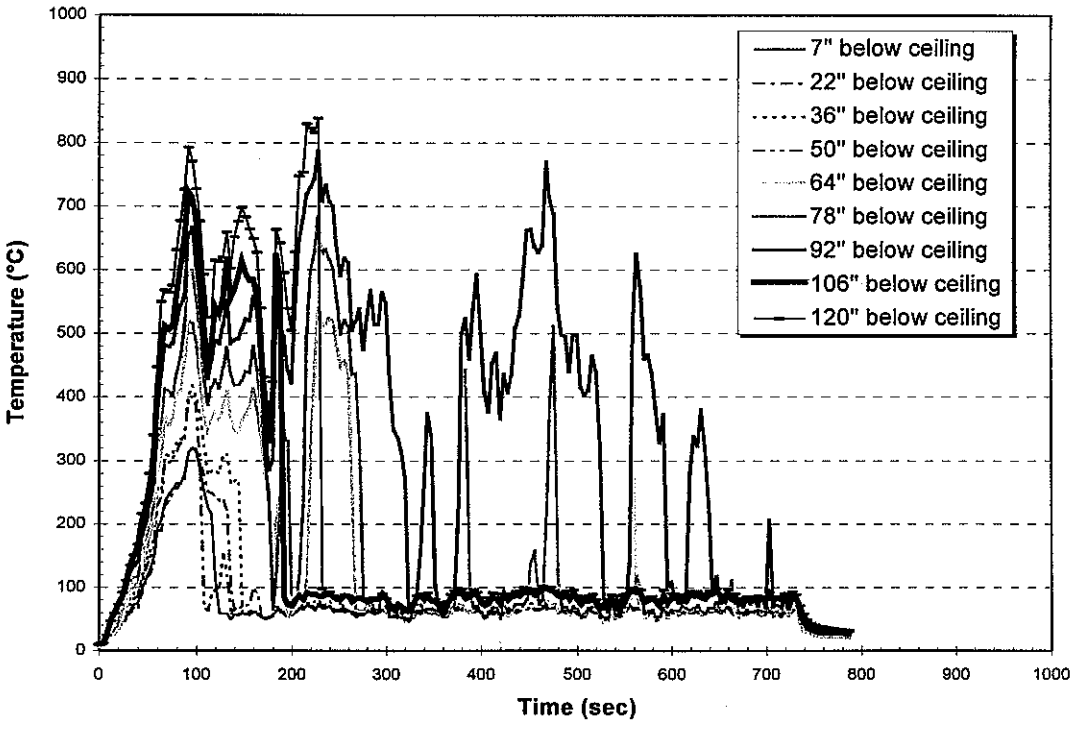


Figure B-14. Temperatures - Tree A : Test 14

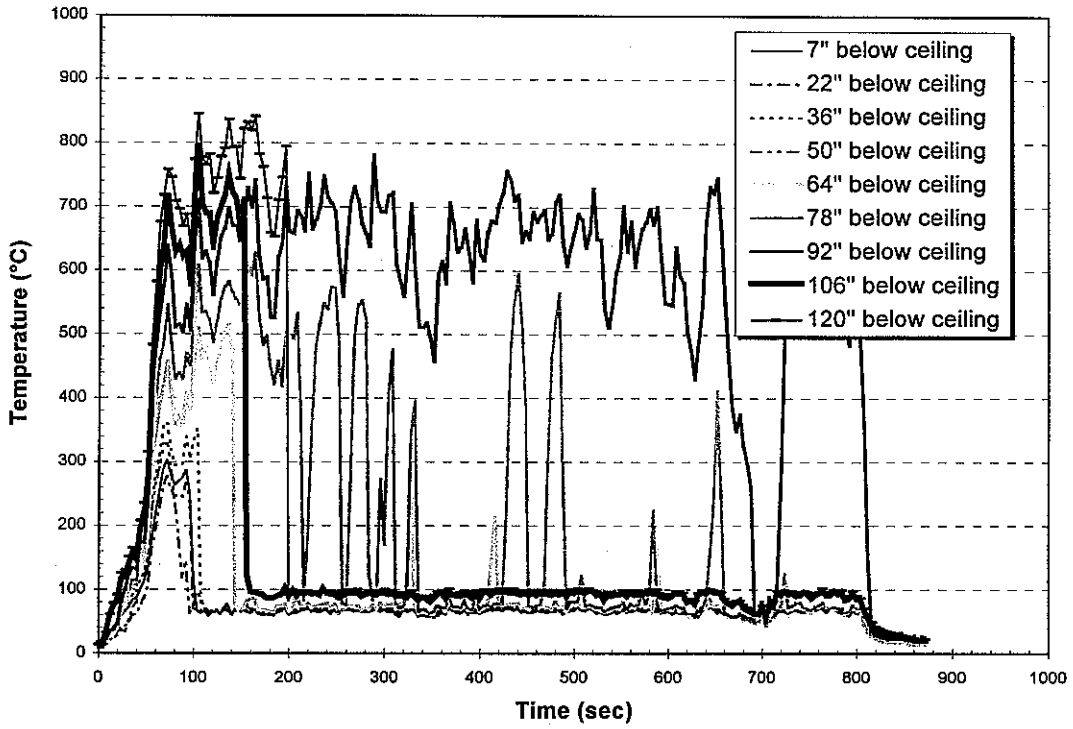


Figure B-15. Temperatures - Tree A : Test 15

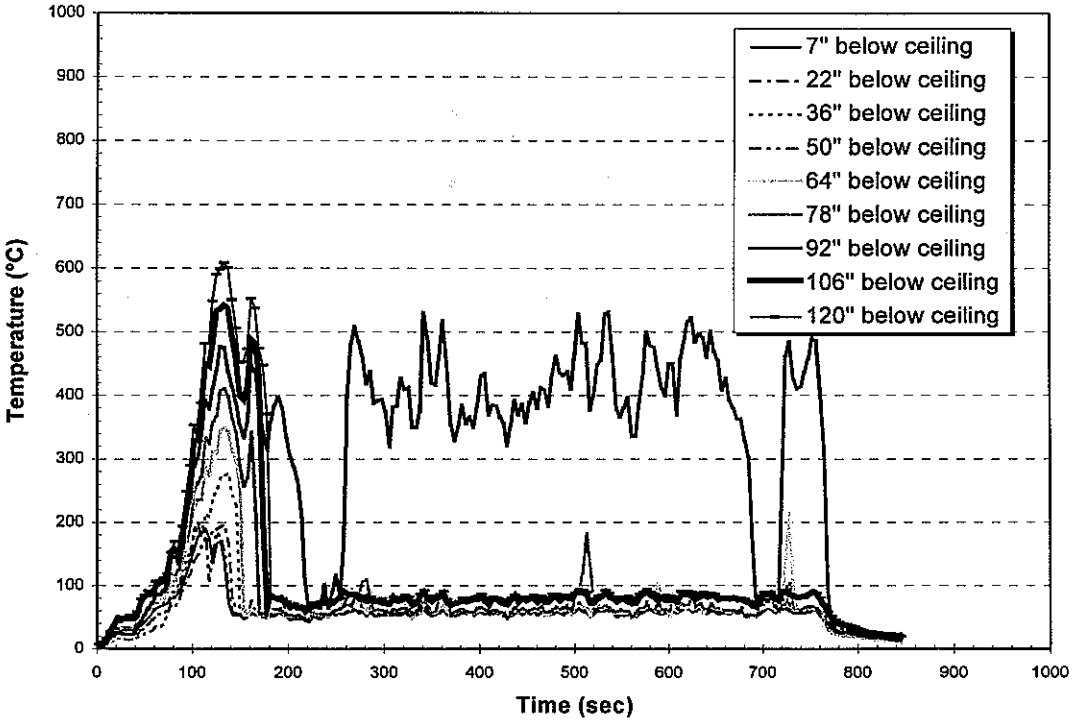


Figure B-16. Temperatures - Tree A : Test 16

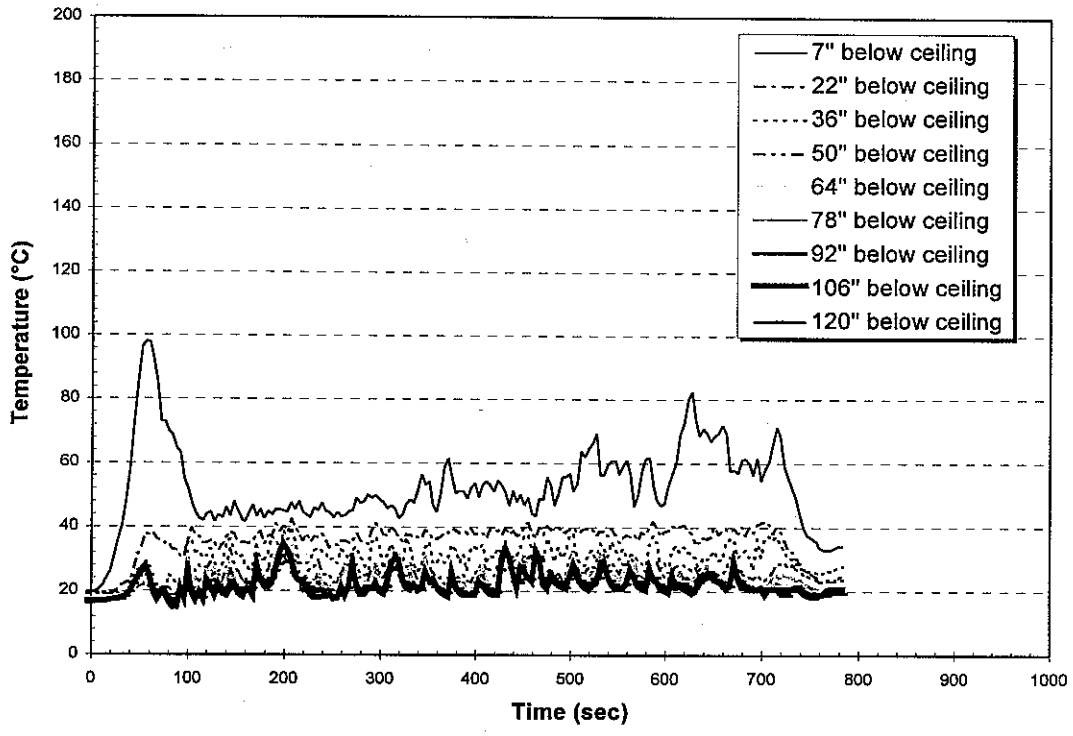


Figure B-17. Temperatures - Tree A : Test 17

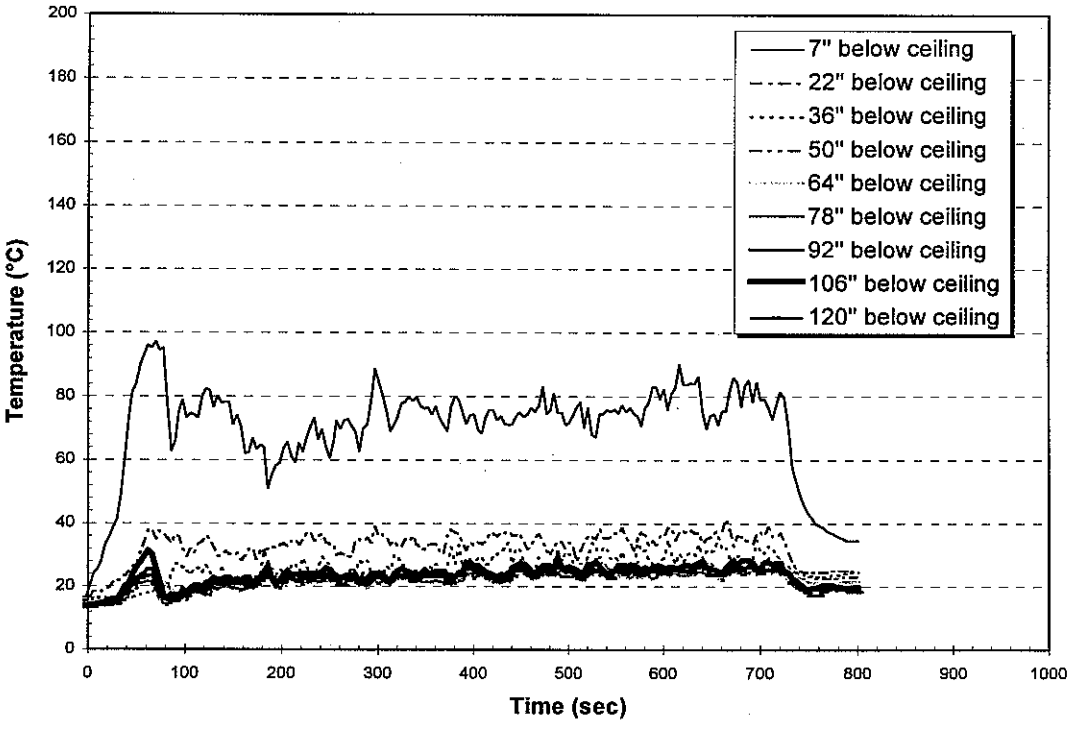


Figure B-18. Temperatures - Tree A : Test 18

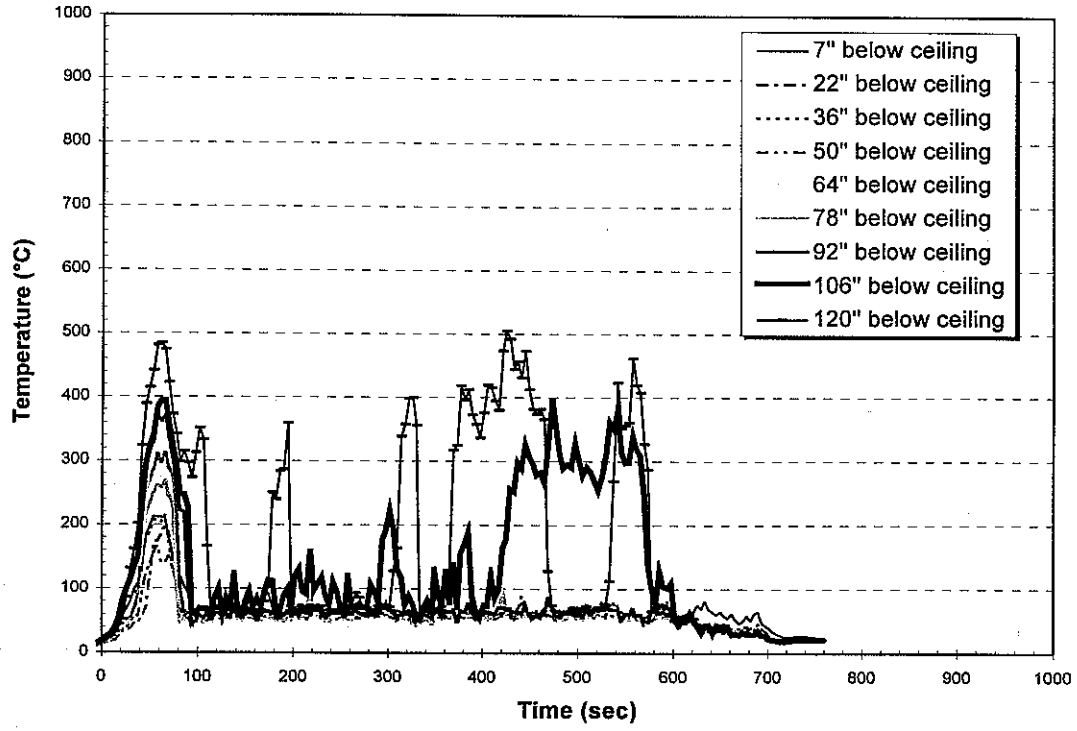


Figure B-19. Temperatures - Tree A : Test 19

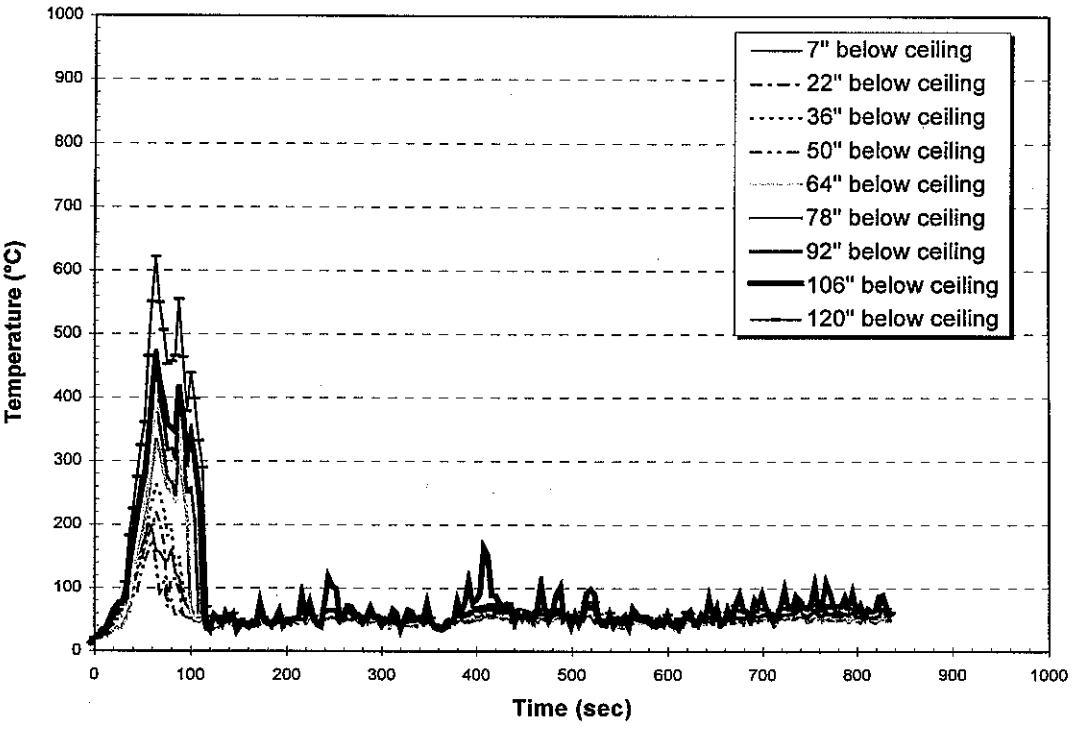


Figure B-20. Temperatures - Tree A : Test 20

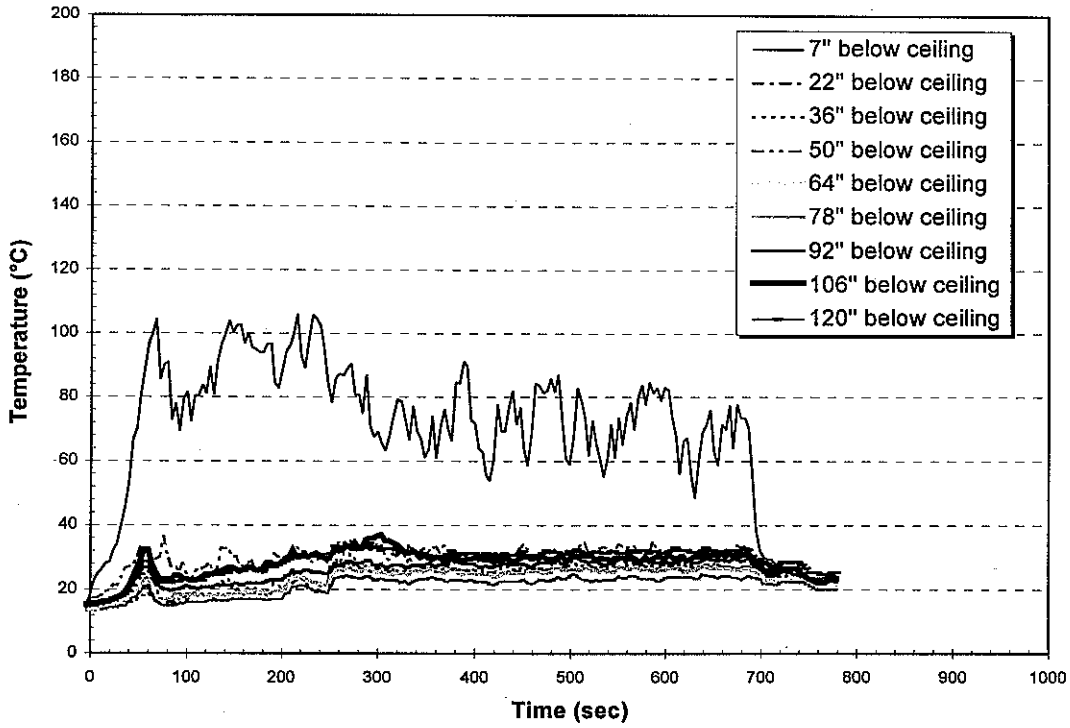


Figure B-21. Temperatures - Tree A : Test 21

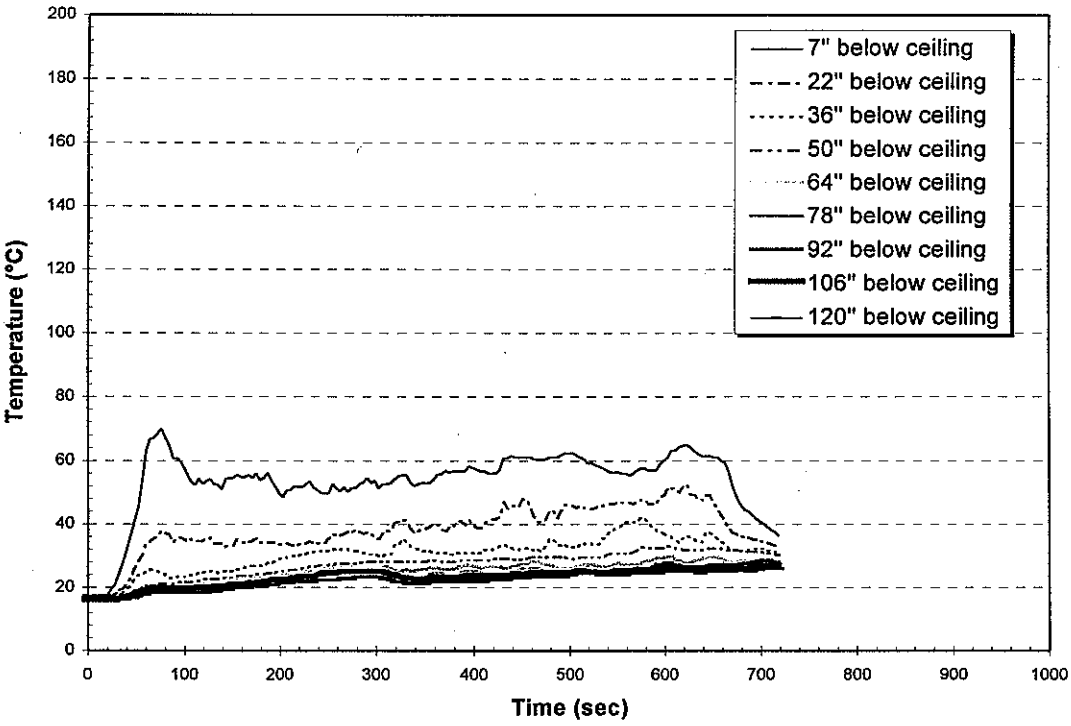


Figure B-22. Temperatures - Tree A : Test 22

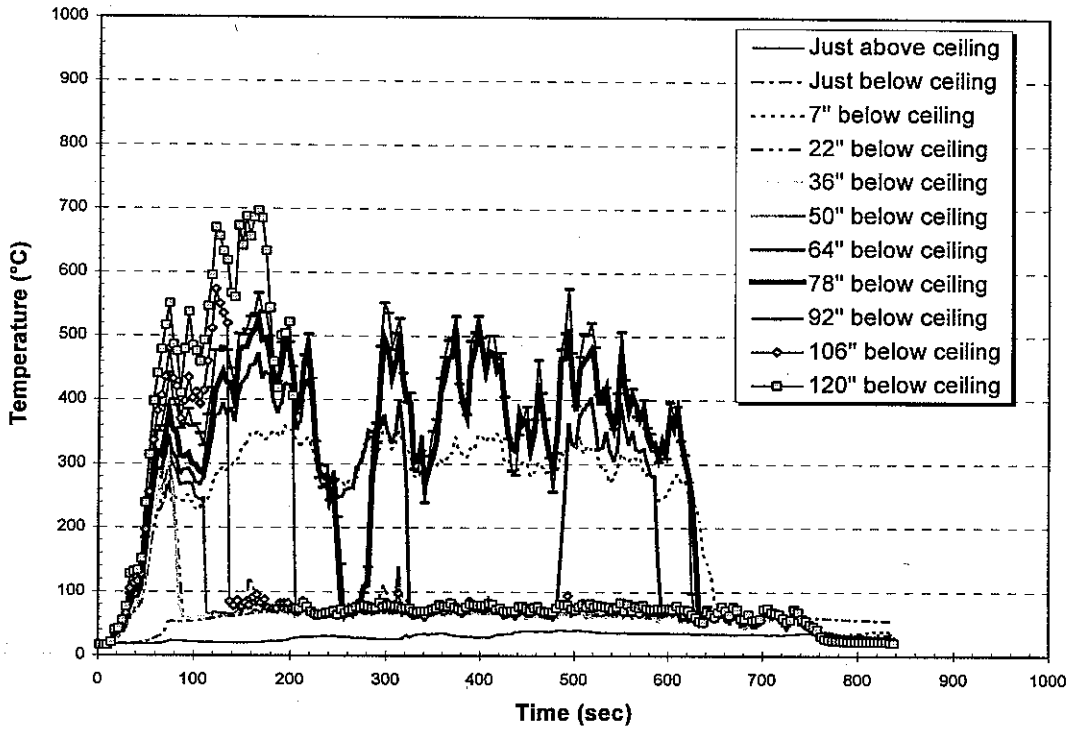


Figure B-23. Temperatures - Tree B : Test 1

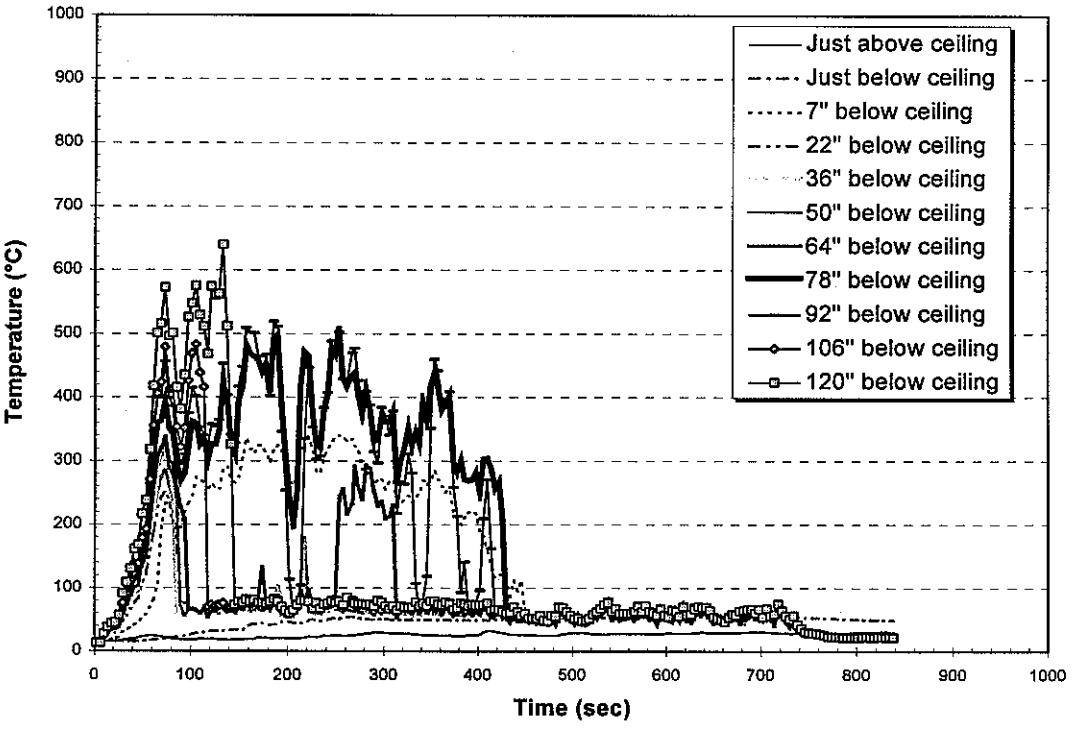


Figure B-24. Temperatures - Tree B : Test 2

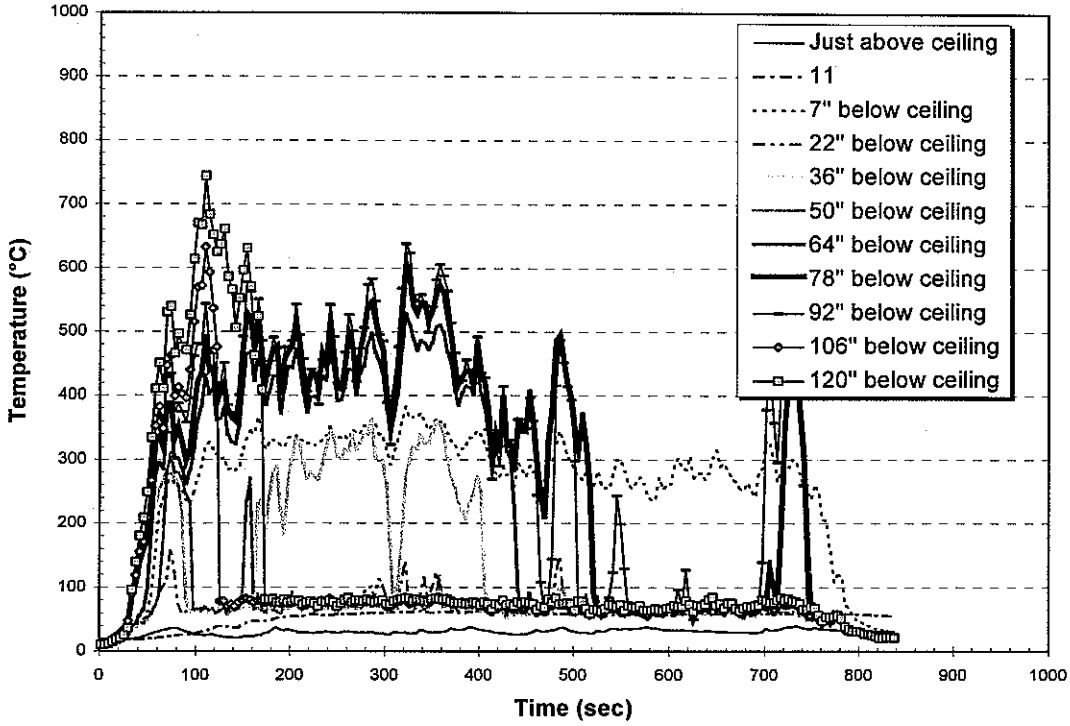


Figure B-25. Temperatures - Tree B : Test 3

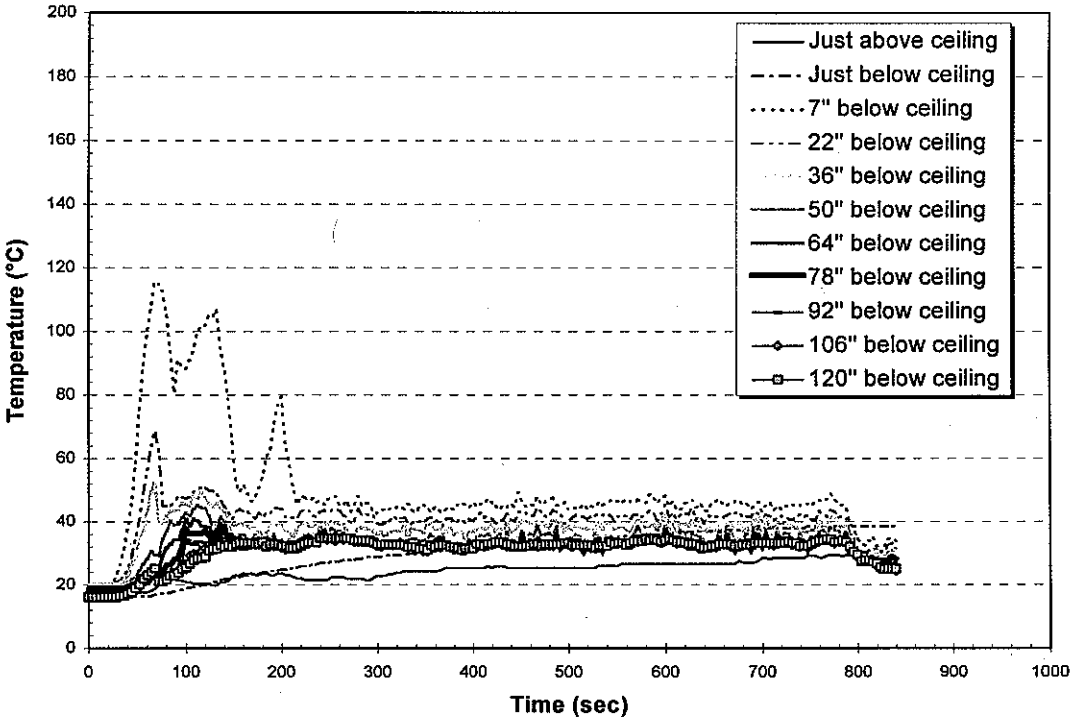


Figure B-26. Temperatures - Tree B : Test 4

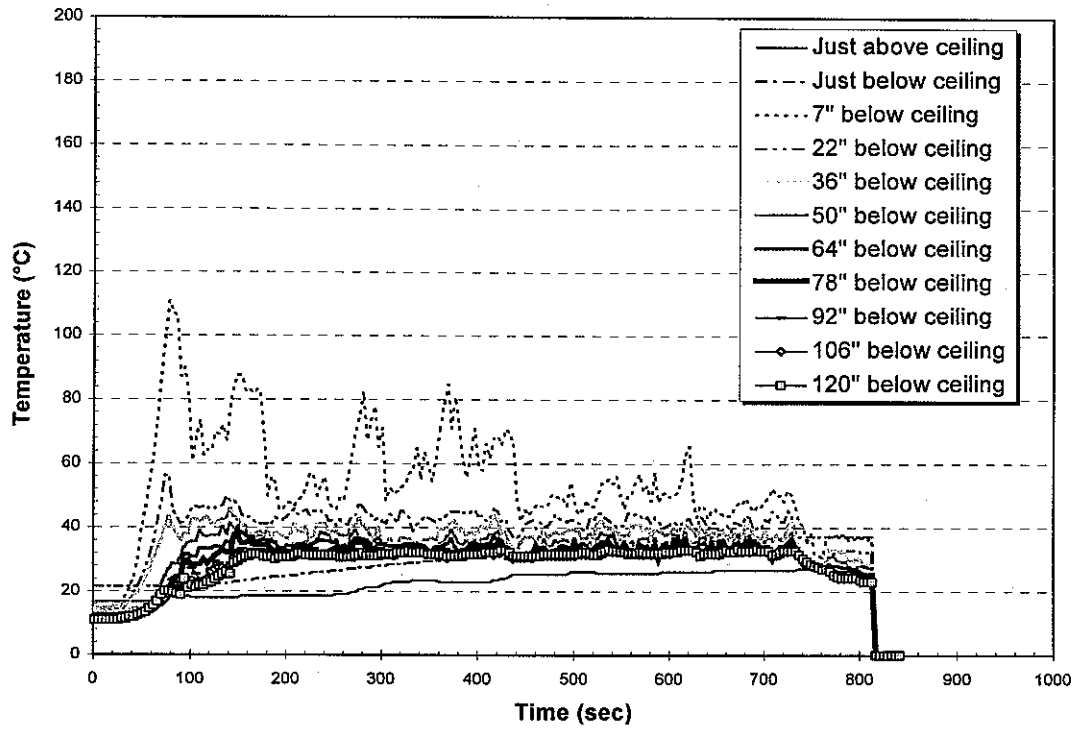


Figure B-27. Temperatures - Tree B : Test 5

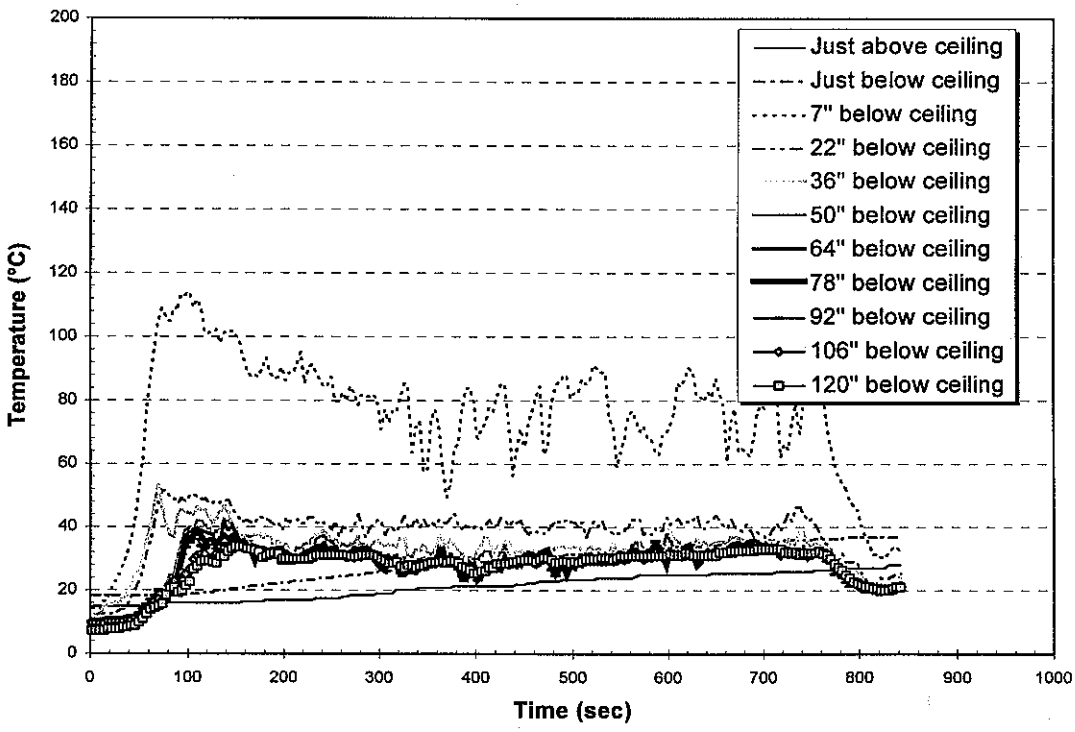


Figure B-28. Temperatures - Tree B : Test 6

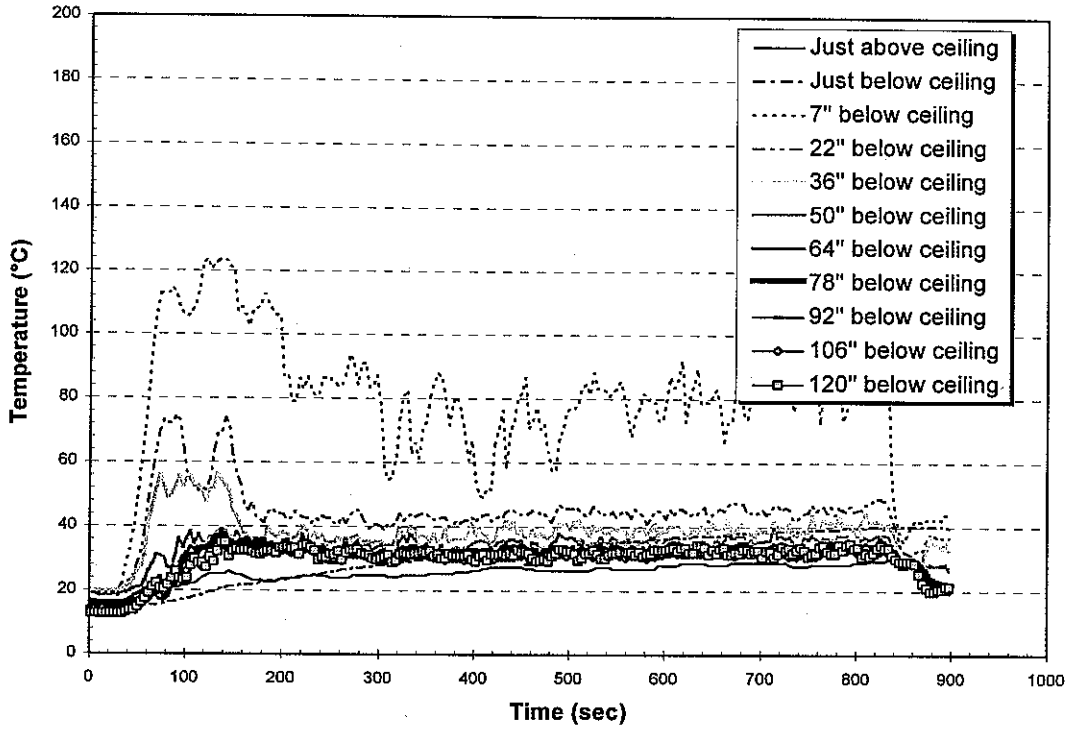


Figure B-29. Temperatures - Tree B : Test 7

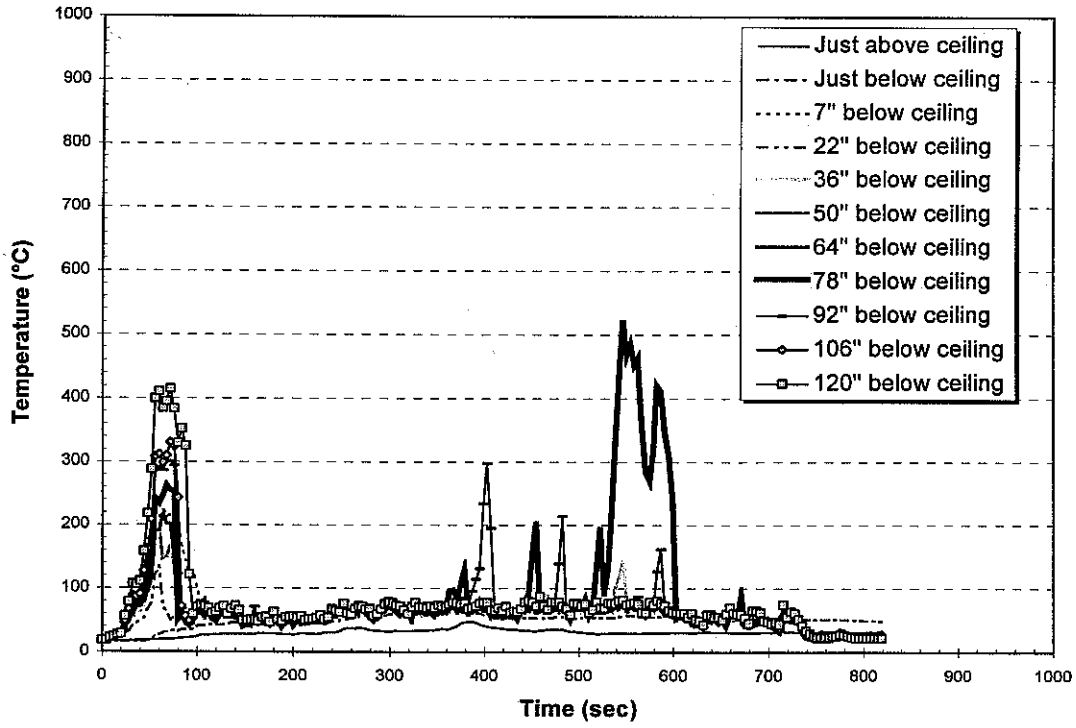


Figure B-30. Temperatures - Tree B : Test 8

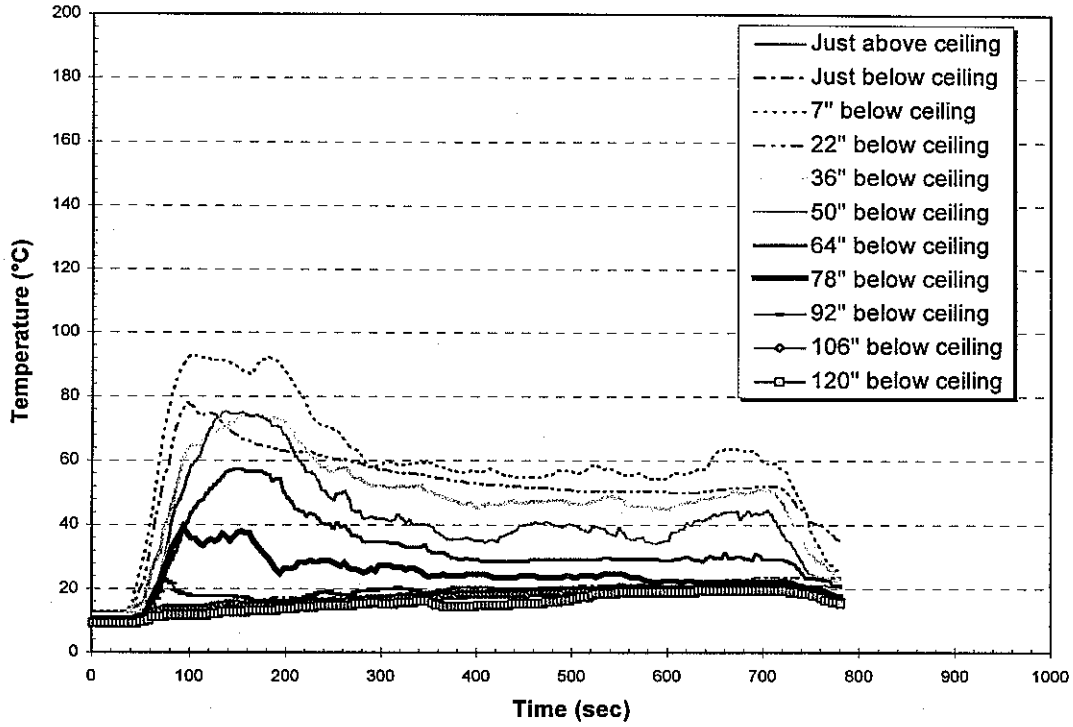


Figure B-31. Temperatures - Tree B : Test 9

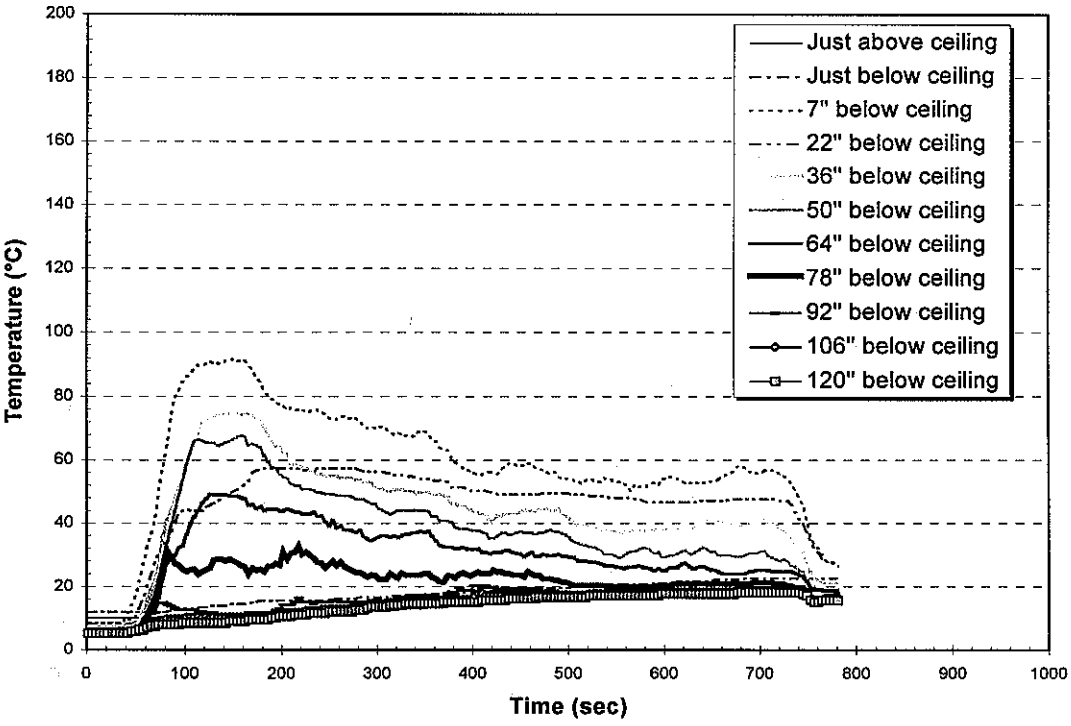


Figure B-32. Temperatures - Tree B : Test 10

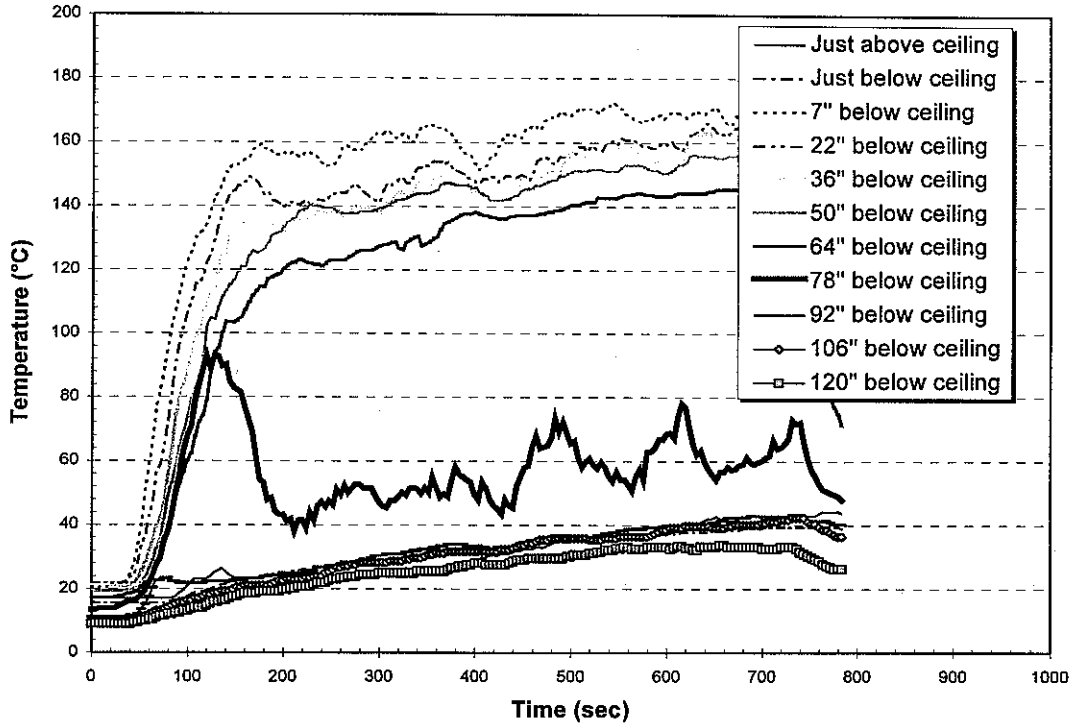


Figure B-33. Temperatures - Tree B : Test 11

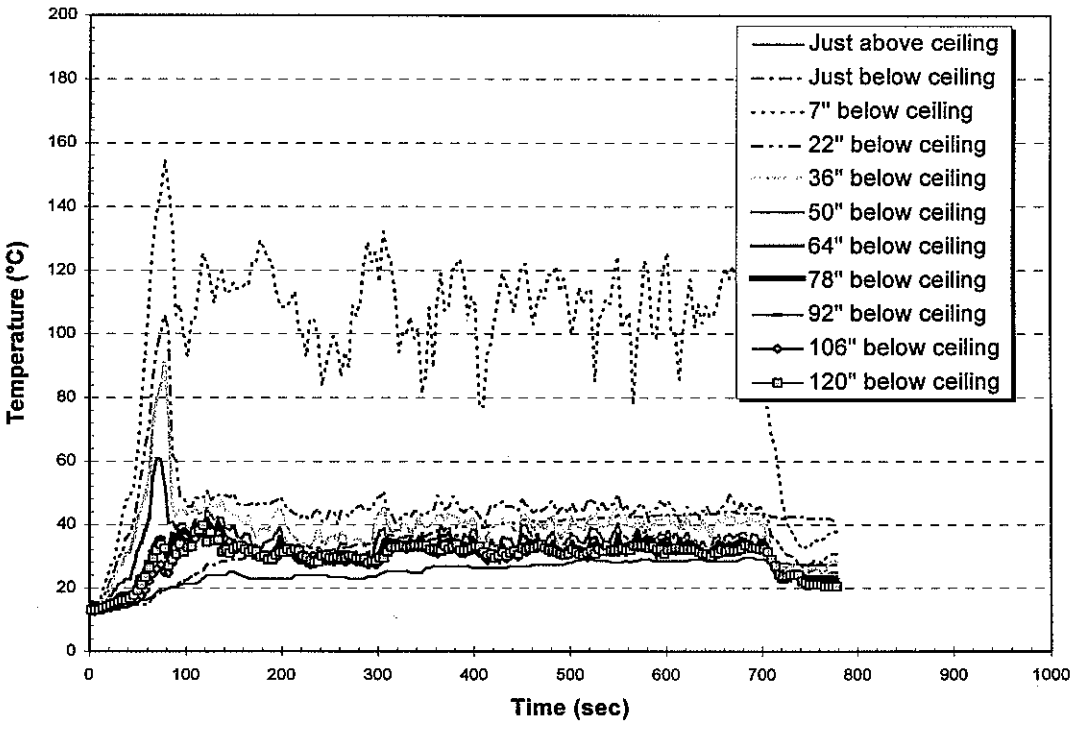


Figure B-34. Temperatures - Tree B : Test 12

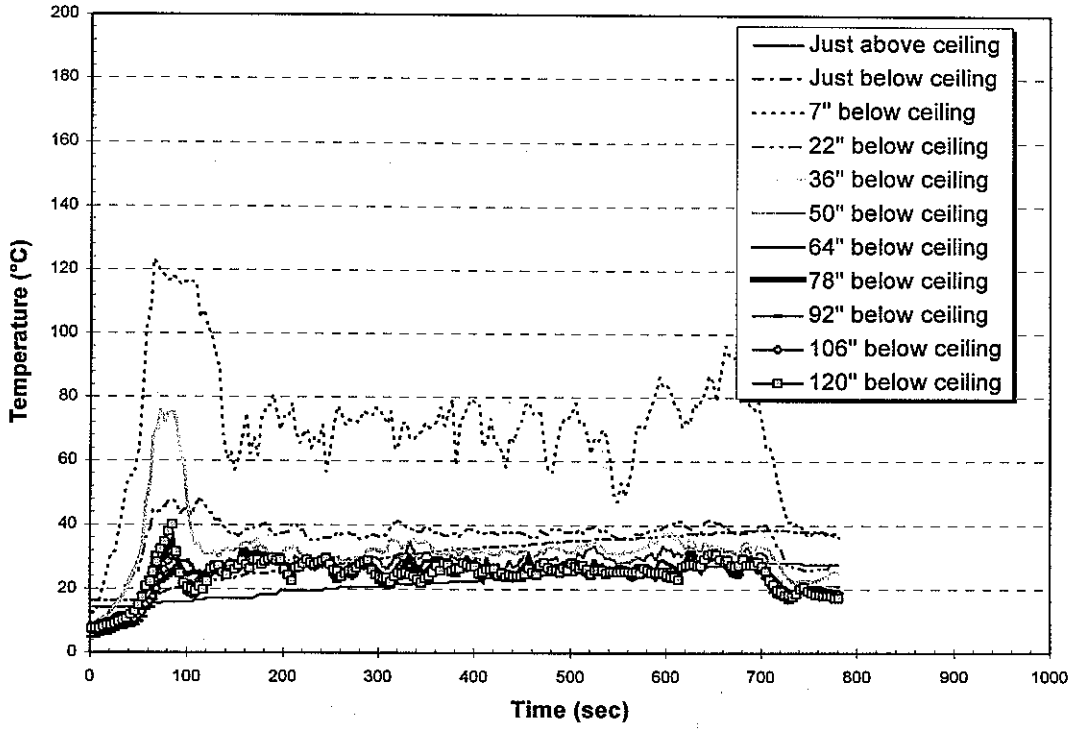


Figure B-35. Temperatures - Tree B : Test 13

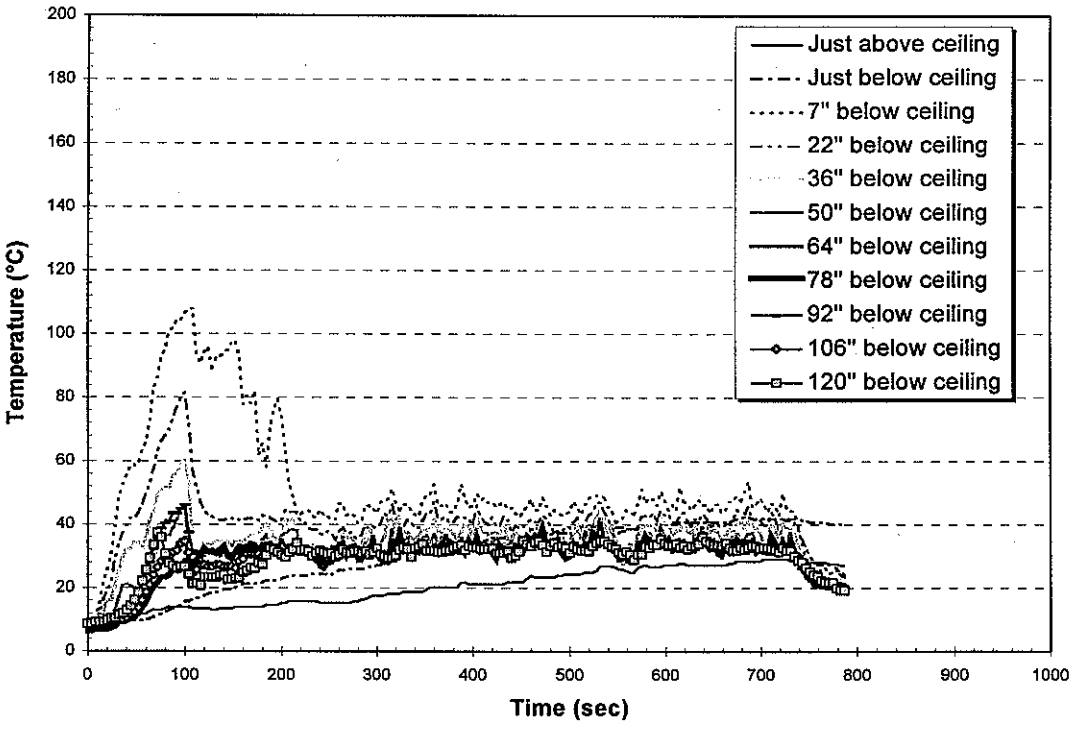


Figure B-36. Temperatures - Tree B : Test 14

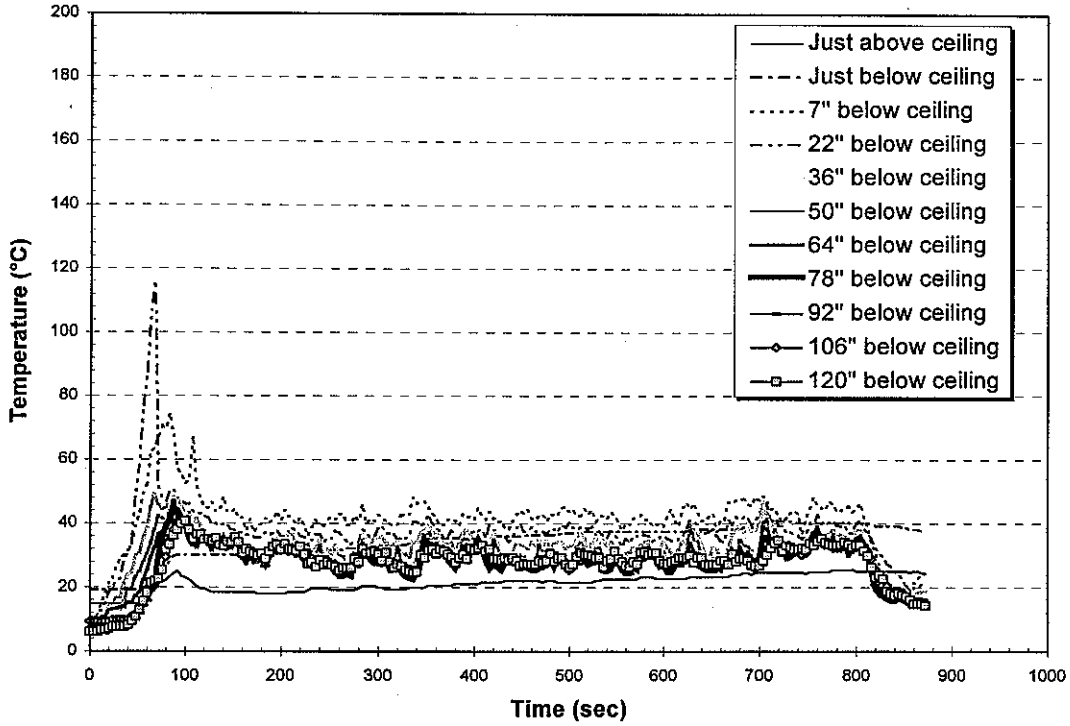


Figure B-37. Temperatures - Tree B : Test 15

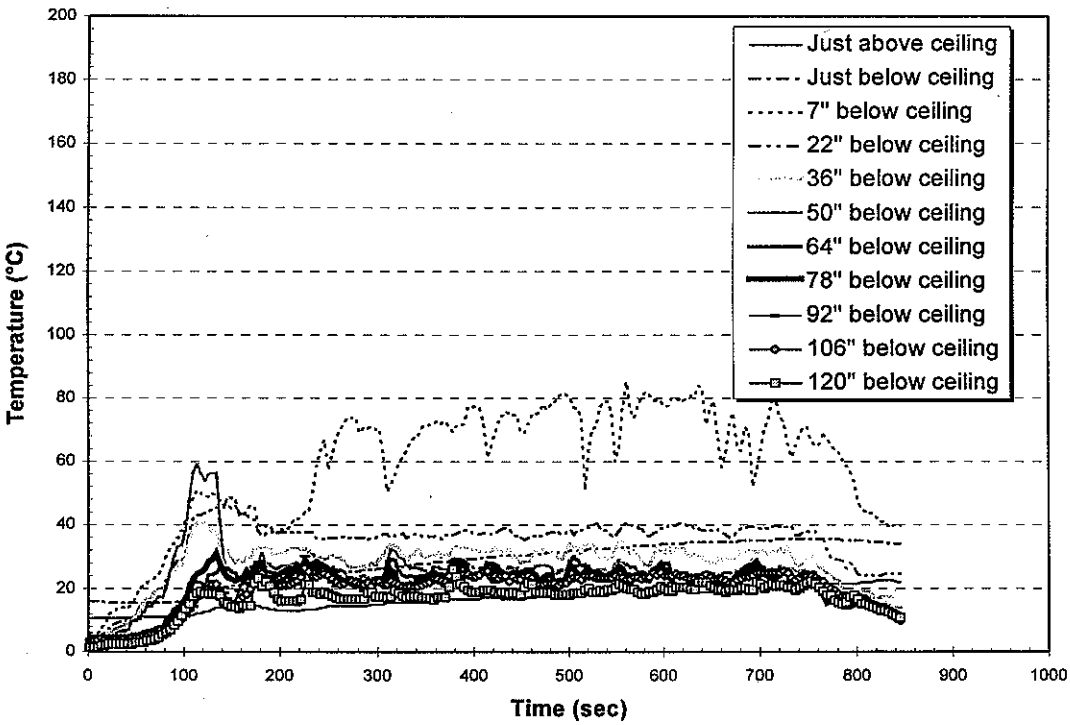


Figure B-38. Temperatures - Tree B : Test 16

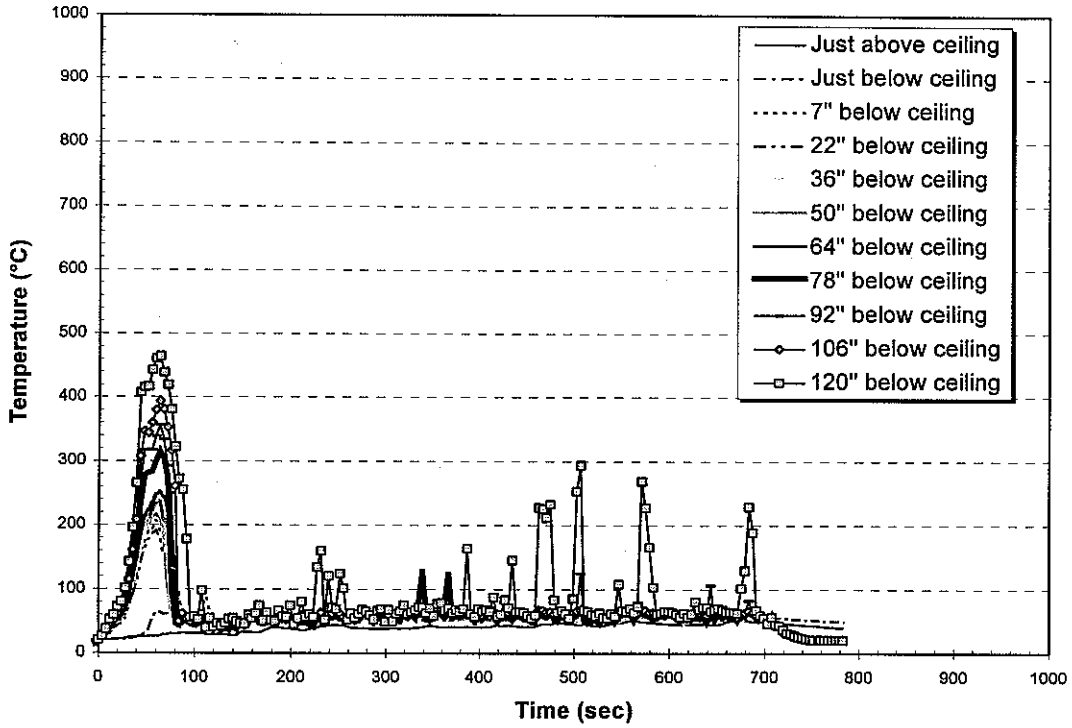


Figure B-39. Temperatures - Tree B : Test 17

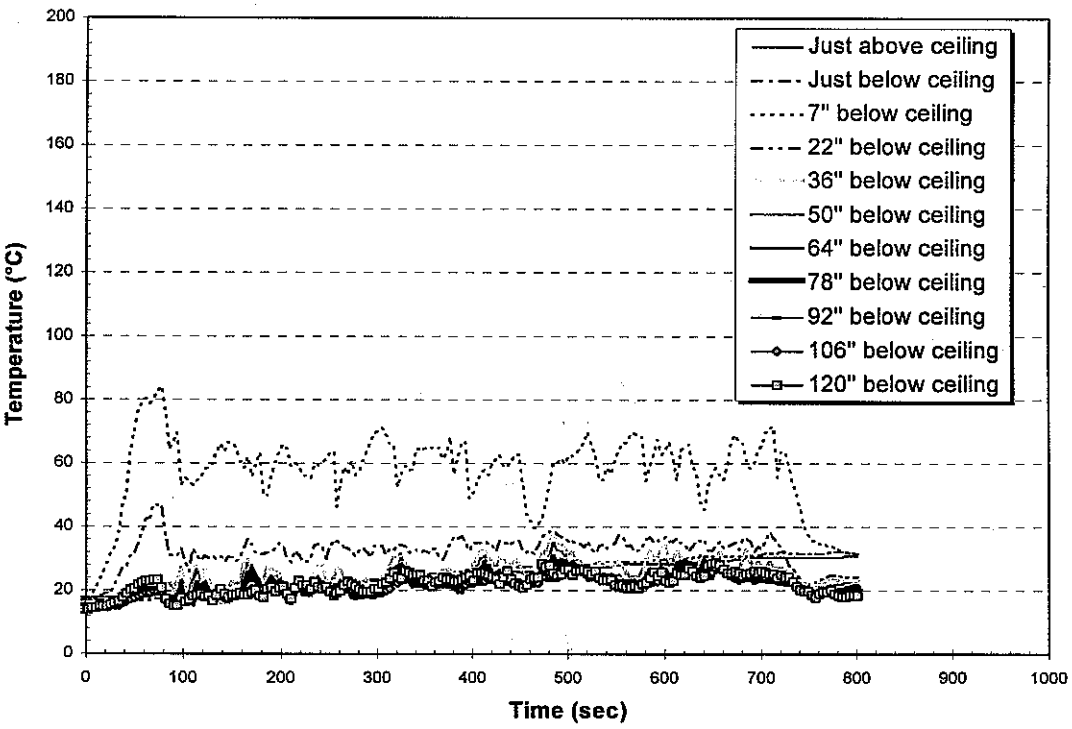


Figure B-40. Temperatures - Tree B : Test 18

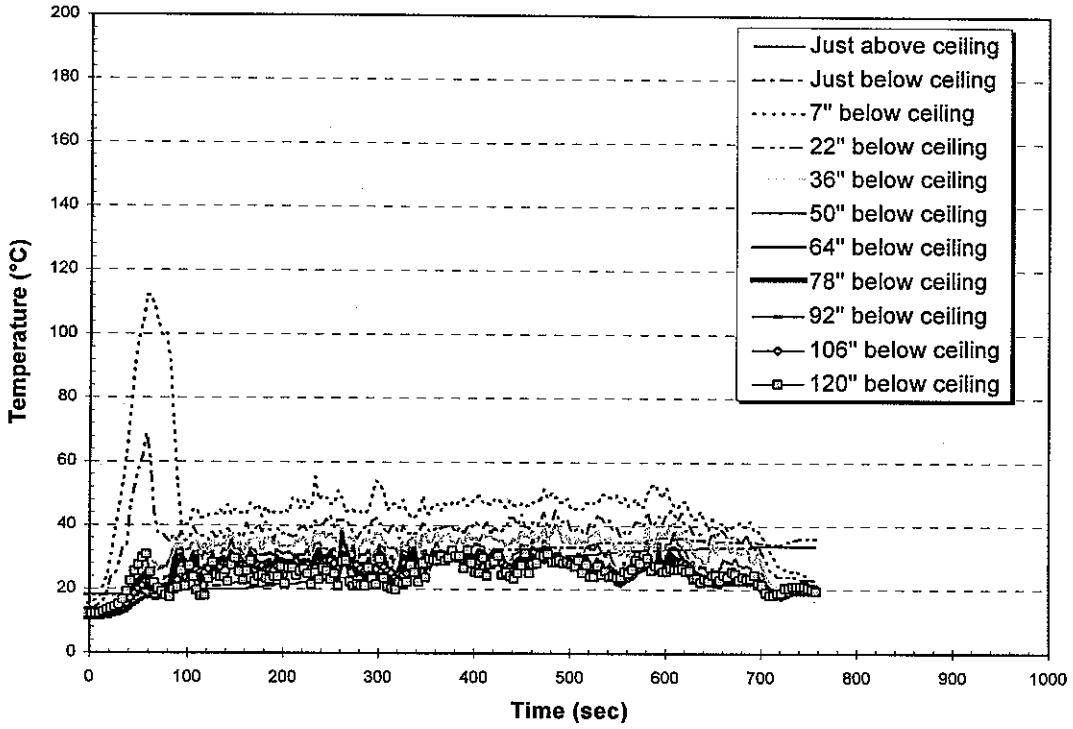


Figure B-41. Temperatures - Tree B : Test 19

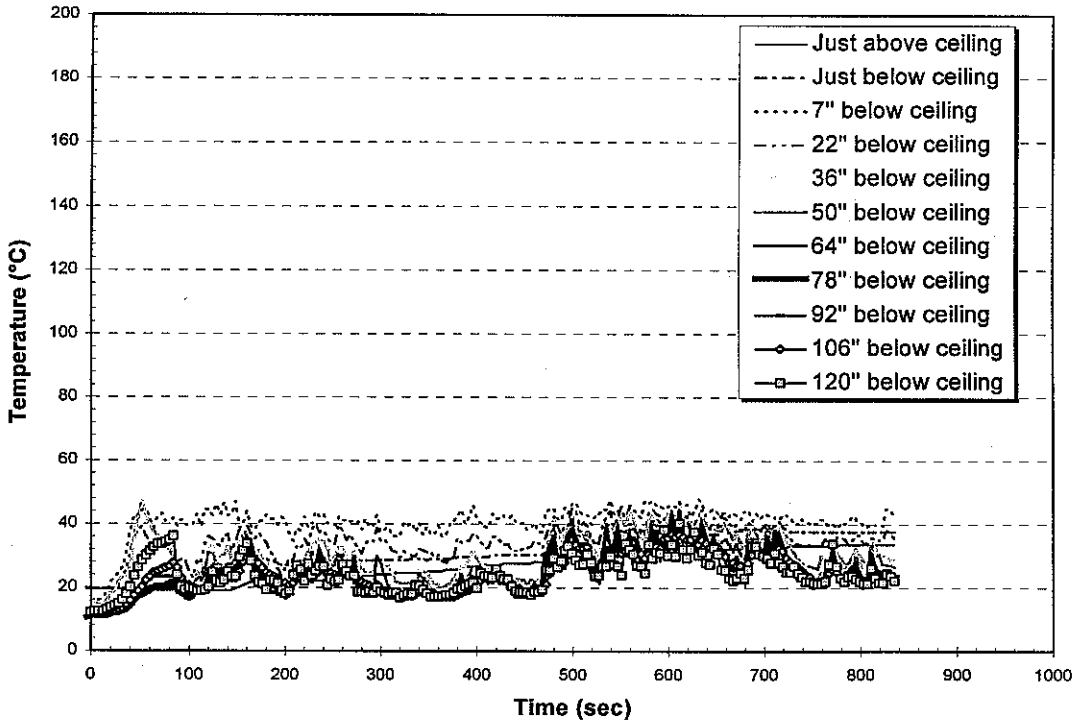


Figure B-42. Temperatures - Tree B : Test 20

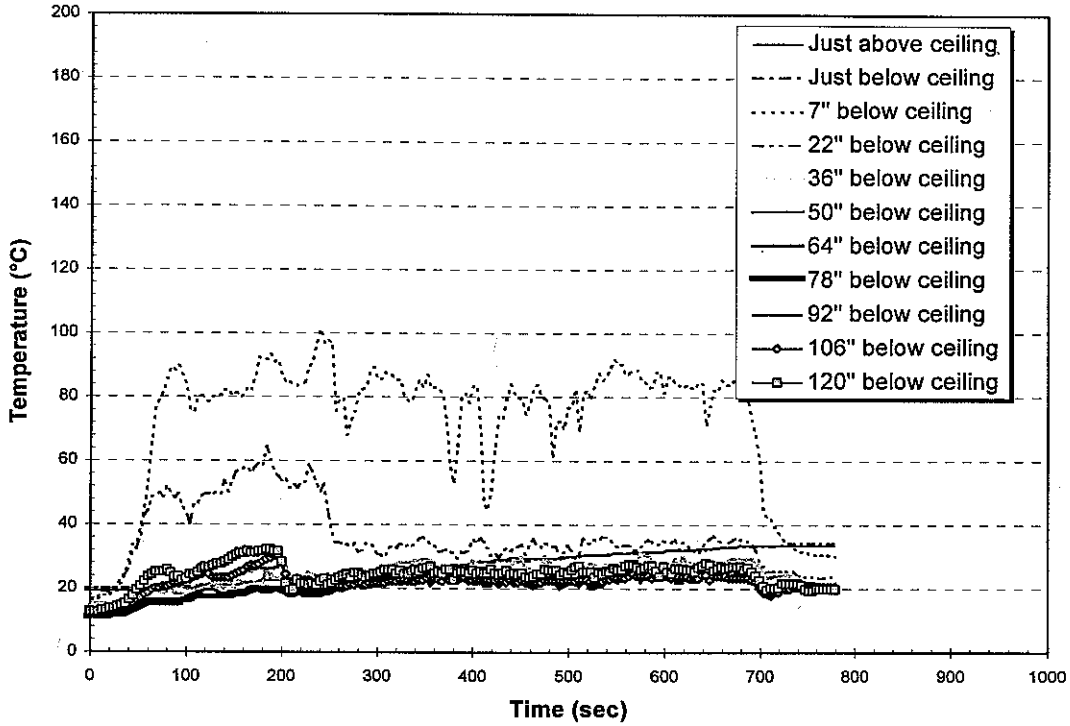


Figure B-43. Temperatures - Tree B : Test 21

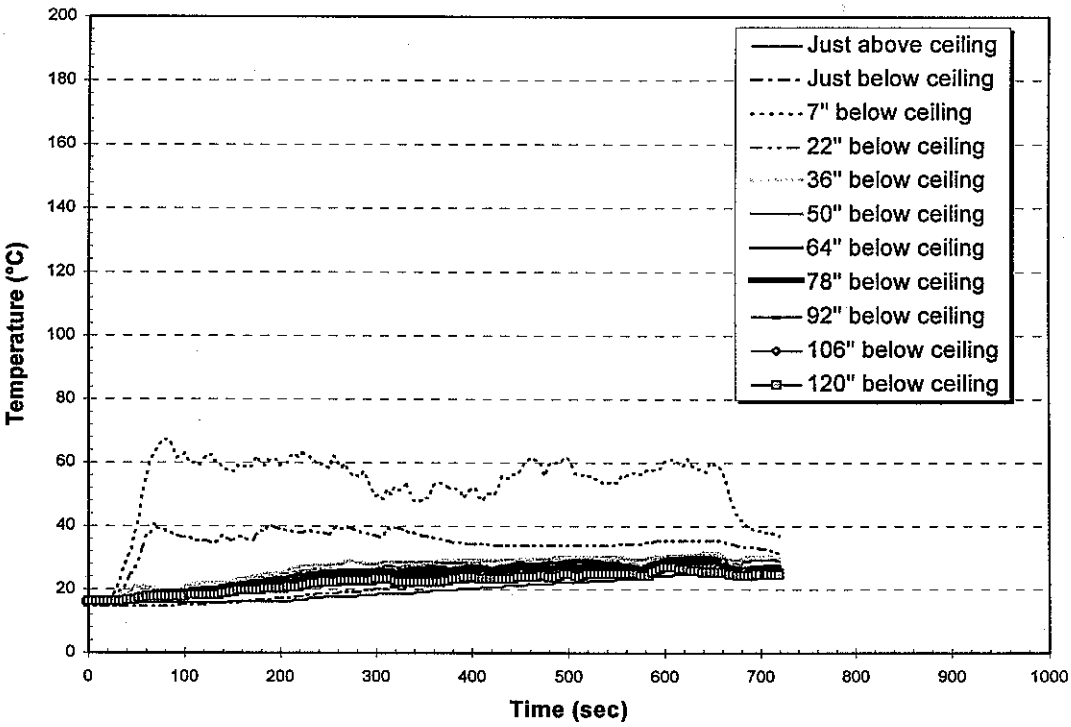


Figure B-44. Temperatures - Tree B : Test 22

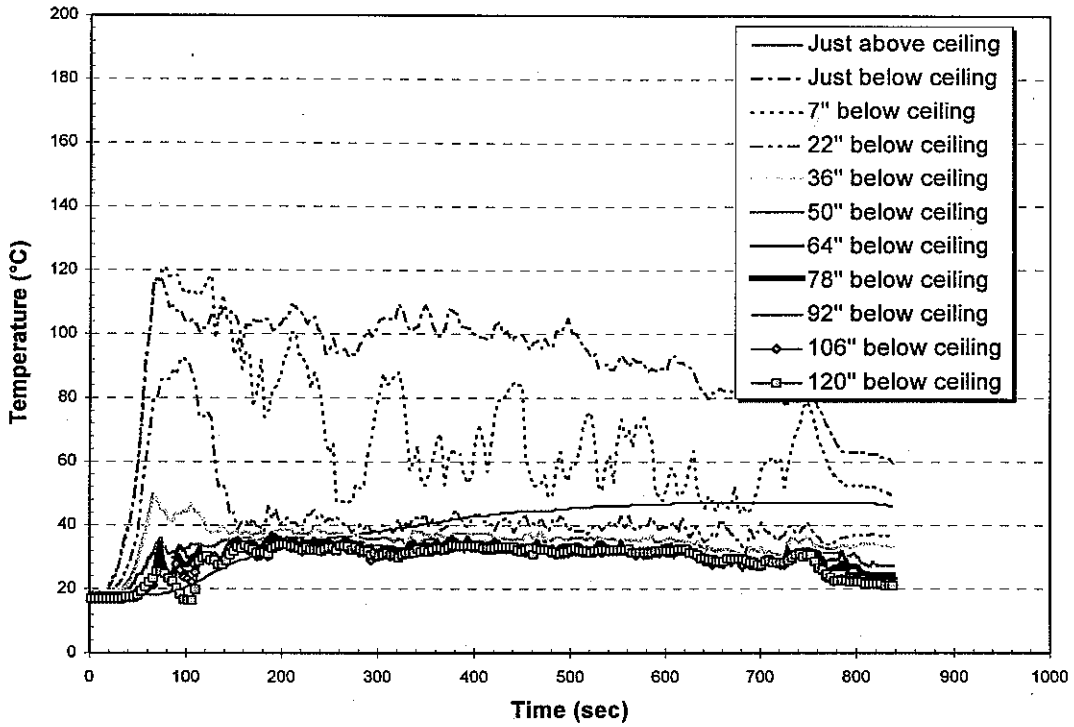


Figure B-45. Temperatures - Tree C : Test 1

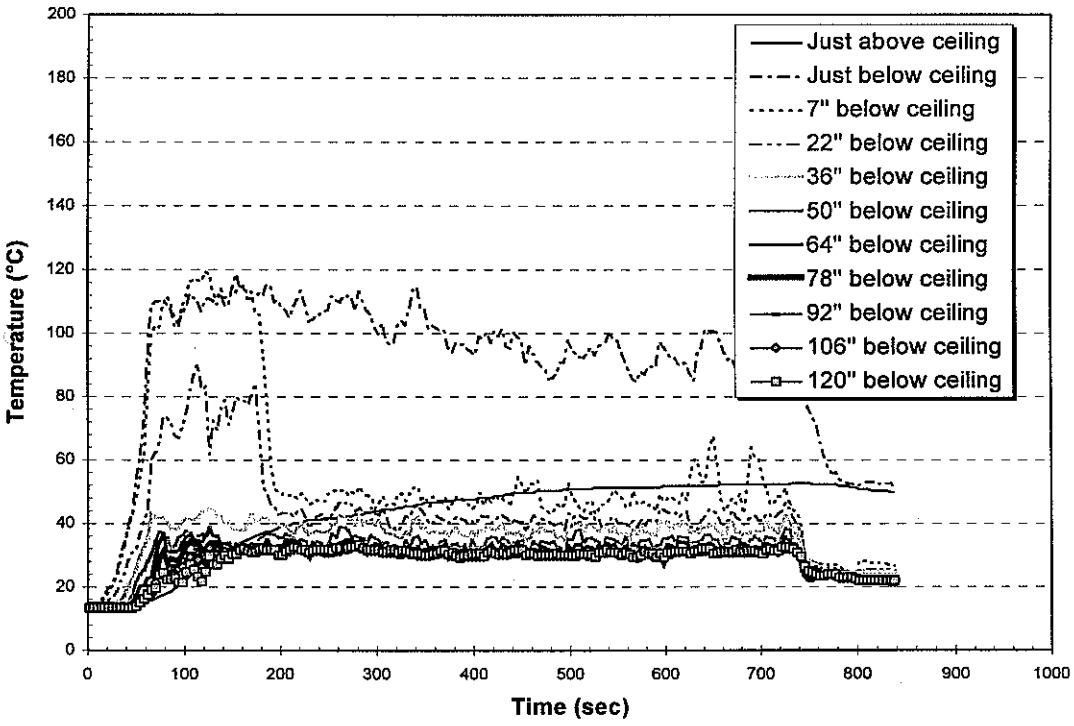


Figure B-46. Temperatures - Tree C : Test 2

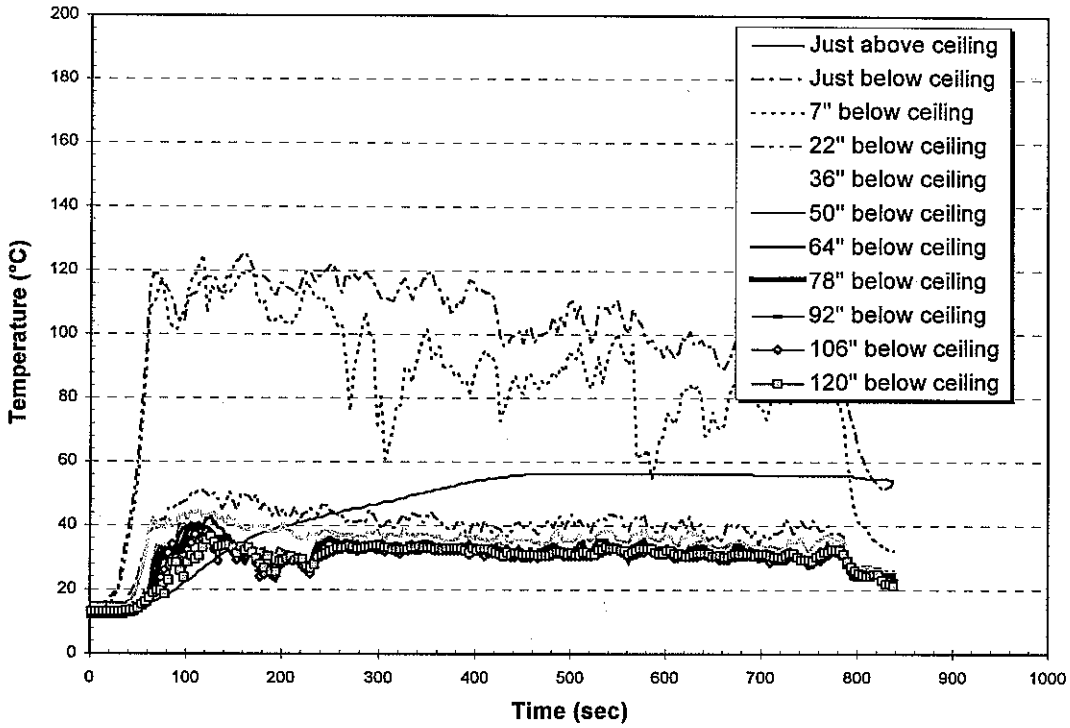


Figure B-47. Temperatures - Tree C : Test 3

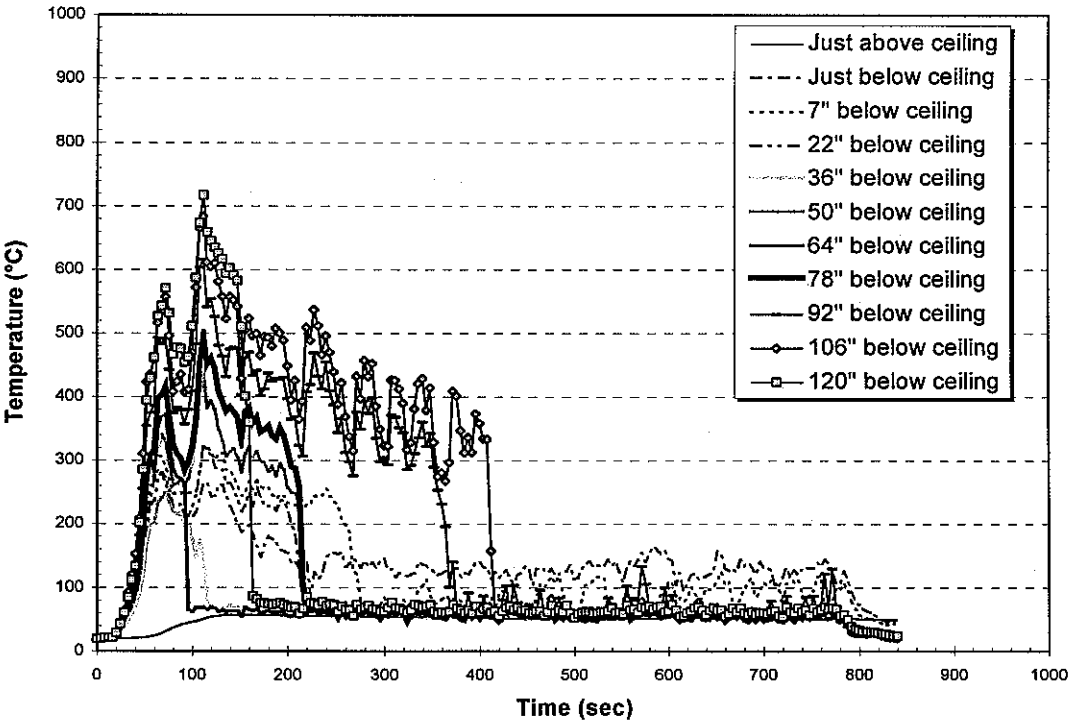


Figure B-48. Temperatures - Tree C : Test 4

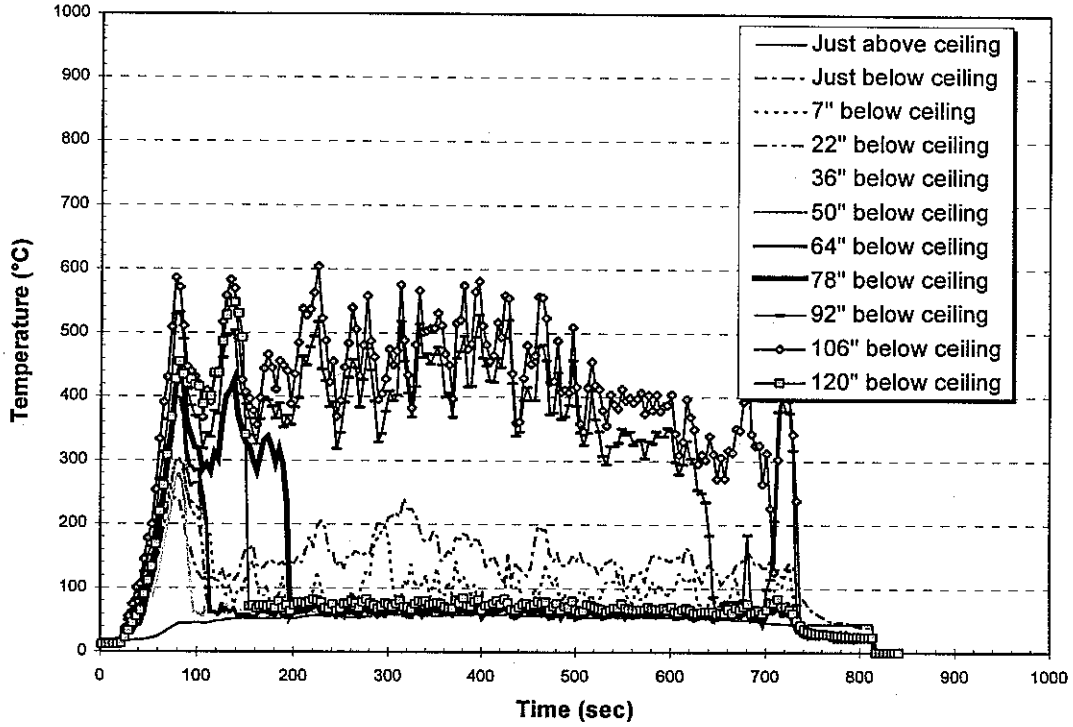


Figure B-49. Temperatures - Tree C : Test 5

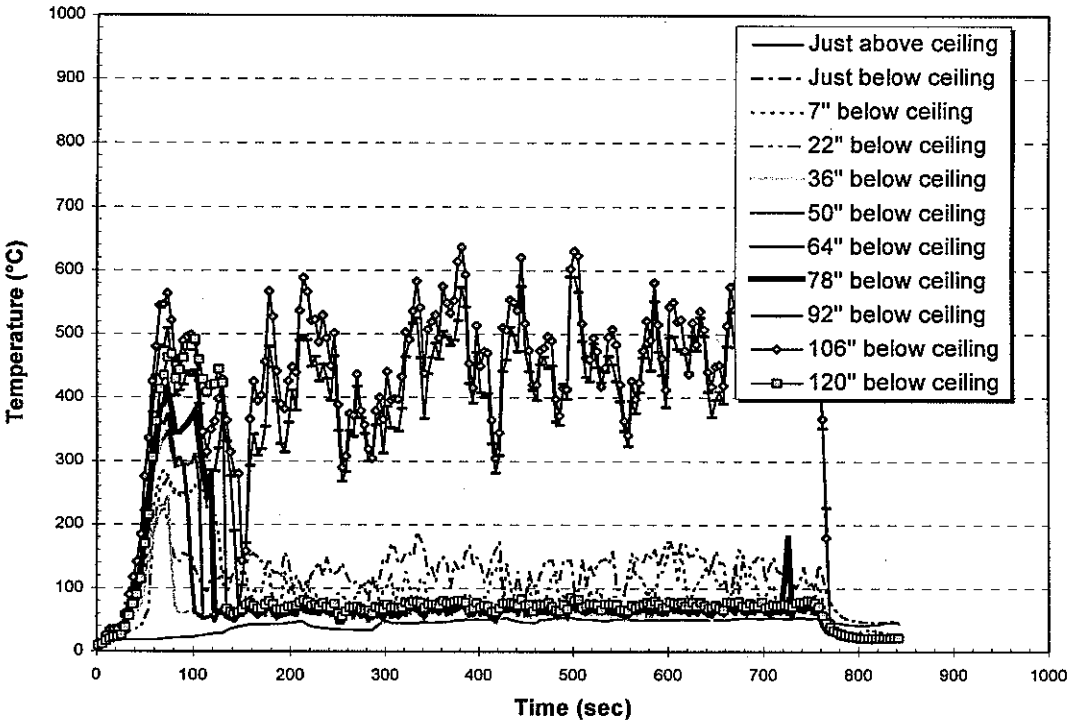


Figure B-50. Temperatures - Tree C : Test 6

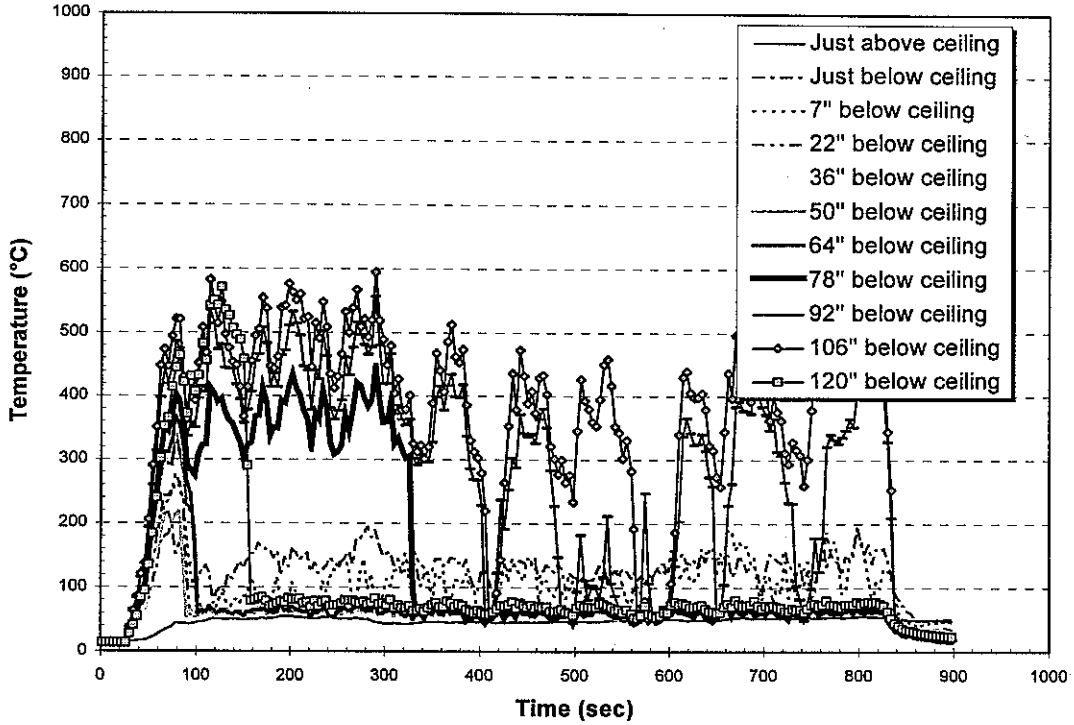


Figure B-51. Temperatures - Tree C : Test 7

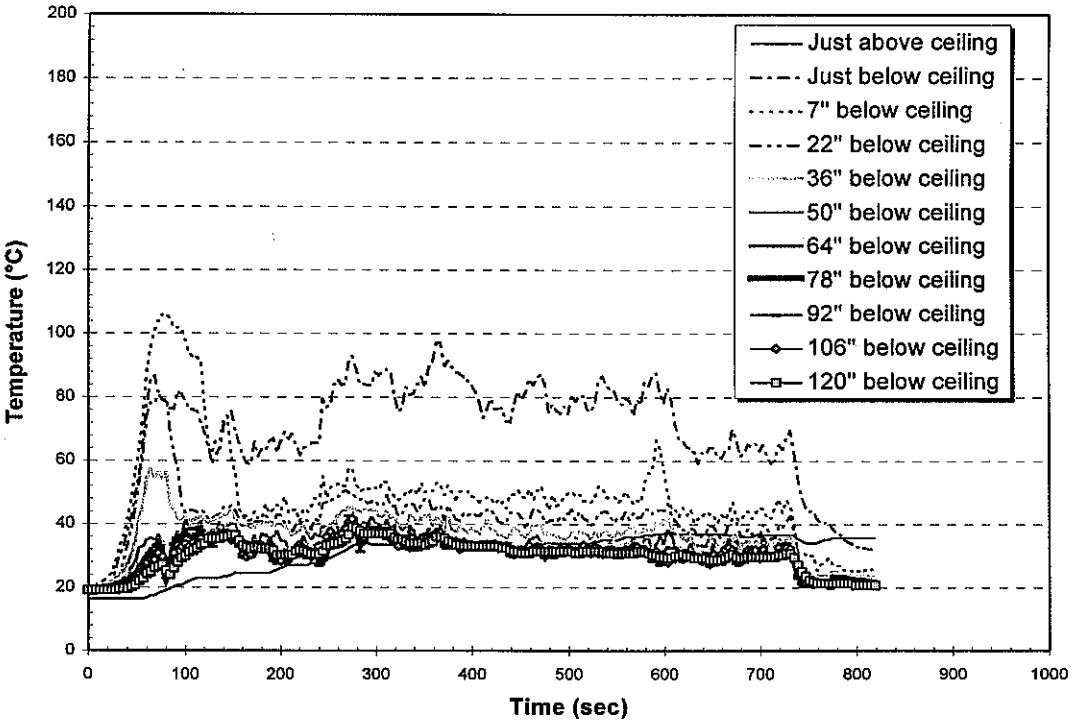


Figure B-52. Temperatures - Tree C : Test 8

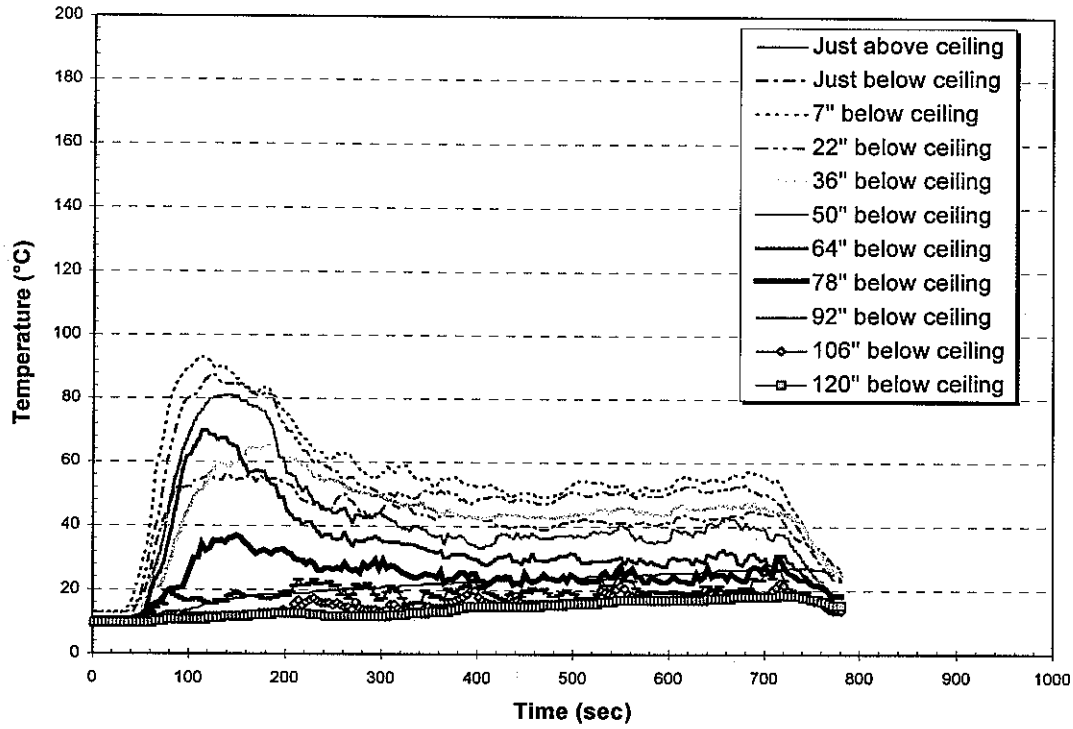


Figure B-53. Temperatures - Tree C : Test 9

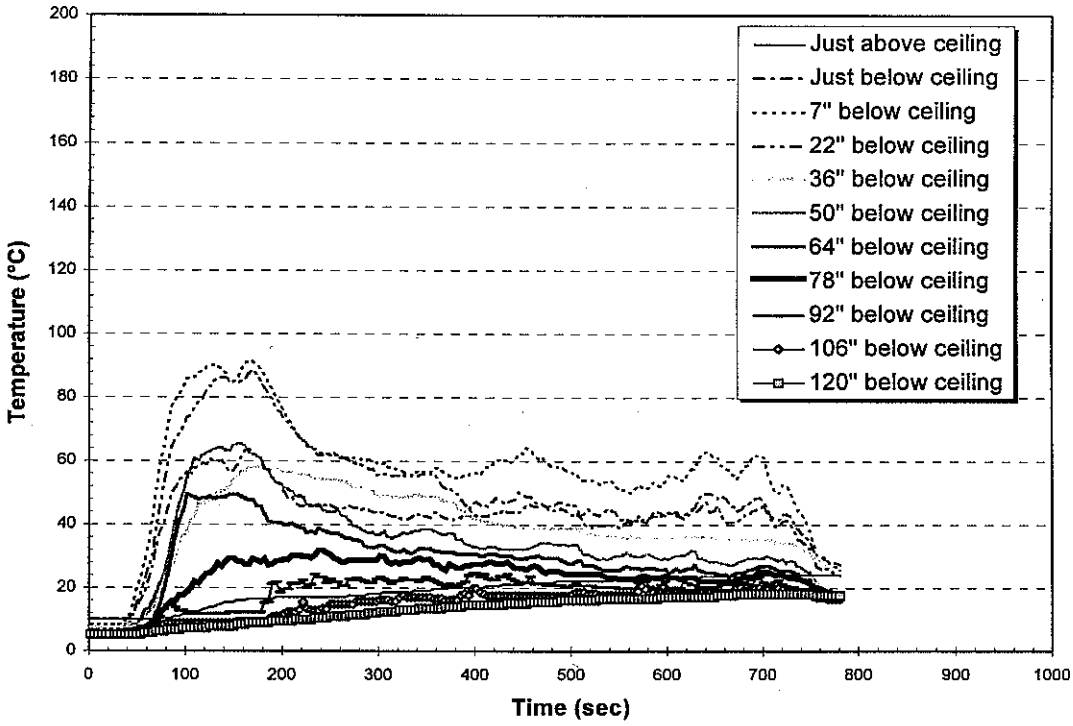


Figure B-54. Temperatures - Tree C : Test 10

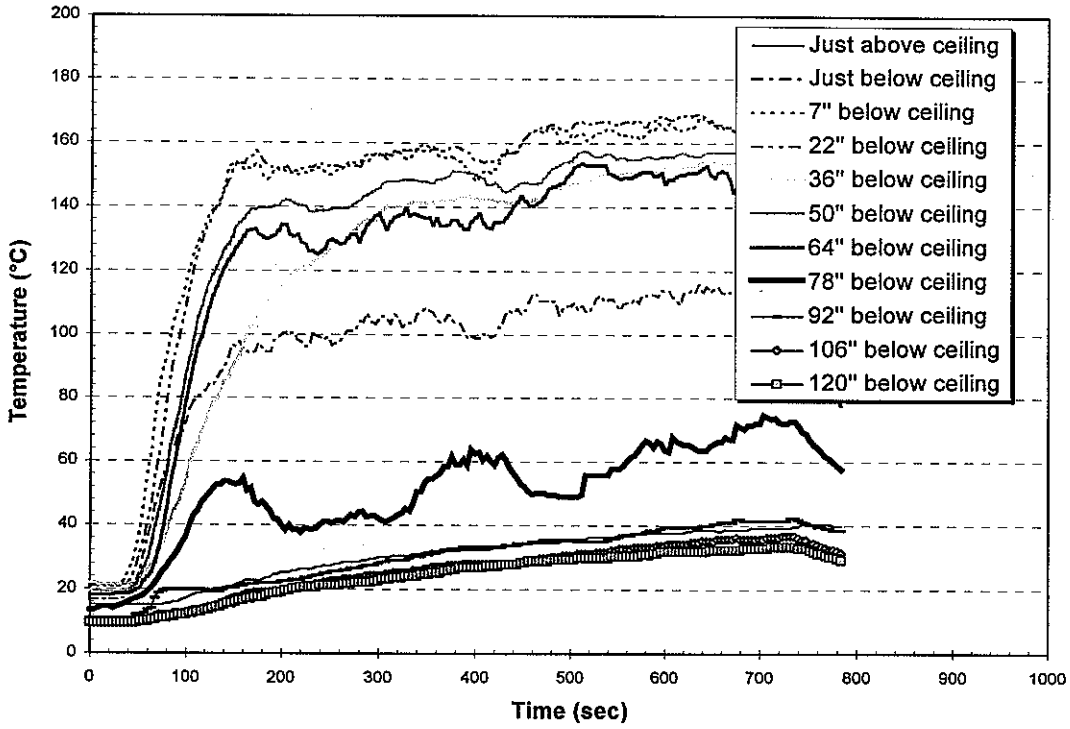


Figure B-55. Temperatures - Tree C : Test 11

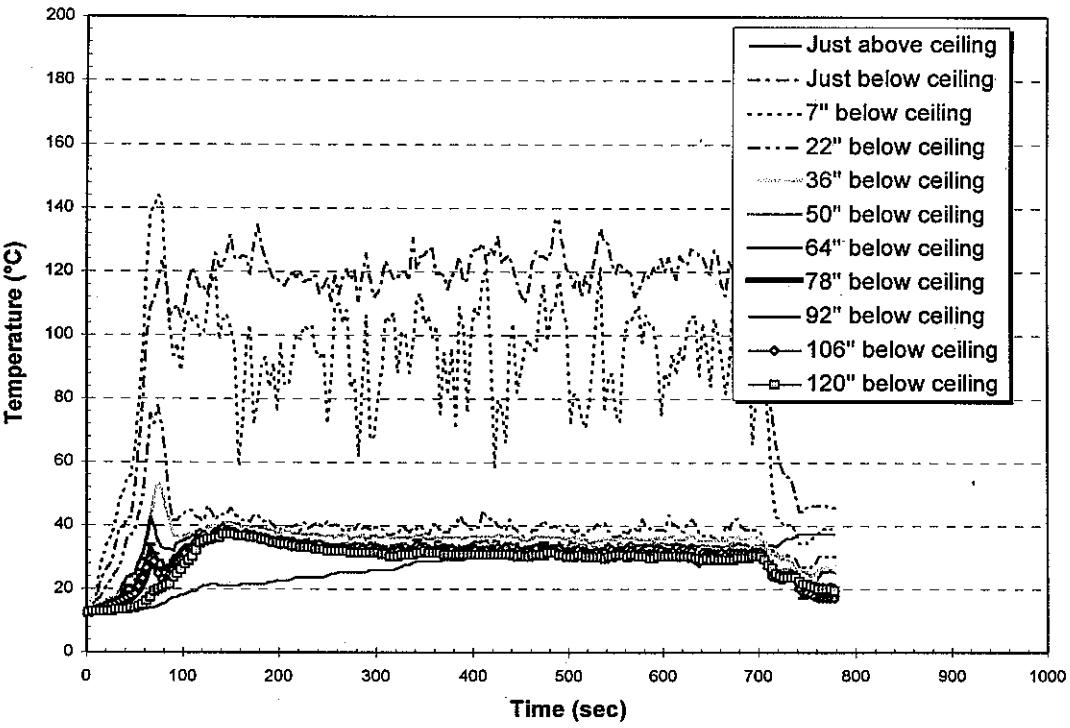


Figure B-56. Temperatures - Tree C : Test 12

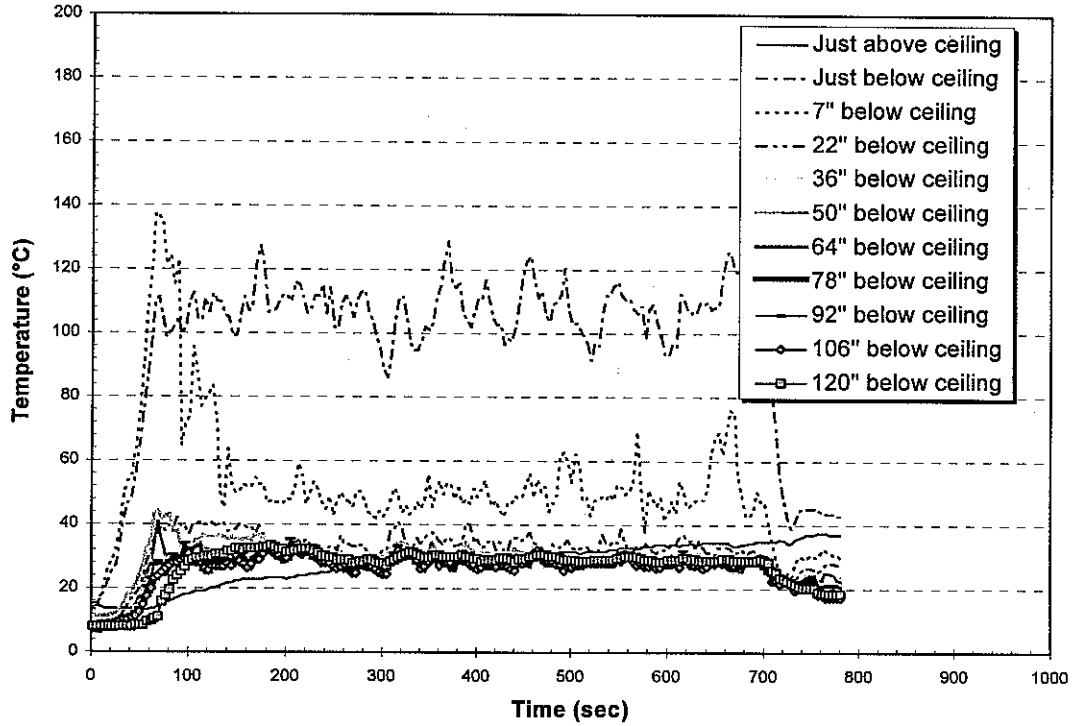


Figure B-57. Temperatures - Tree C : Test 13

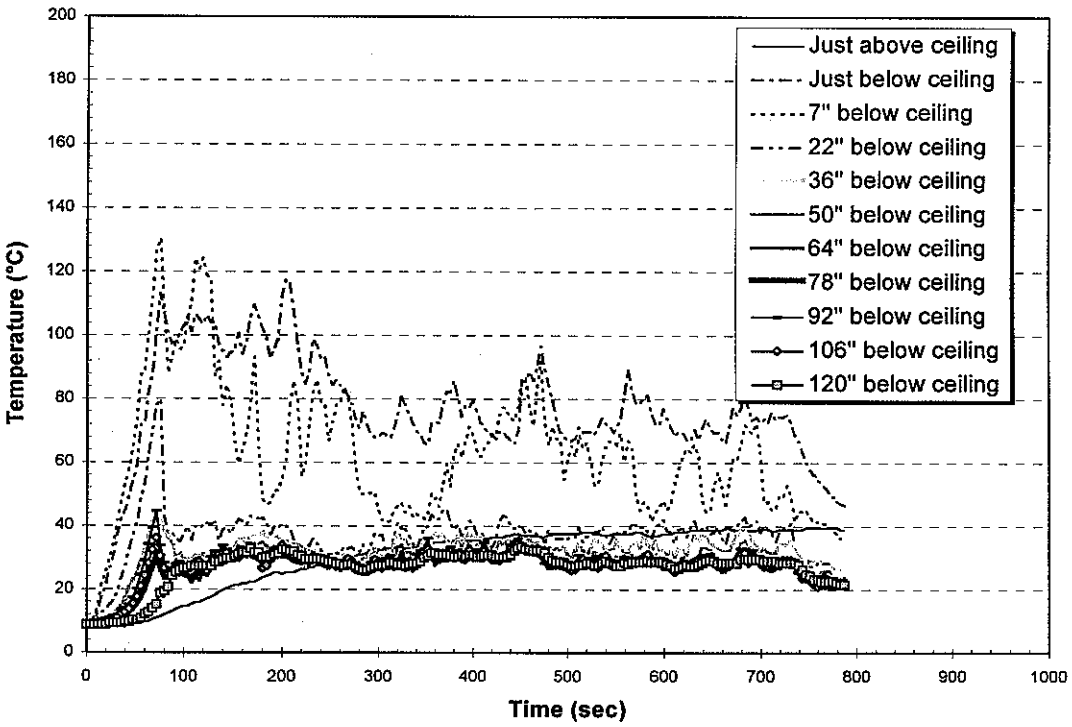


Figure B-58. Temperatures - Tree C : Test 14

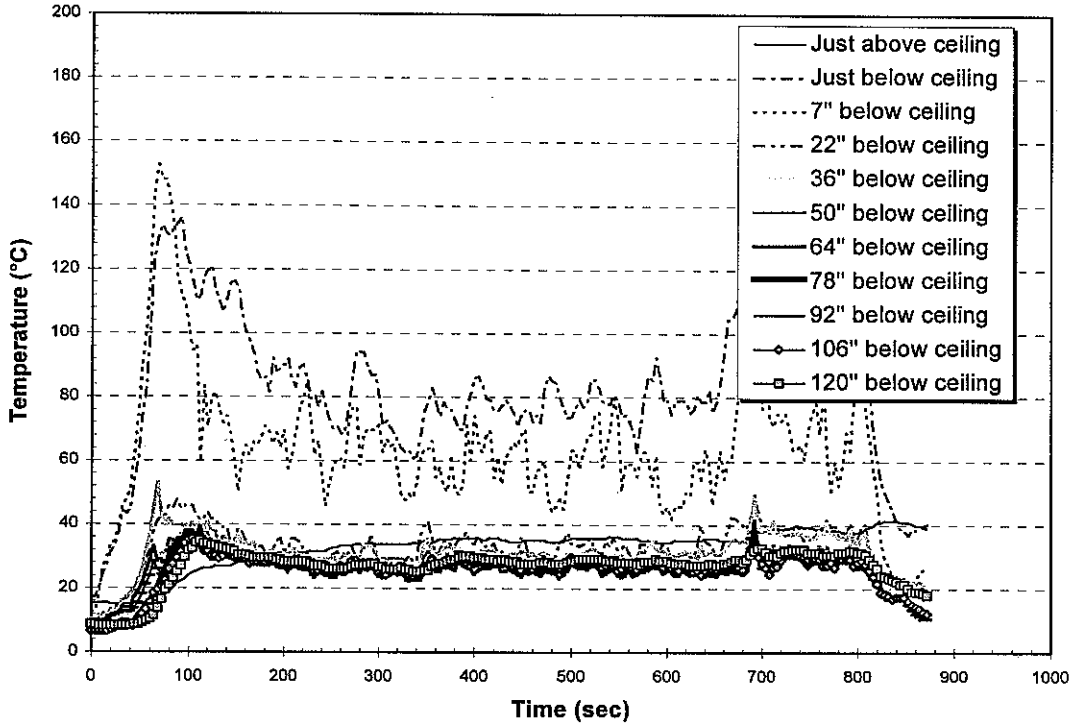


Figure B-59. Temperatures - Tree C : Test 15

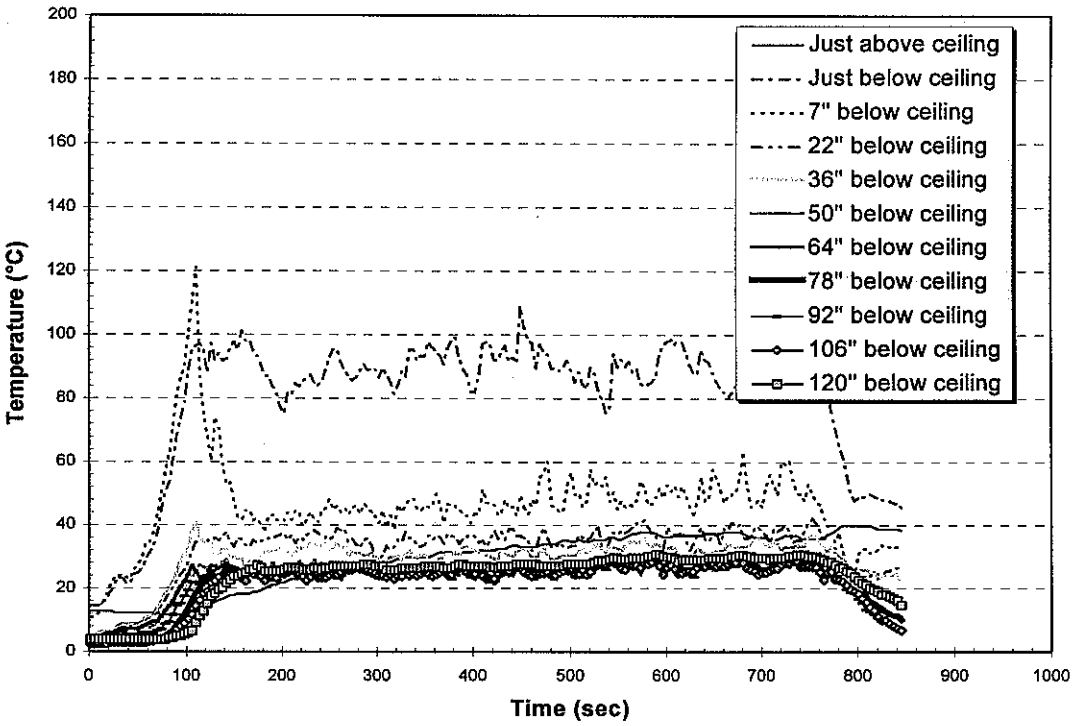


Figure B-60. Temperatures - Tree C : Test 16

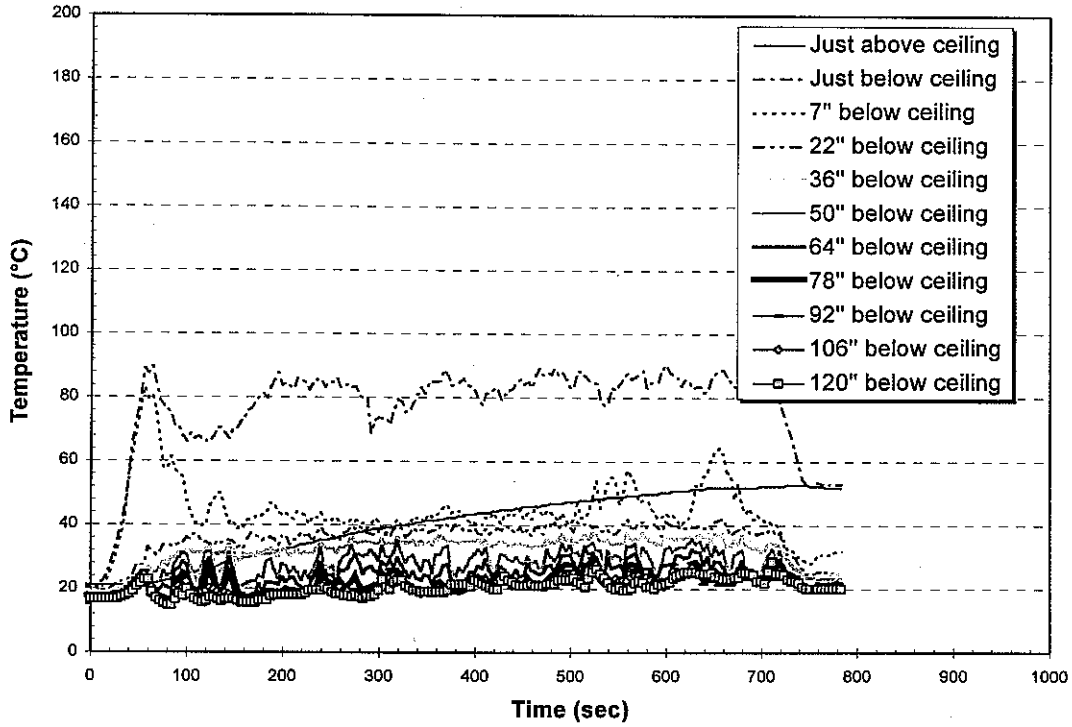


Figure B-61. Temperatures - Tree C : Test 17

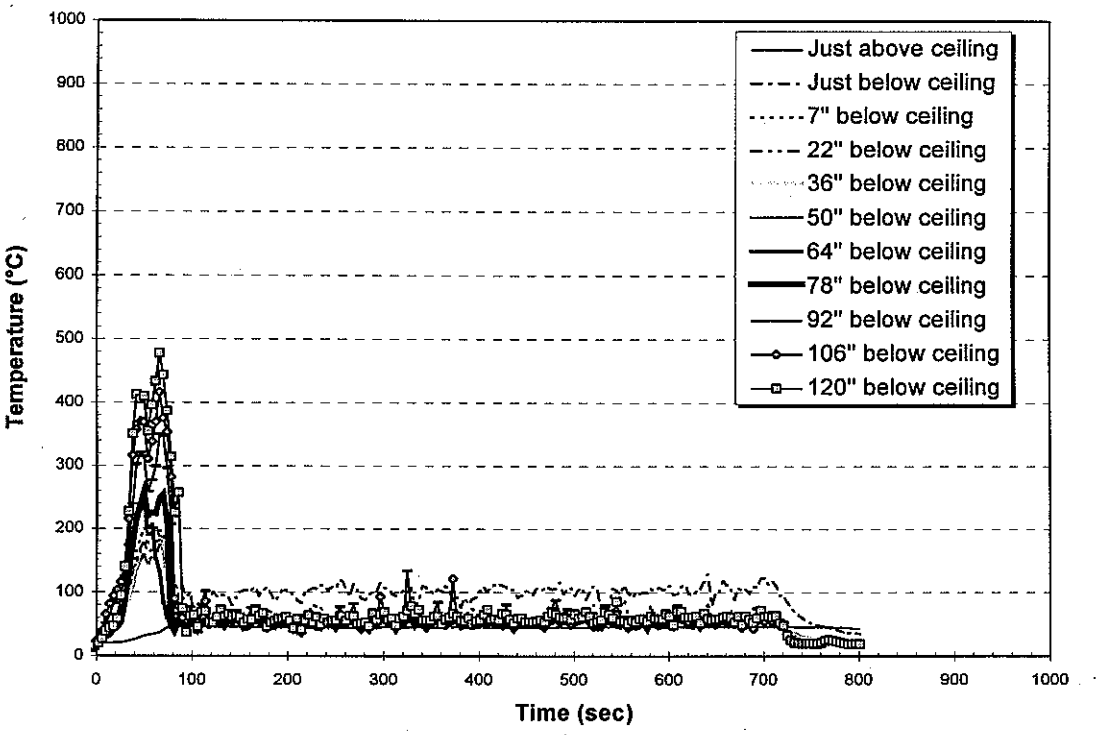


Figure B-62. Temperatures - Tree C : Test 18

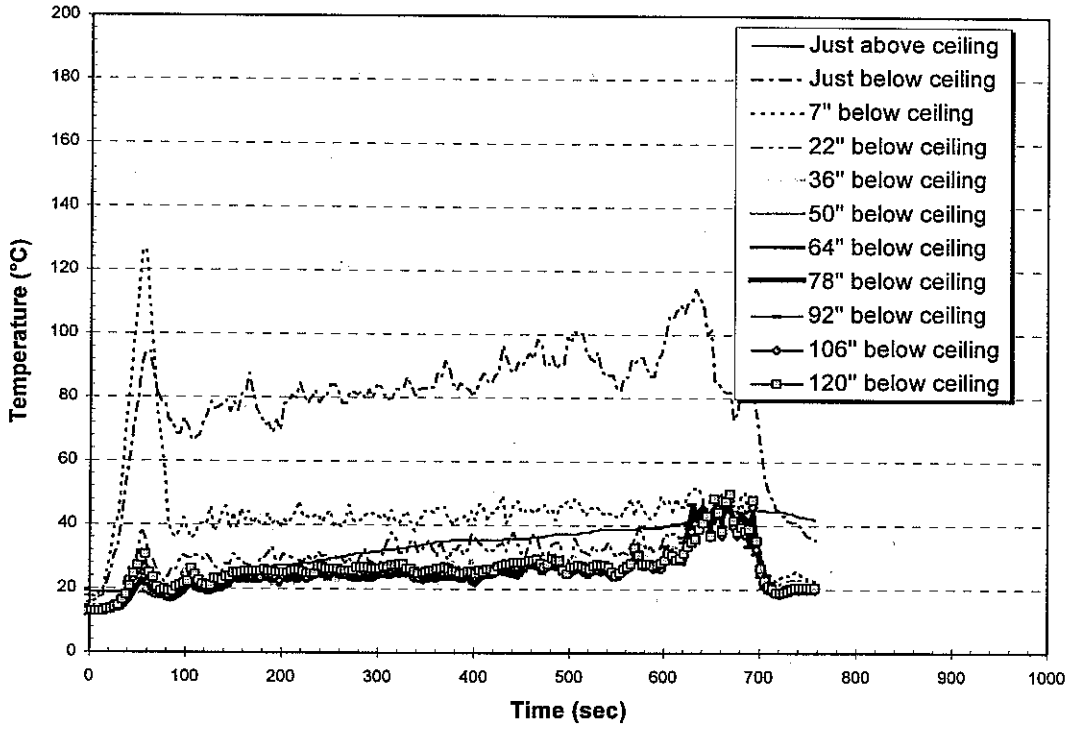


Figure B-63. Temperatures - Tree C : Test 19

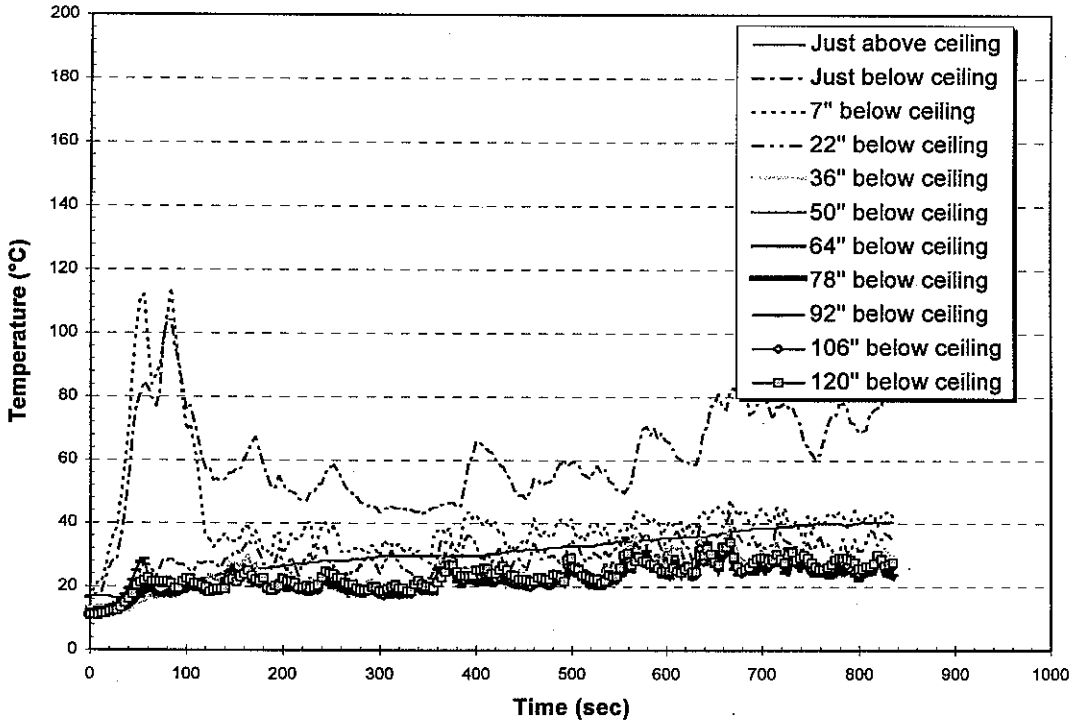


Figure B-64. Temperatures - Tree C : Test 20

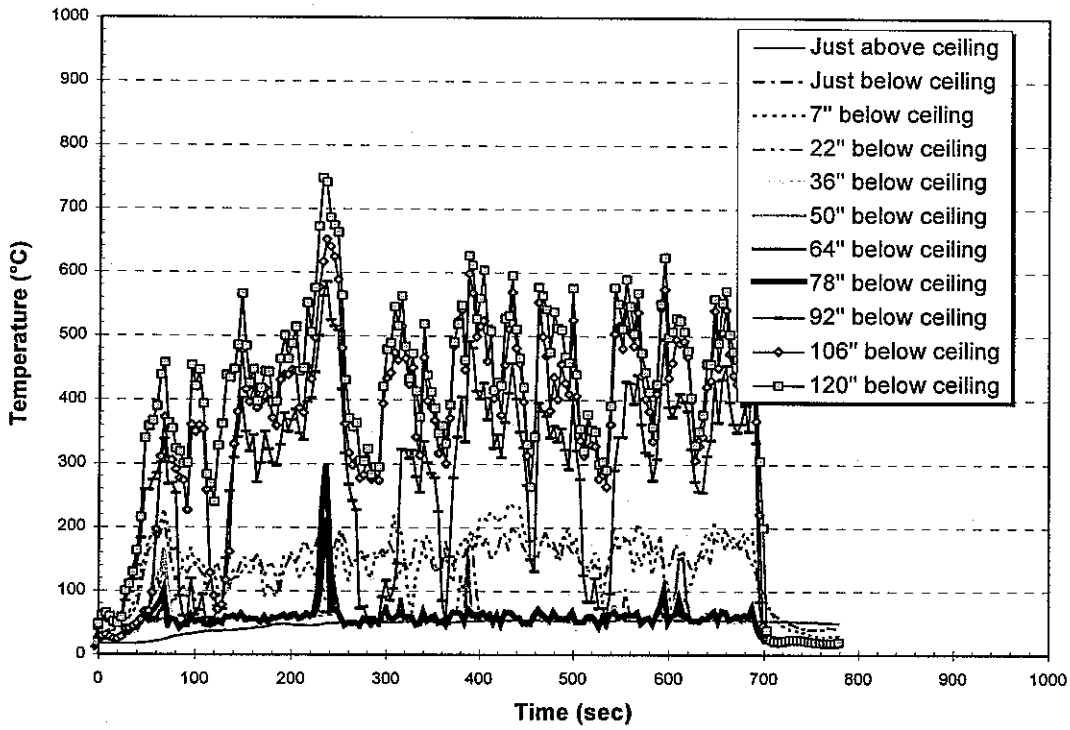


Figure B-65. Temperatures - Tree C : Test 21

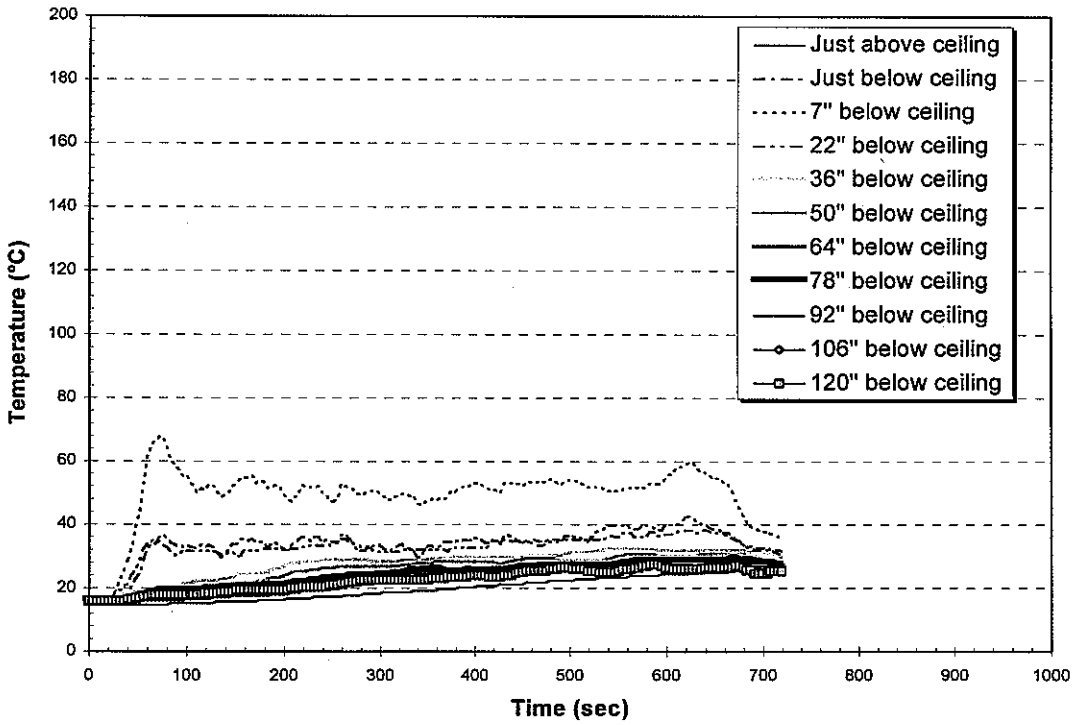


Figure B-66. Temperatures - Tree C : Test 22

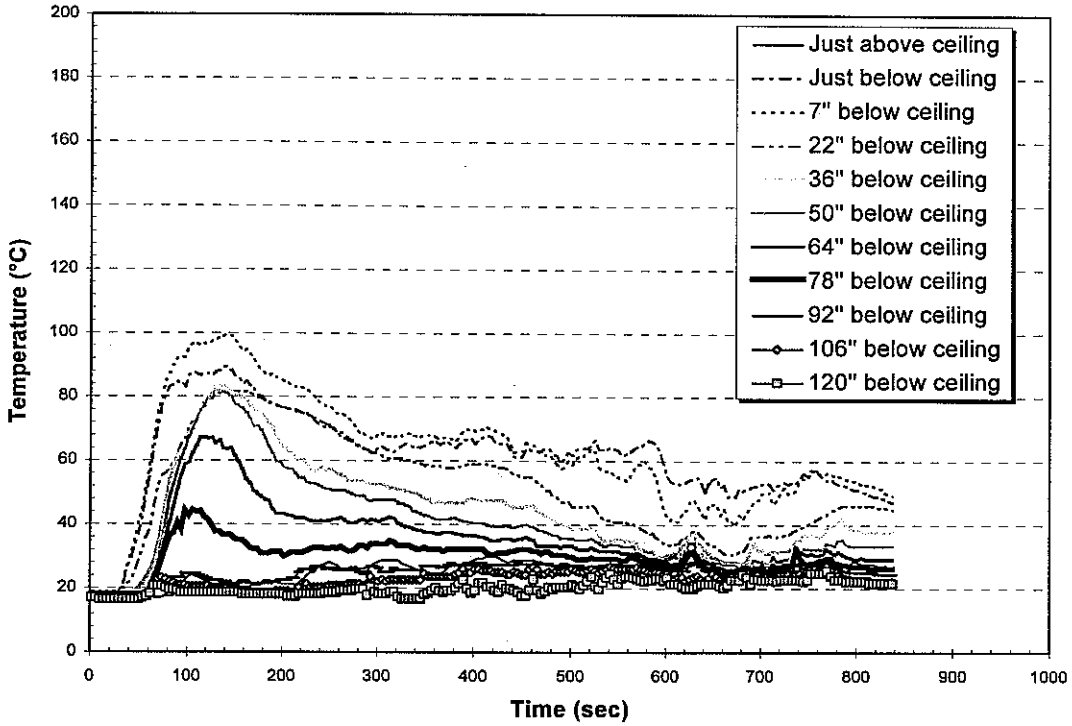


Figure B-67. Temperatures - Tree D : Test 1

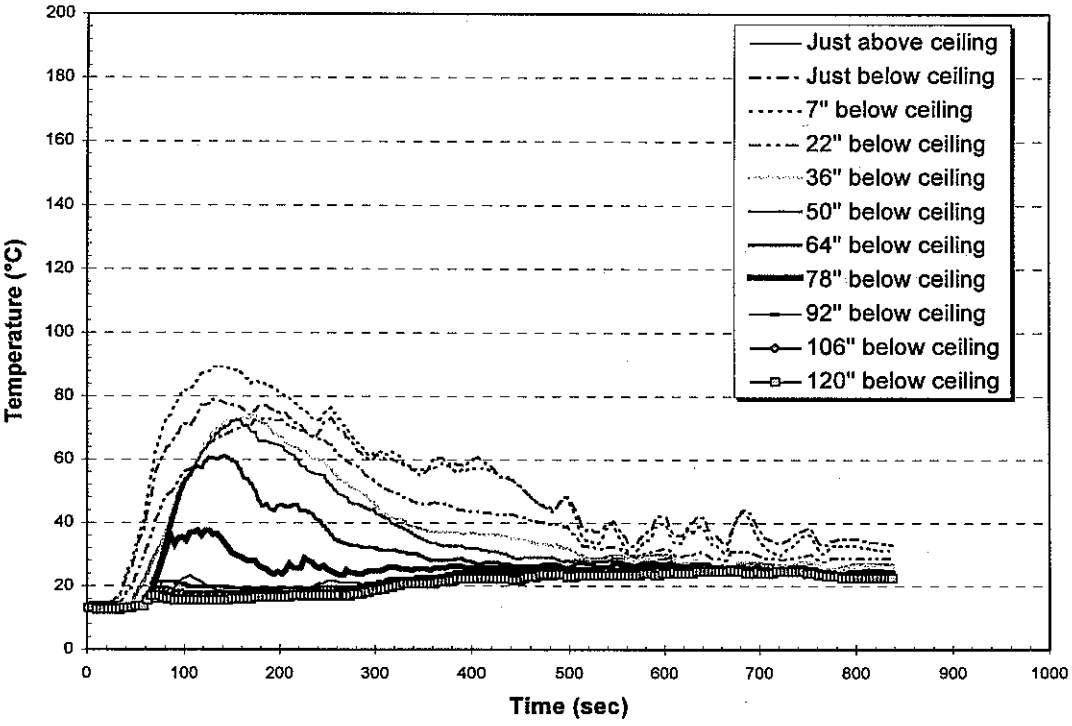


Figure B-68. Temperatures - Tree D : Test 2

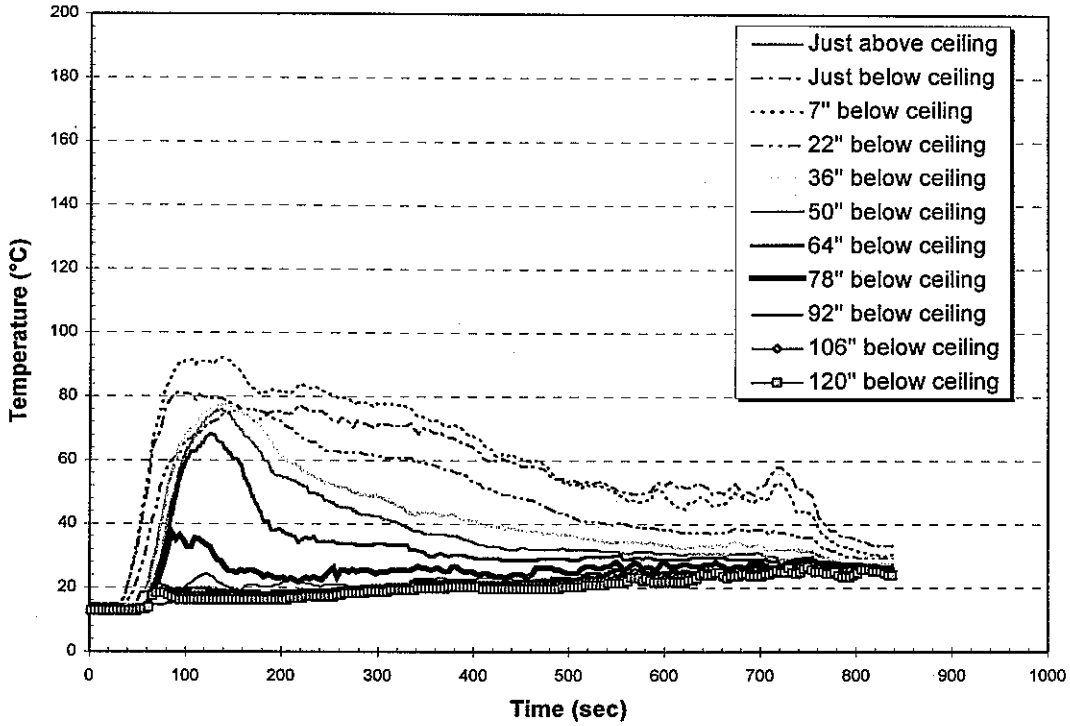


Figure B-69. Temperatures - Tree D : Test 3

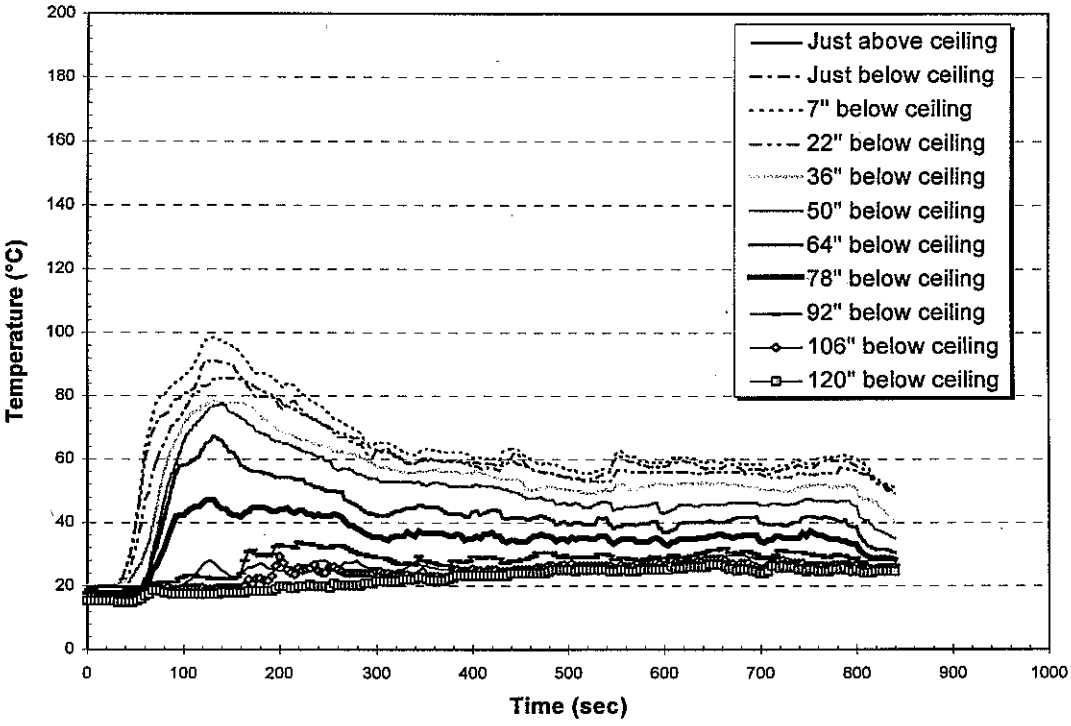


Figure B-70. Temperatures - Tree D : Test 4

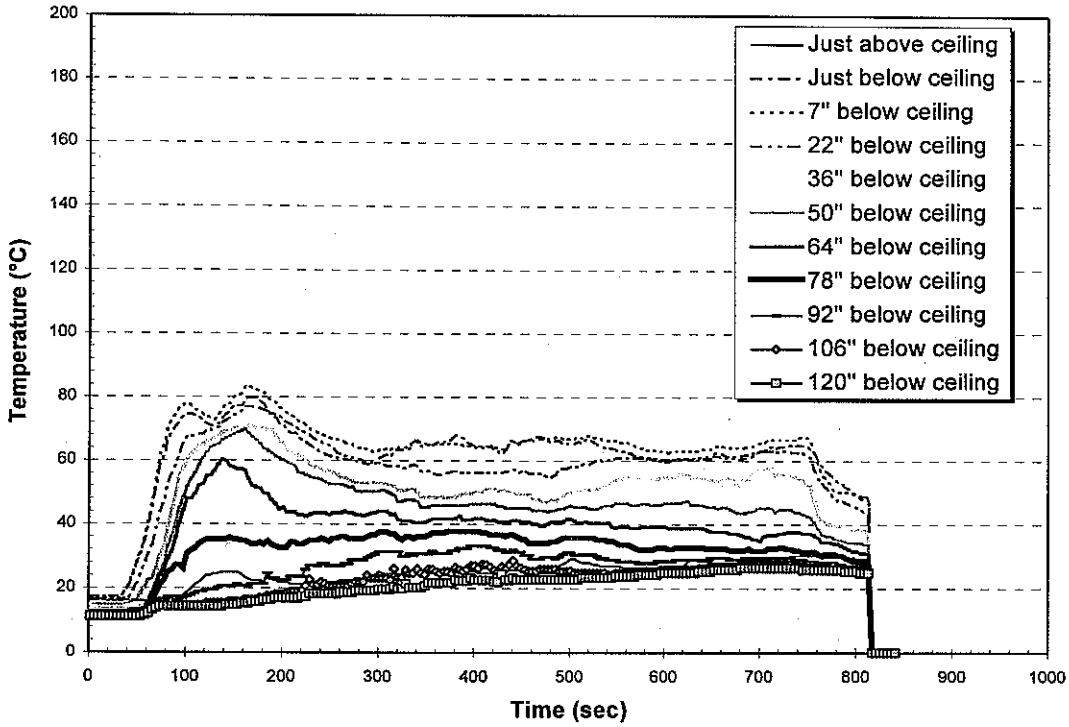


Figure B-71. Temperatures - Tree D : Test 5

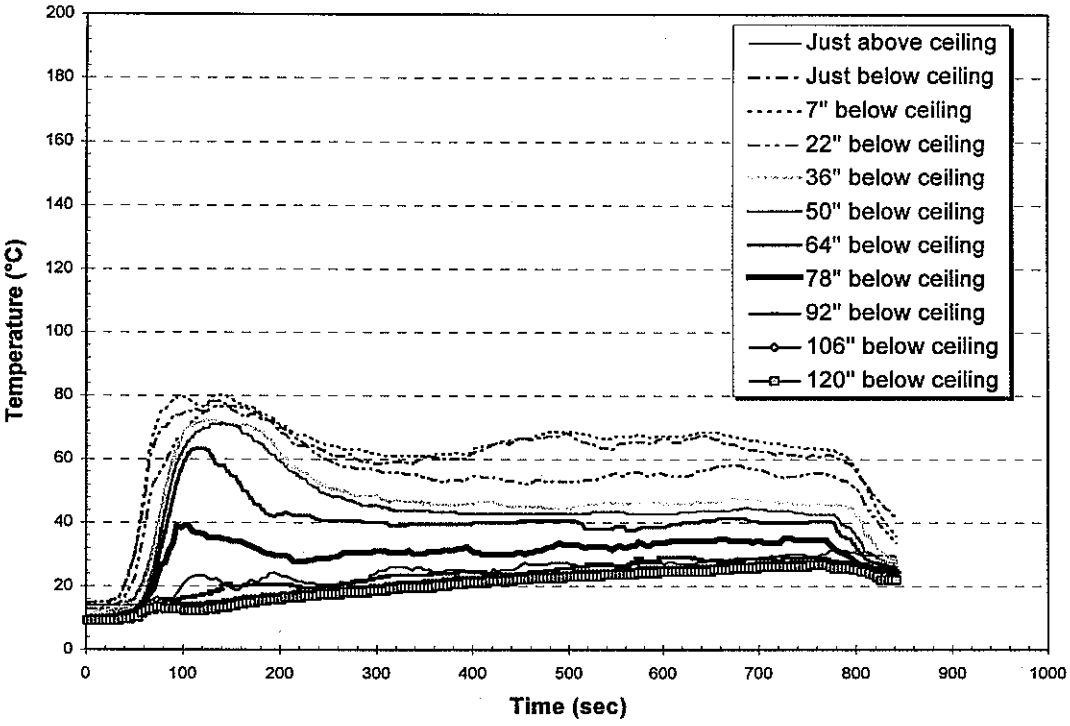


Figure B-72. Temperatures - Tree D : Test 6

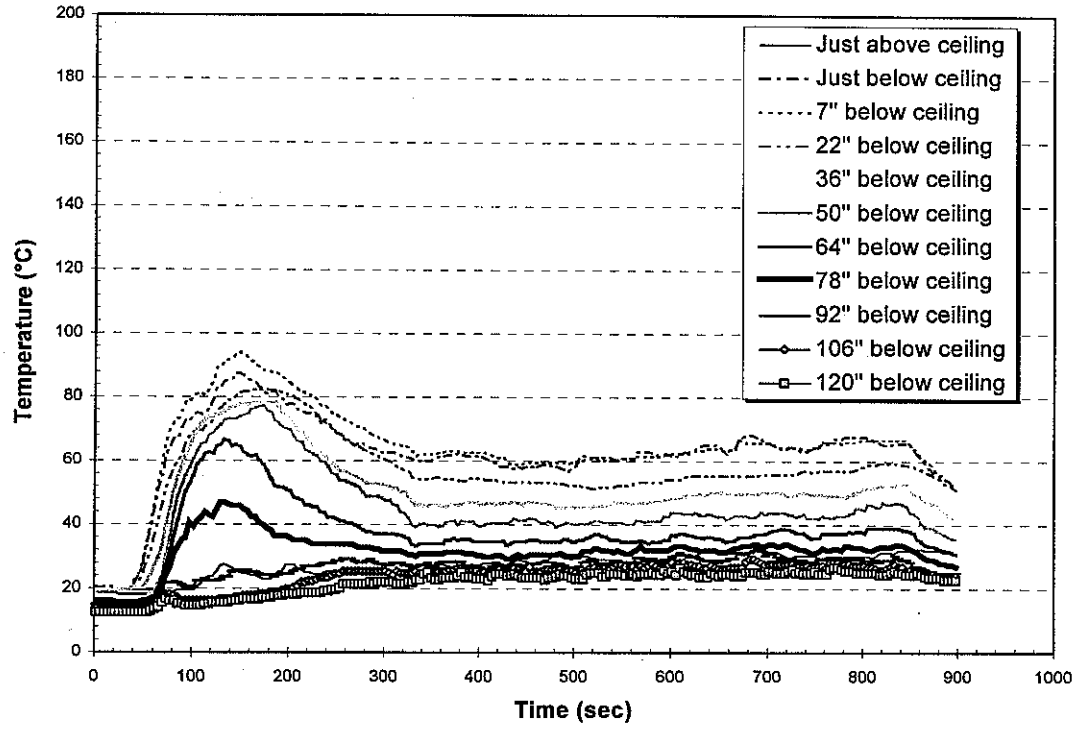


Figure B-73. Temperatures - Tree D : Test 7

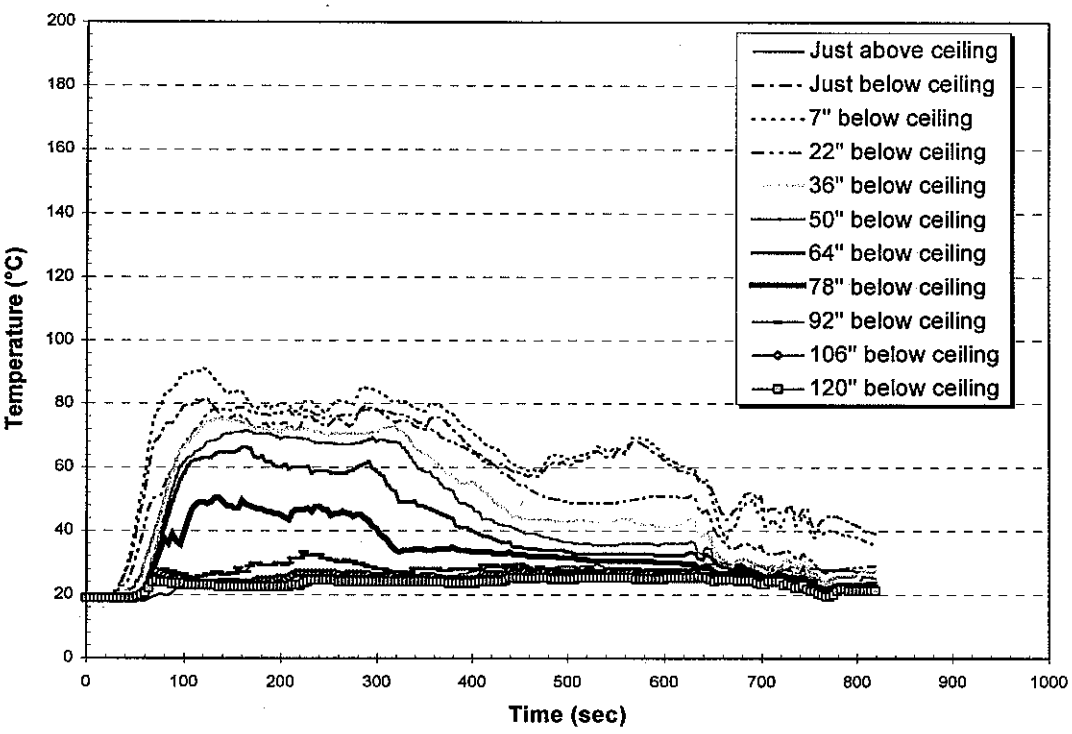


Figure B-74. Temperatures - Tree D : Test 8

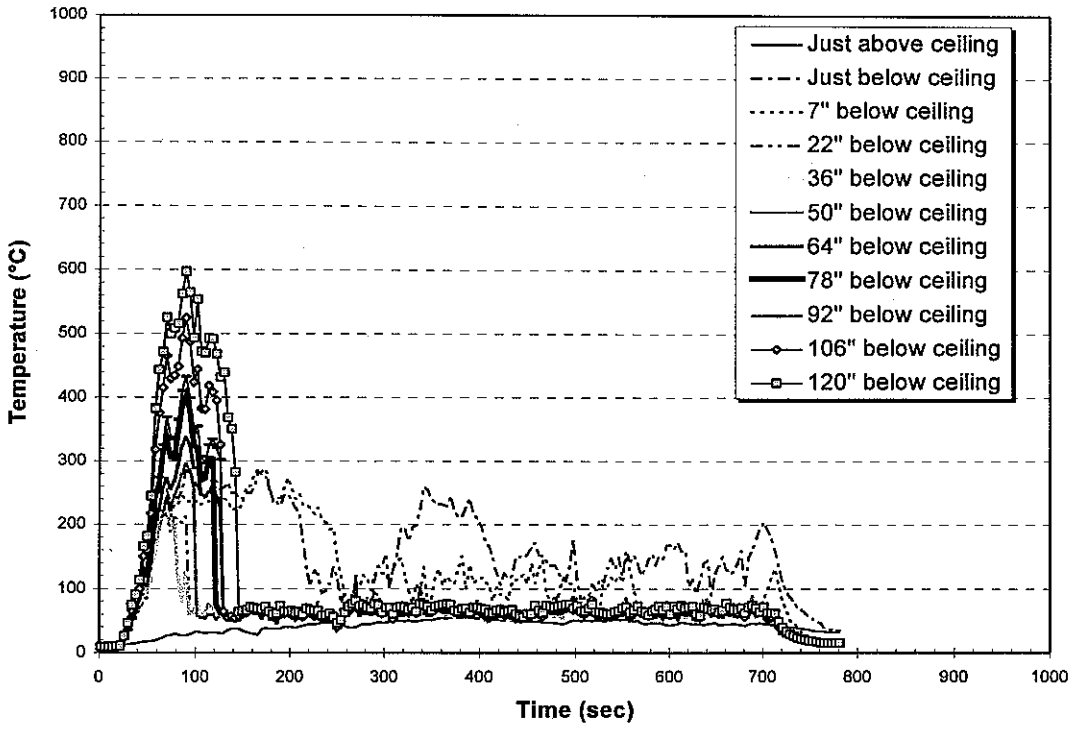


Figure B-75. Temperatures - Tree D : Test 9

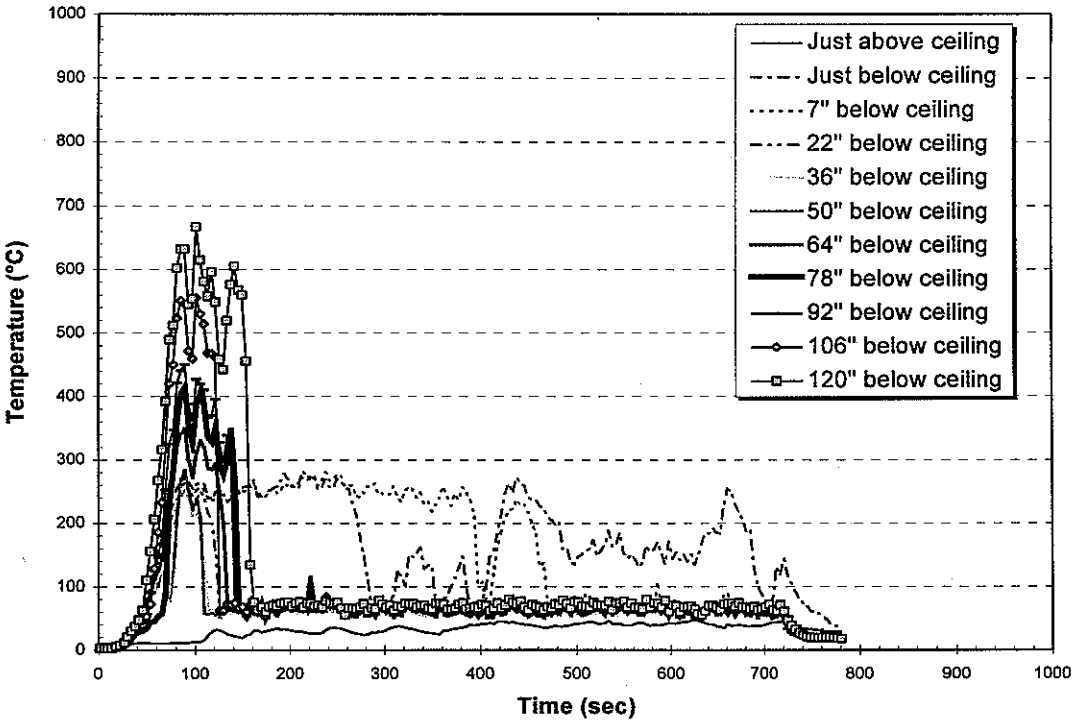


Figure B-76. Temperatures - Tree D : Test 10

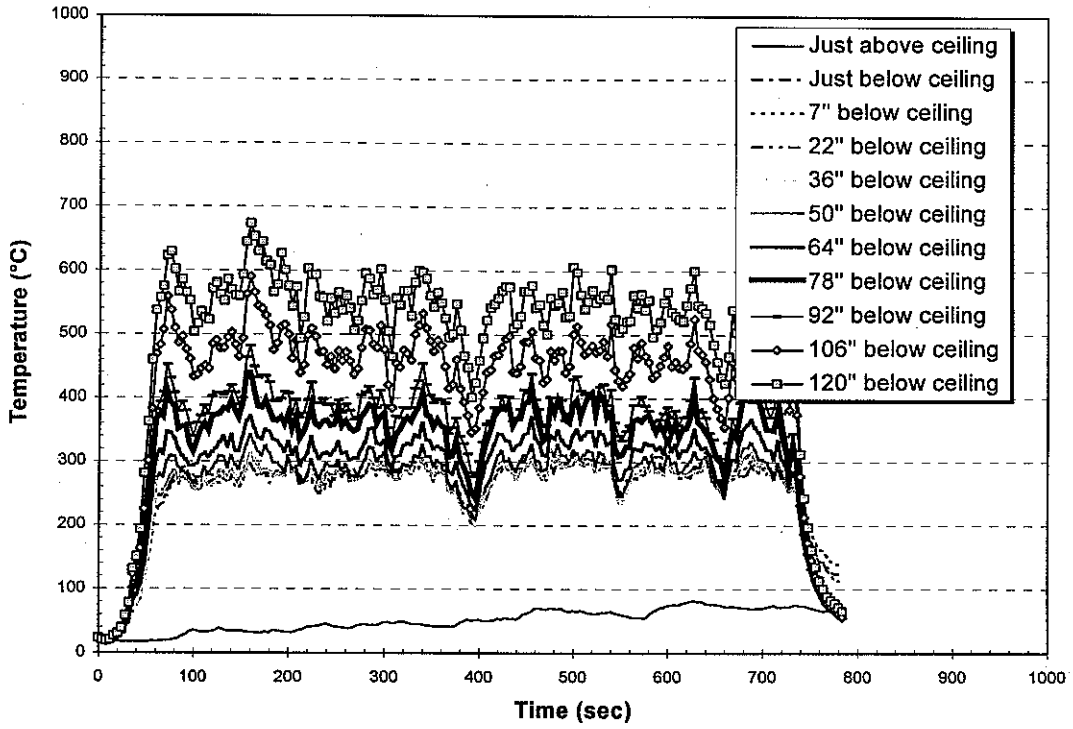


Figure B-77. Temperatures - Tree D : Test 11

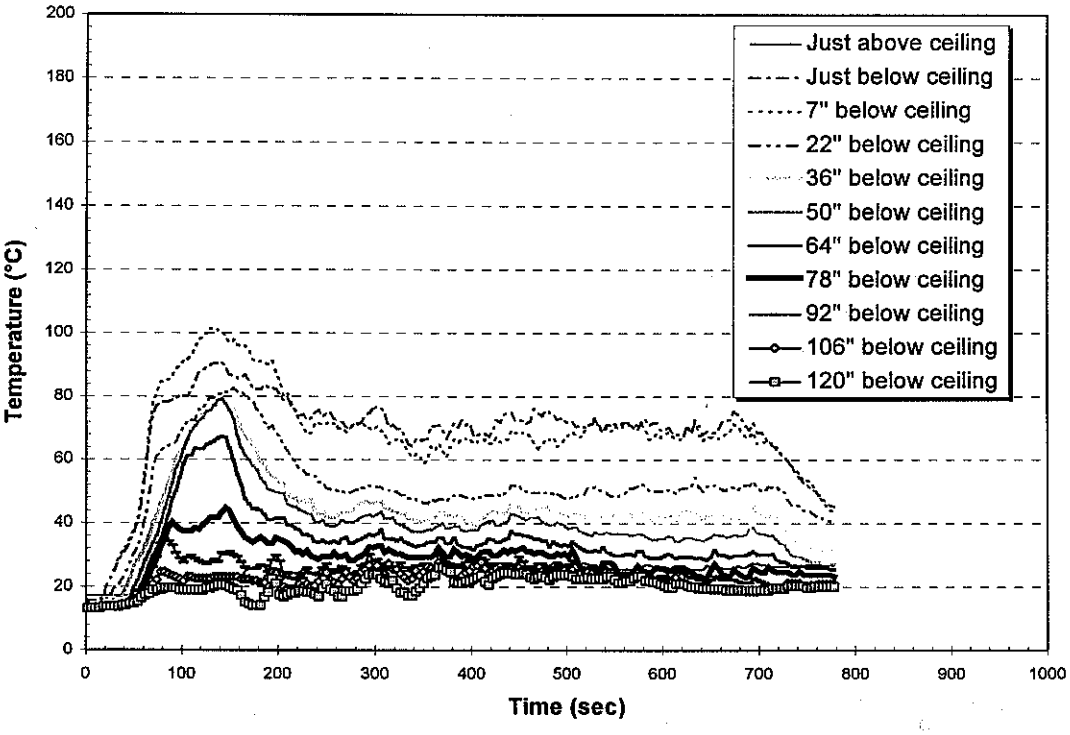


Figure B-78. Temperatures - Tree D : Test 12

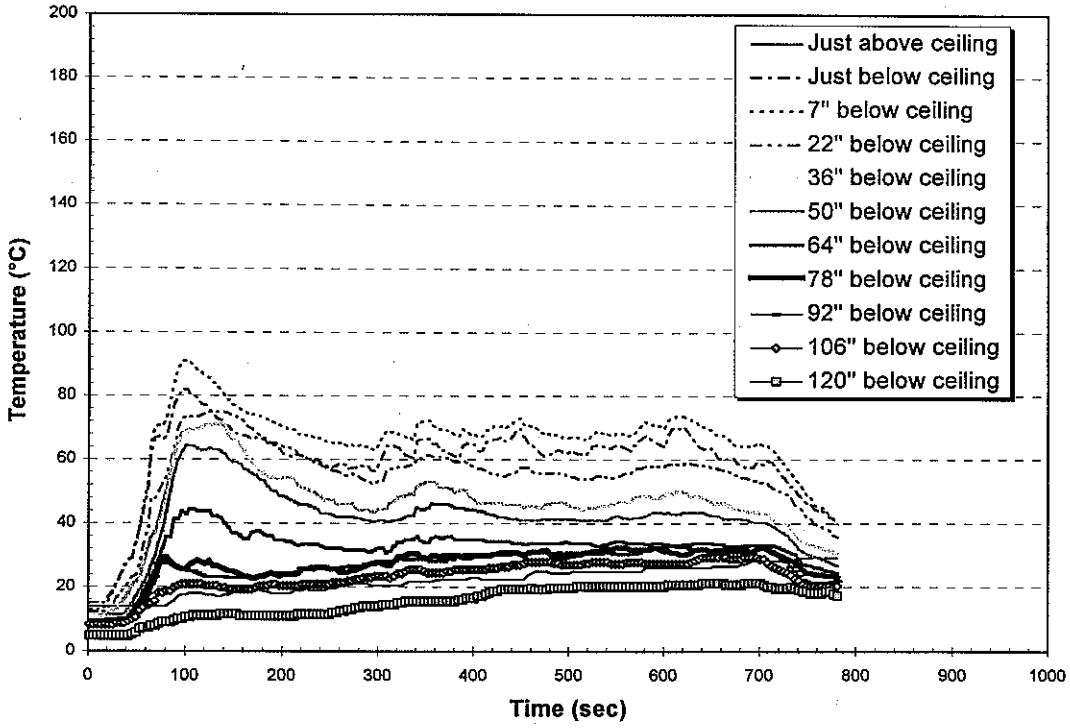


Figure B-79. Temperatures - Tree D : Test 13

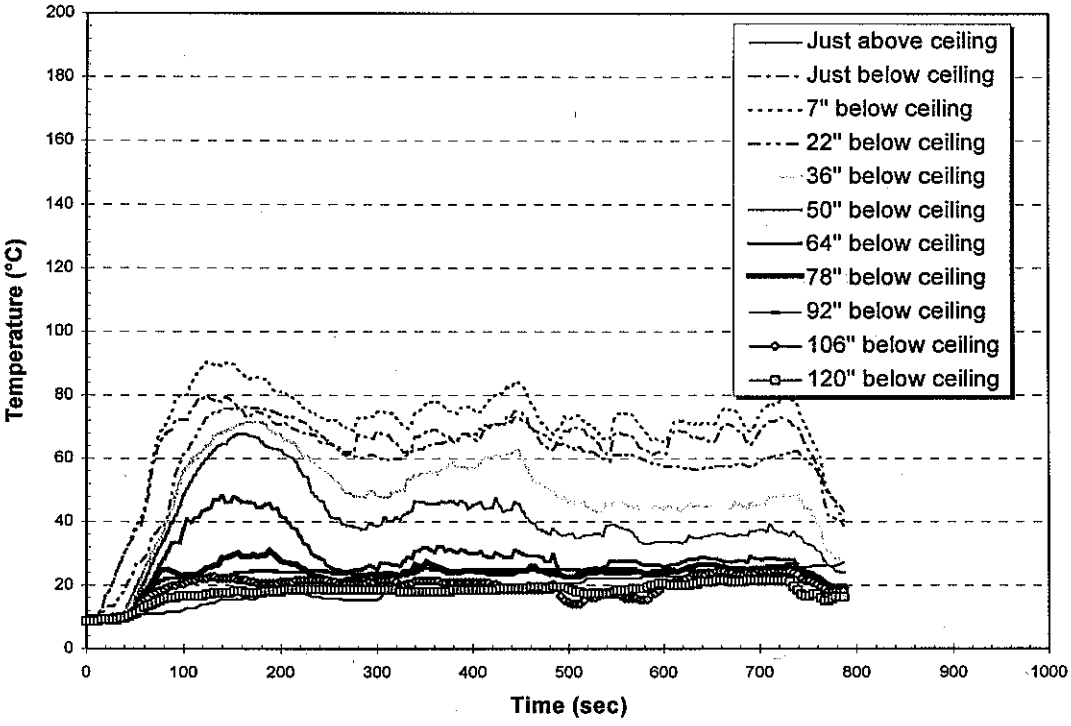


Figure B-80. Temperatures - Tree D : Test 14

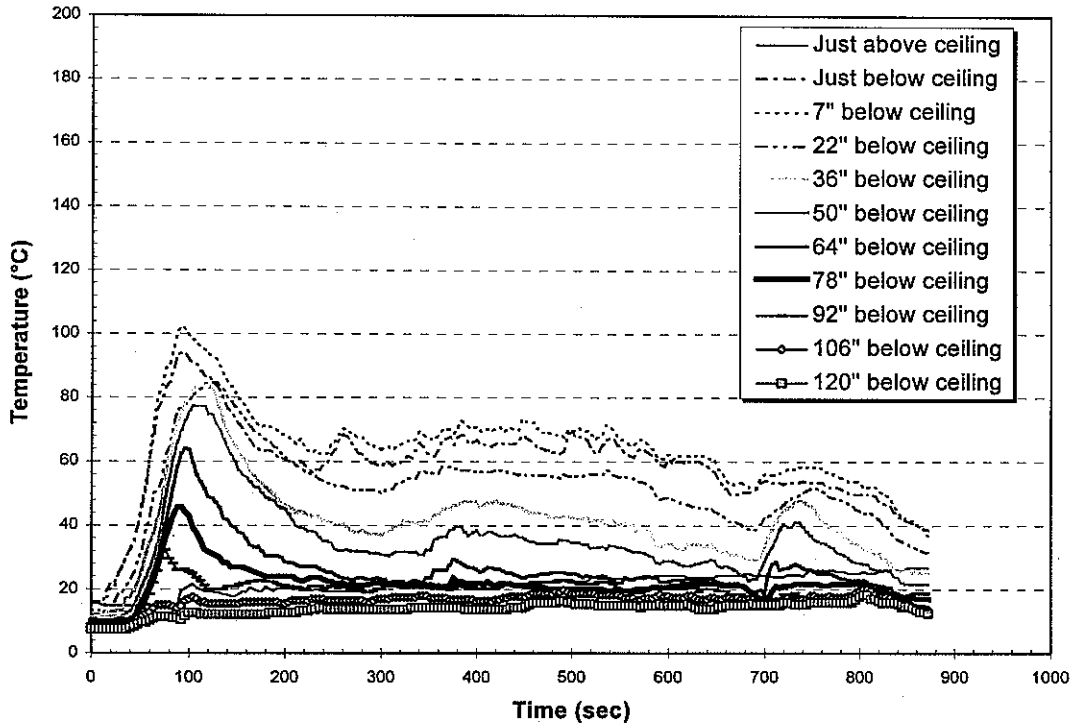


Figure B-81. Temperatures - Tree D : Test 15

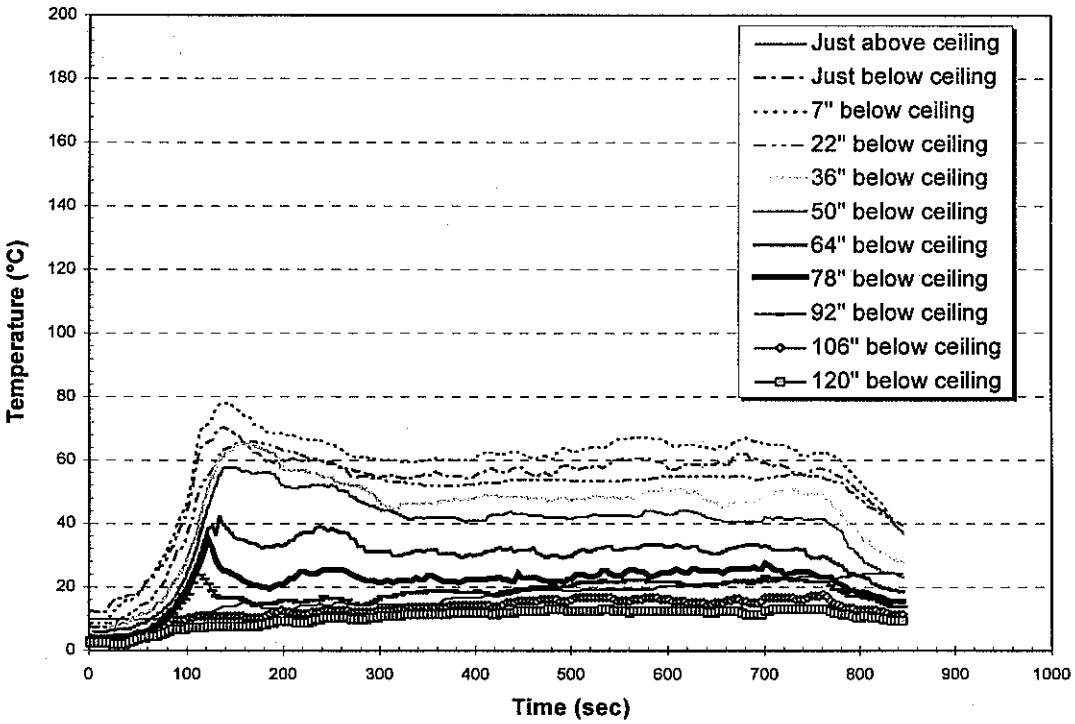


Figure B-82. Temperatures - Tree D : Test 16

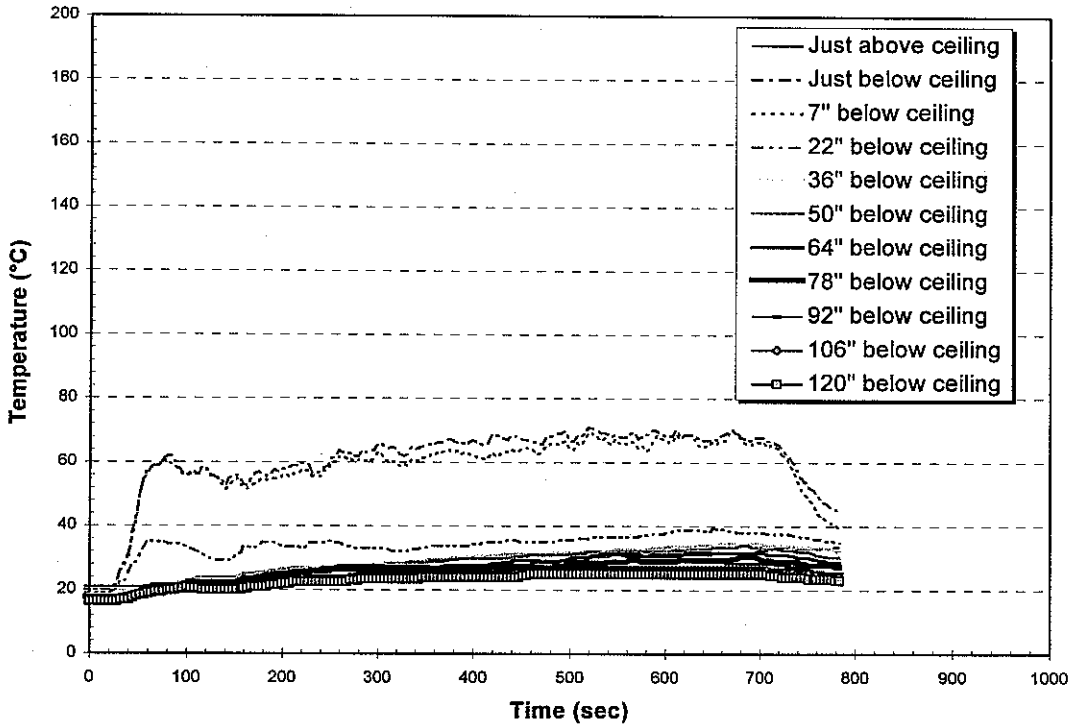


Figure B-83. Temperatures - Tree D : Test 17

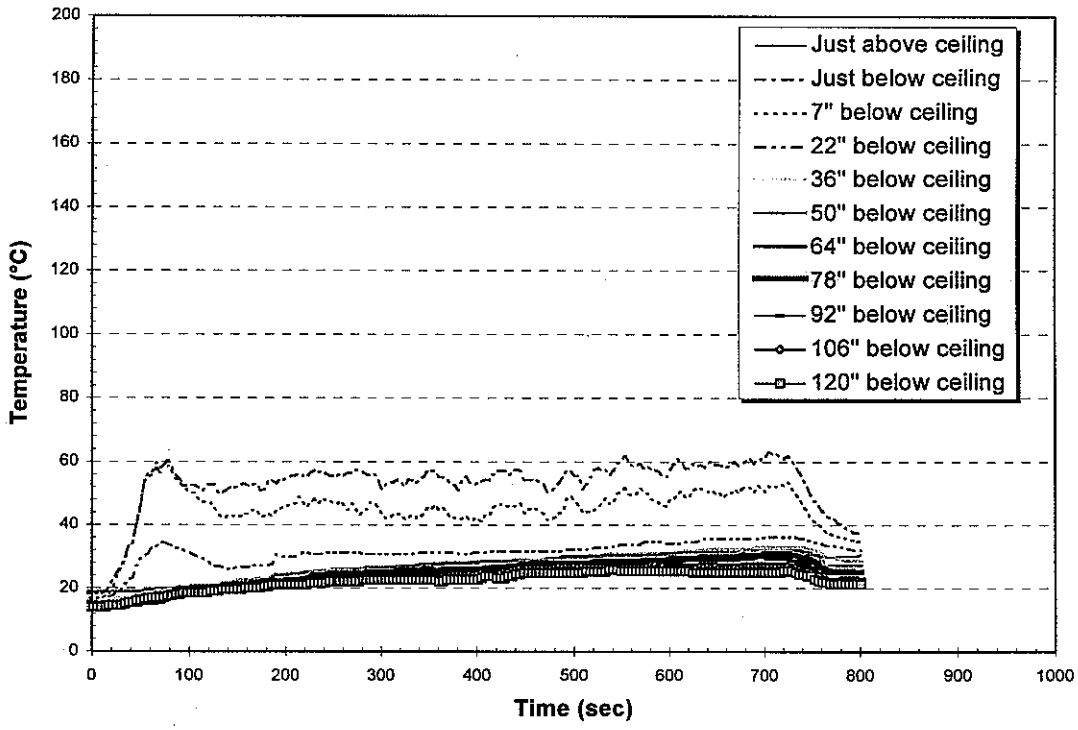


Figure B-84. Temperatures - Tree D : Test 18

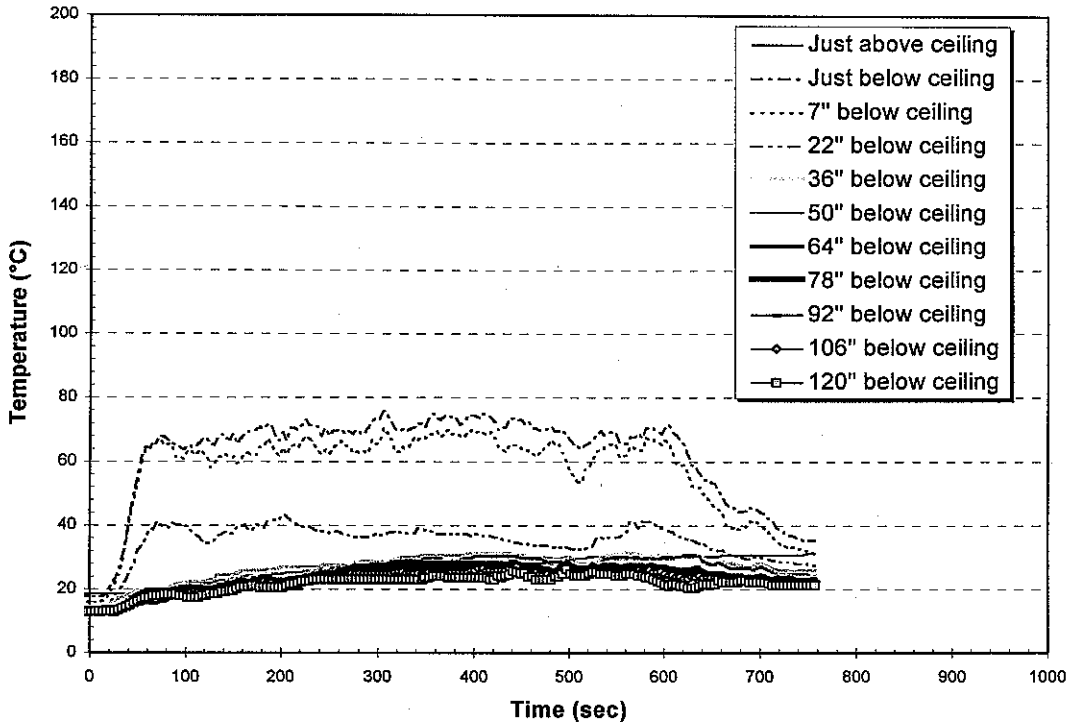


Figure B-85. Temperatures - Tree D : Test 19

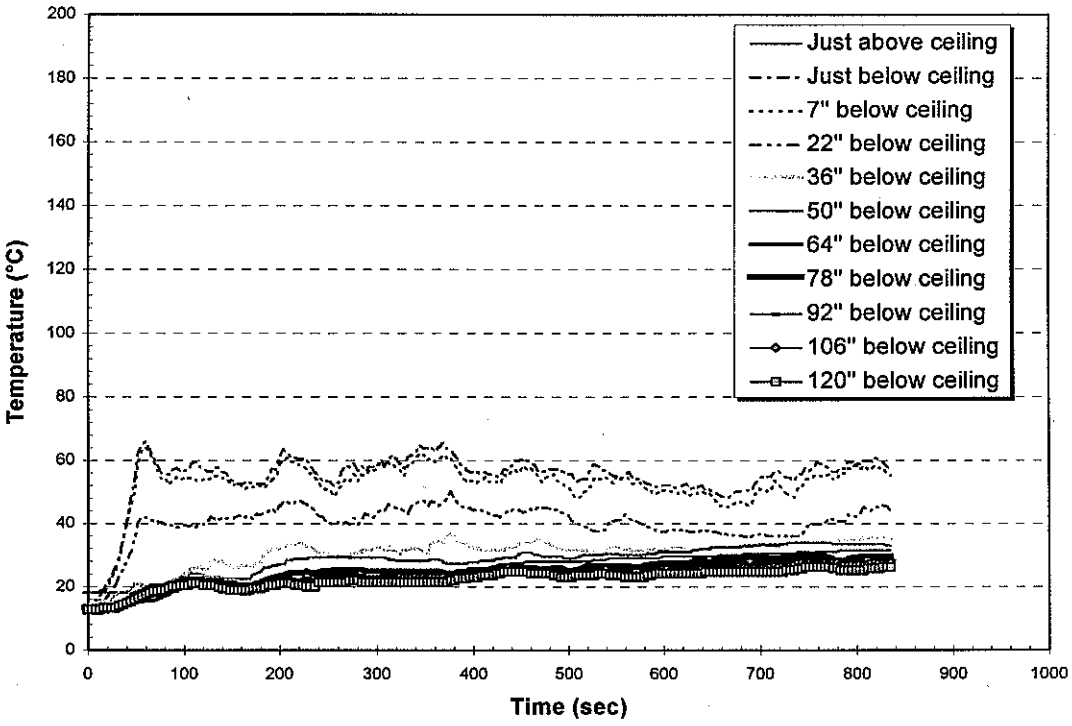


Figure B-86. Temperatures - Tree D : Test 20

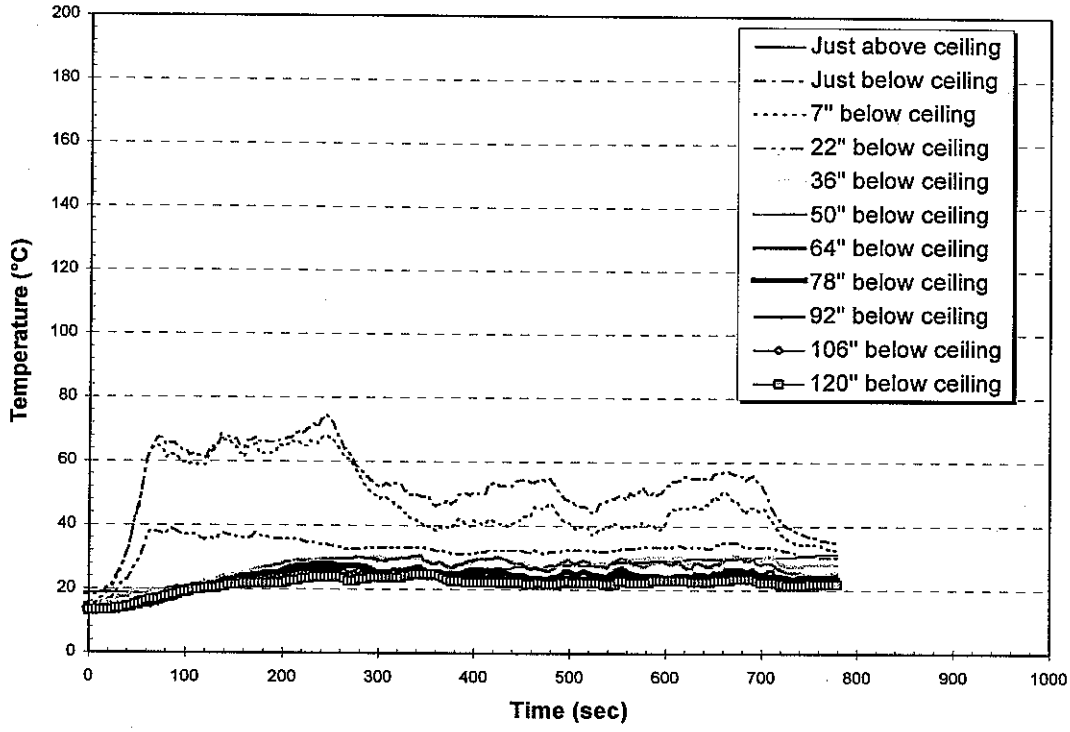


Figure B-87. Temperatures - Tree D : Test 21

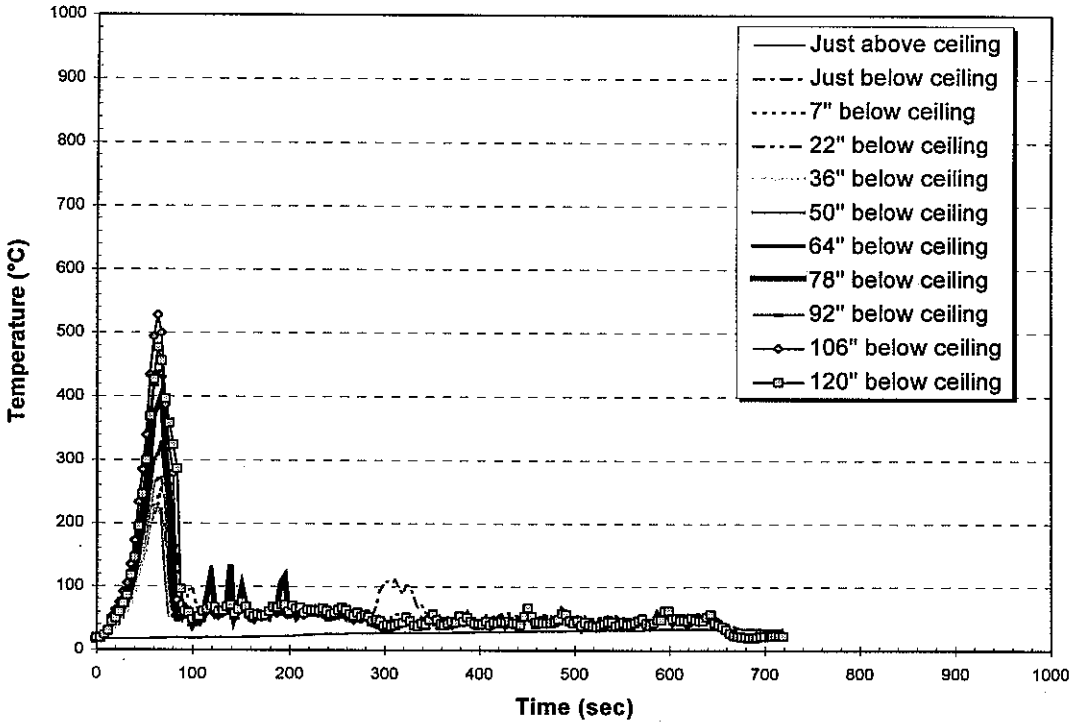


Figure B-88. Temperatures - Tree D : Test 22

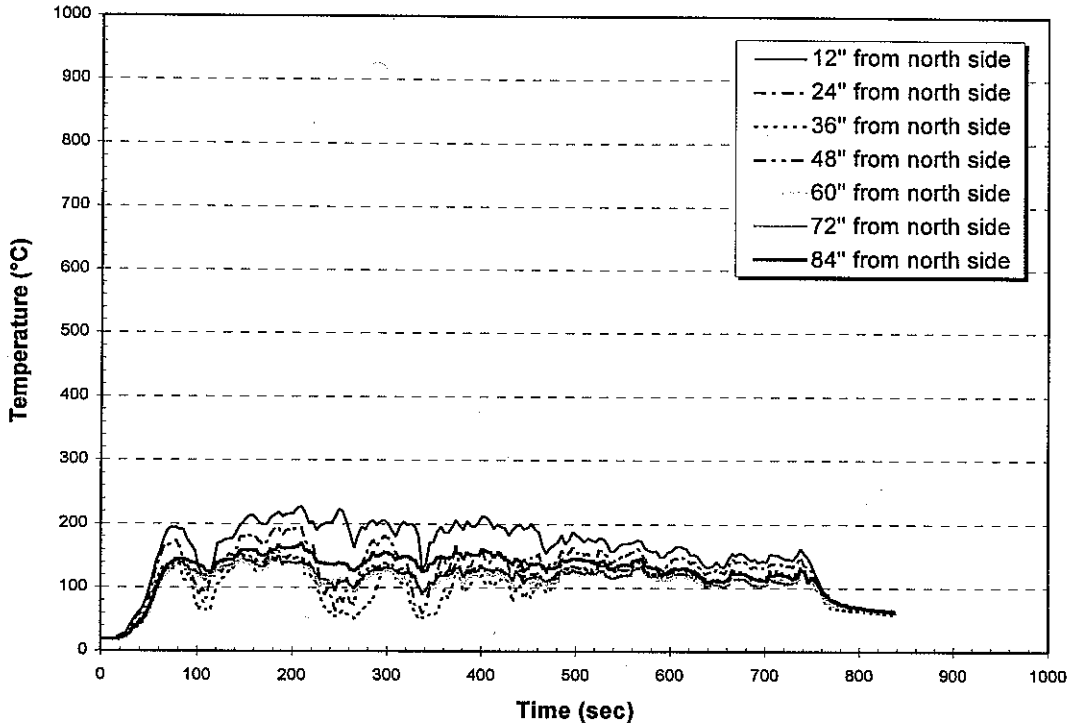


Figure B-89. Temperatures - Vent : Test 1

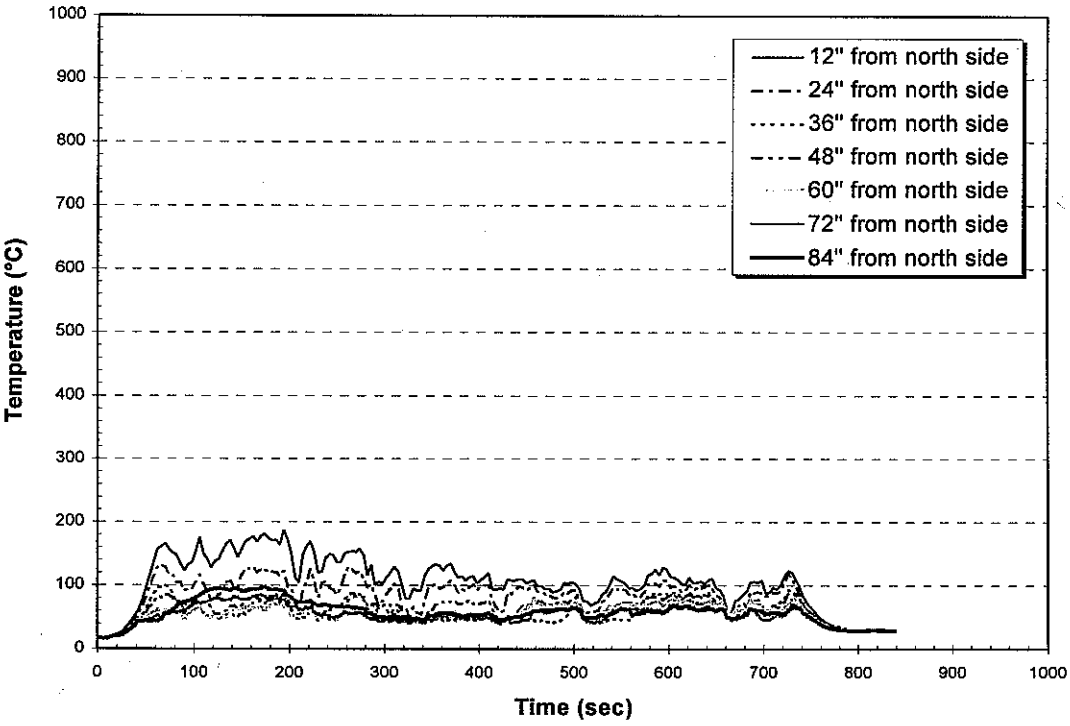


Figure B-90. Temperatures - Vent : Test 2

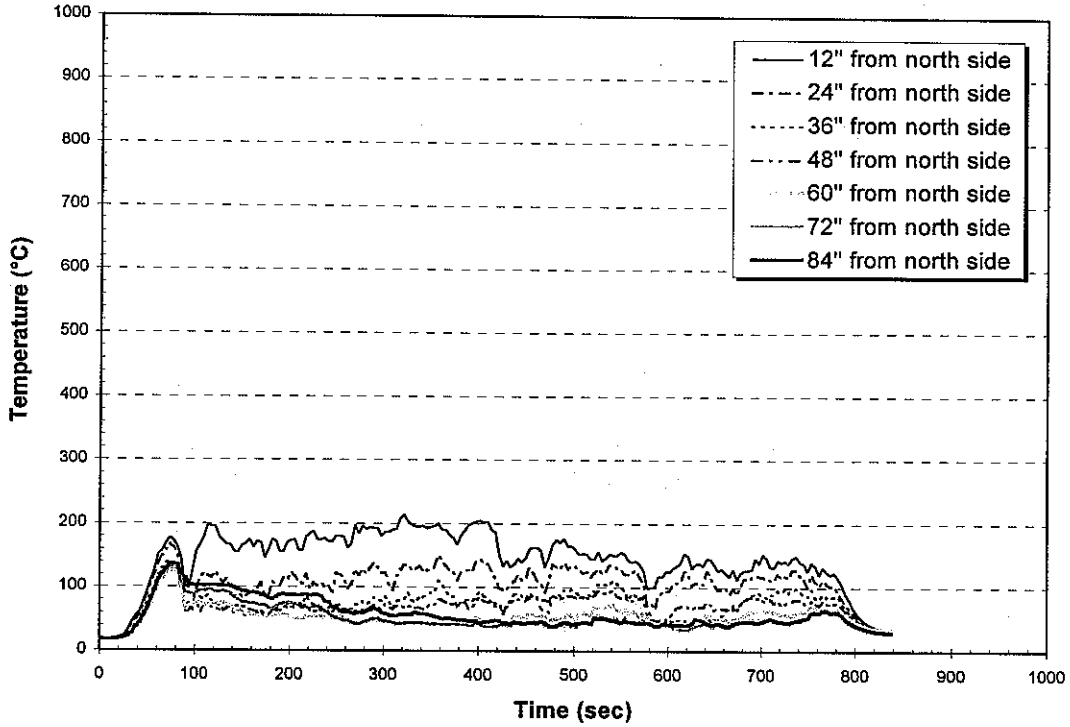


Figure B-91. Temperatures - Vent : Test 3

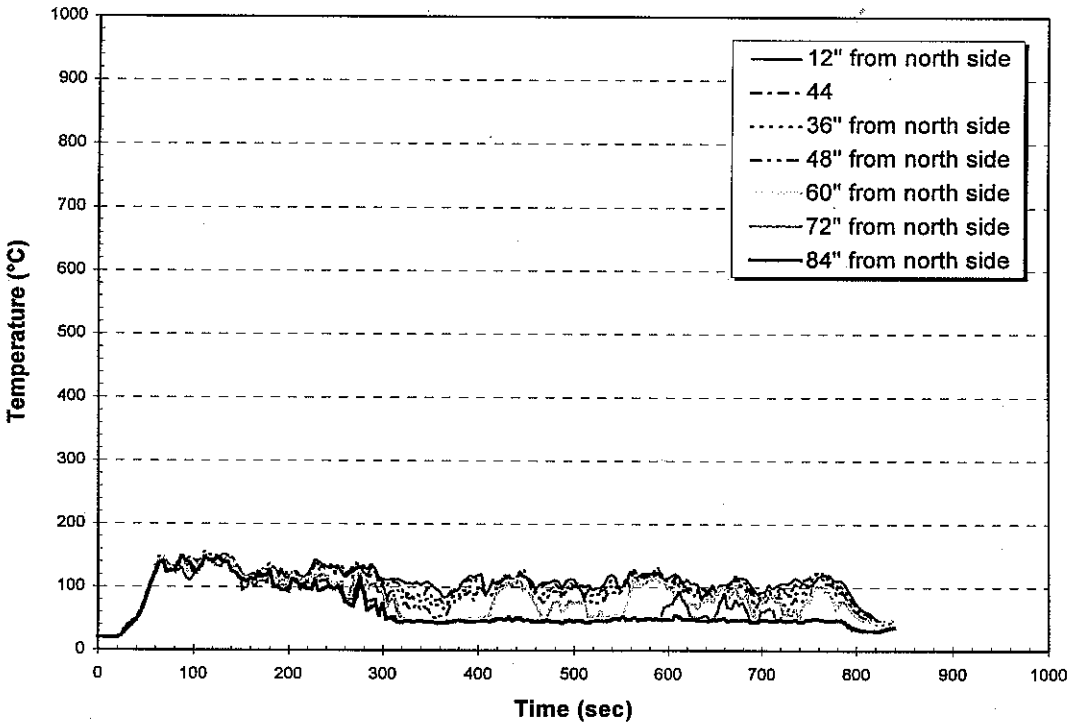


Figure B-92. Temperatures - Vent : Test 4

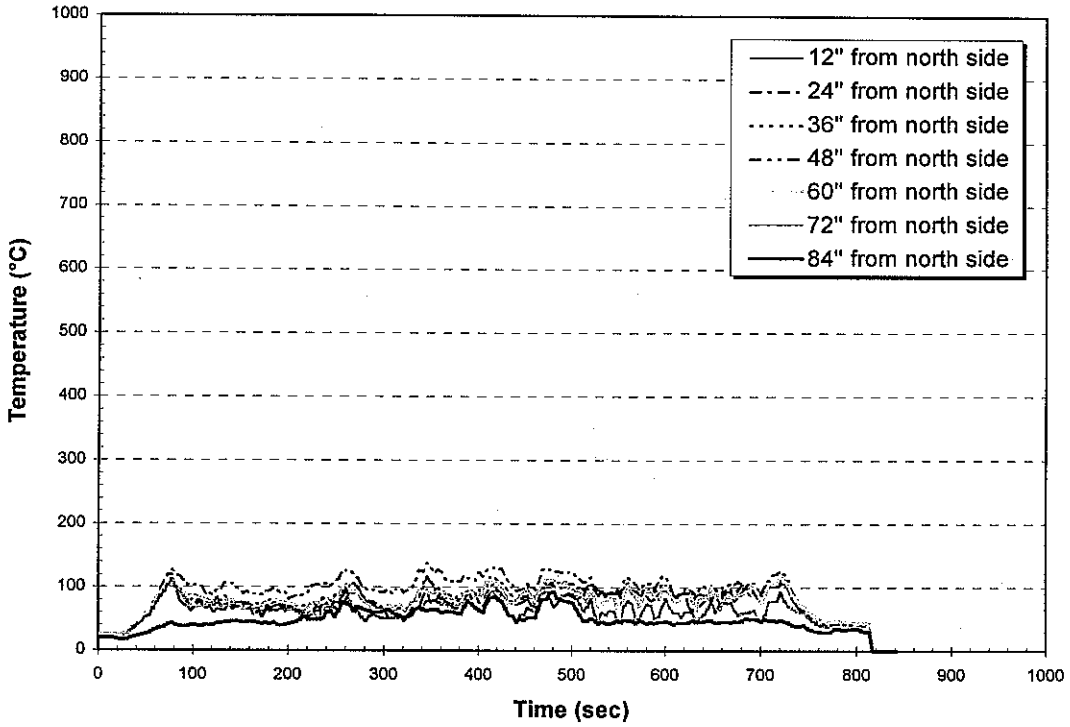


Figure B-93. Temperatures - Vent : Test 5

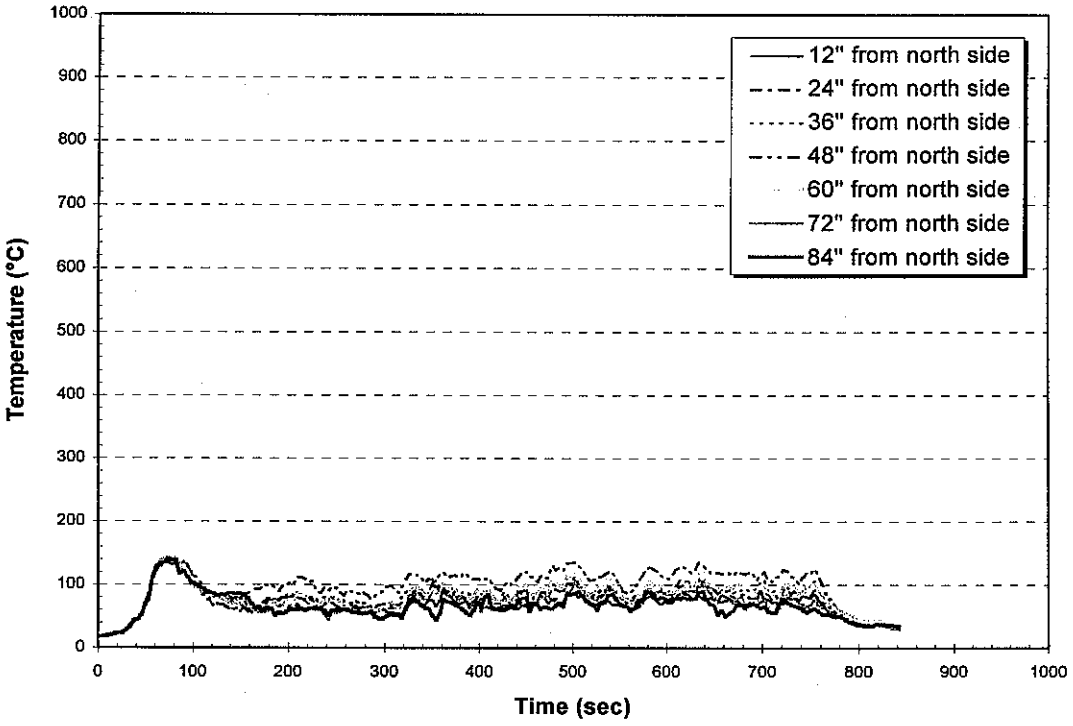


Figure B-94. Temperatures - Vent : Test 6

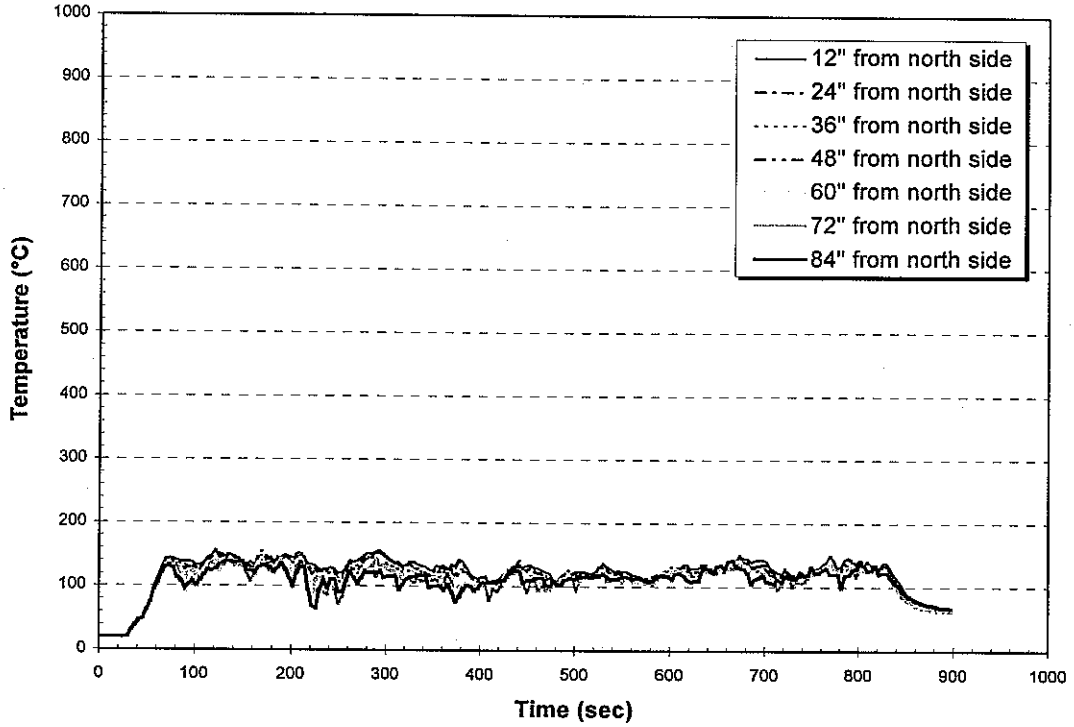


Figure B-95. Temperatures - Vent : Test 7

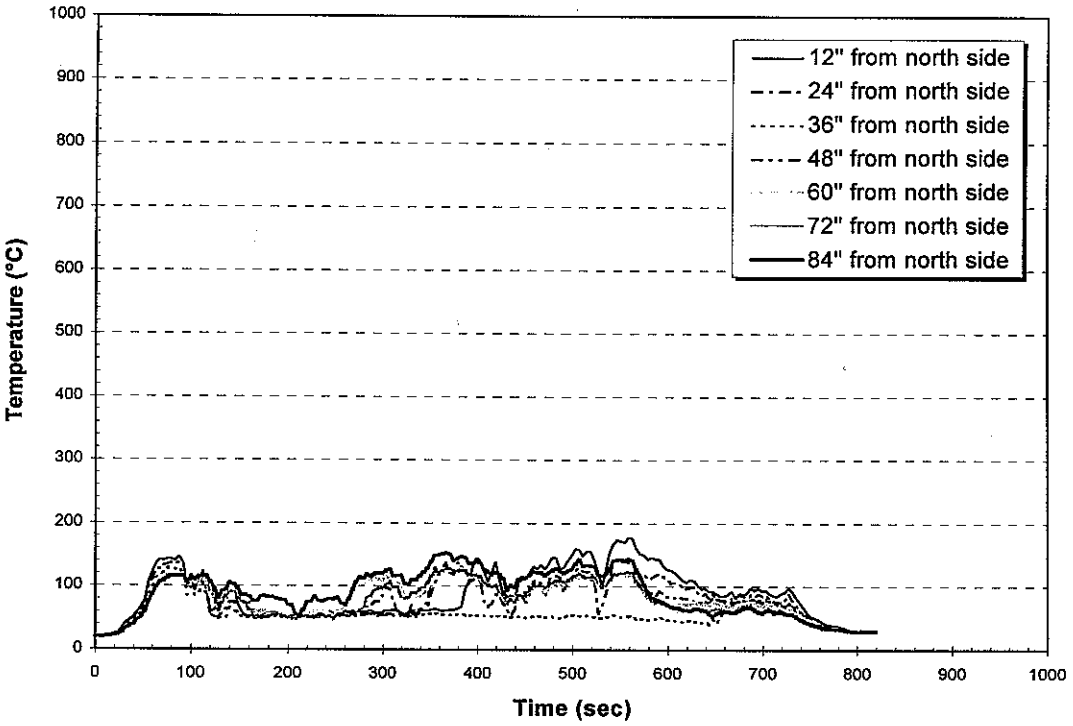


Figure B-96. Temperatures - Vent : Test 8

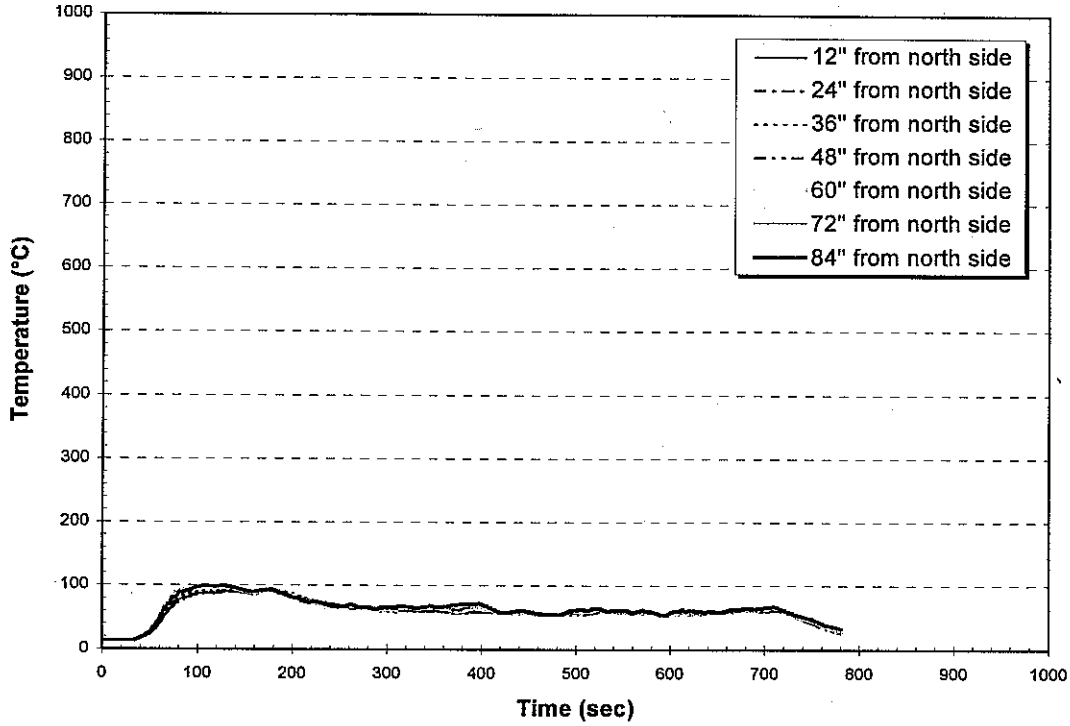


Figure B-97. Temperatures - Vent : Test 9

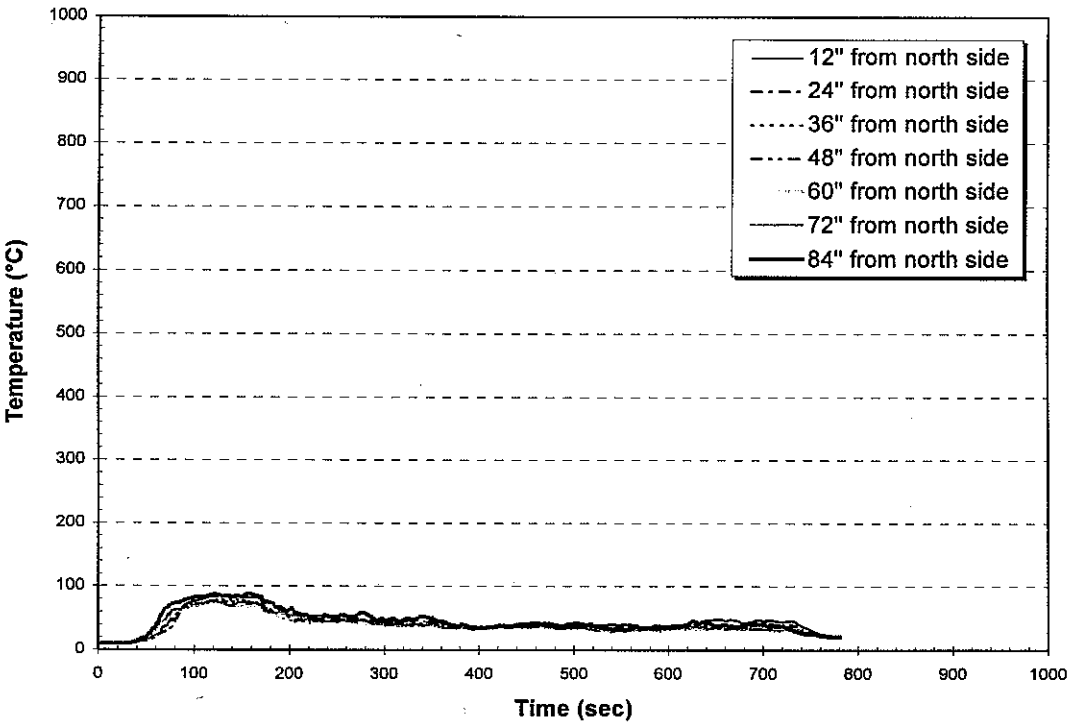


Figure B-98. Temperatures - Vent : Test 10

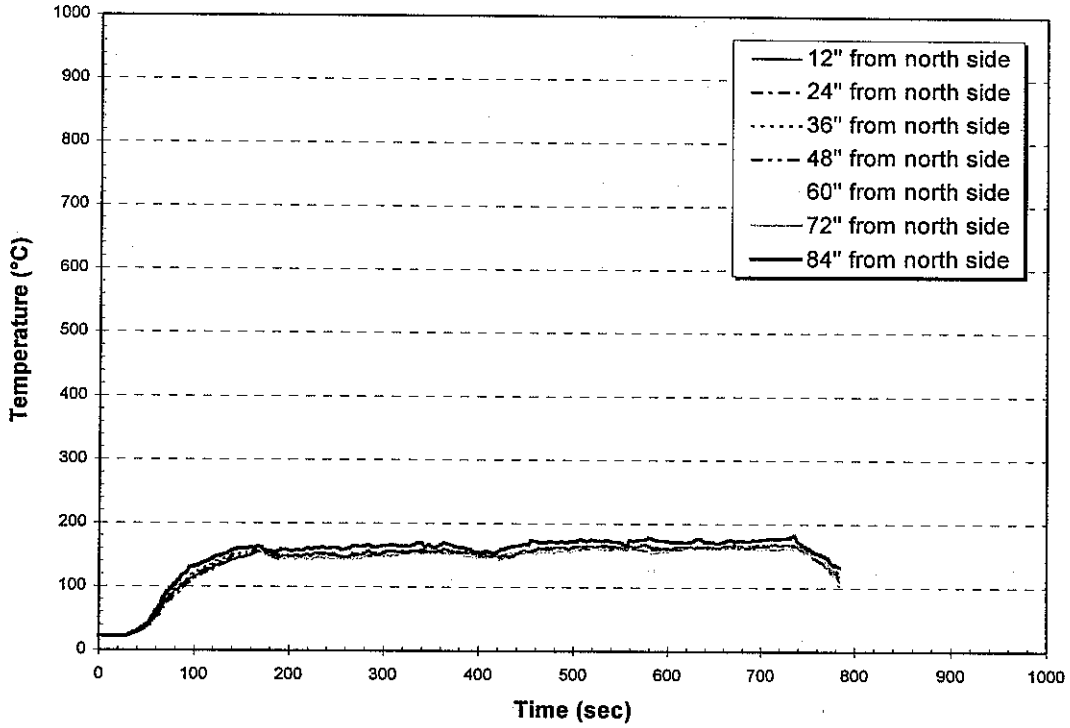


Figure B-99. Temperatures - Vent : Test 11

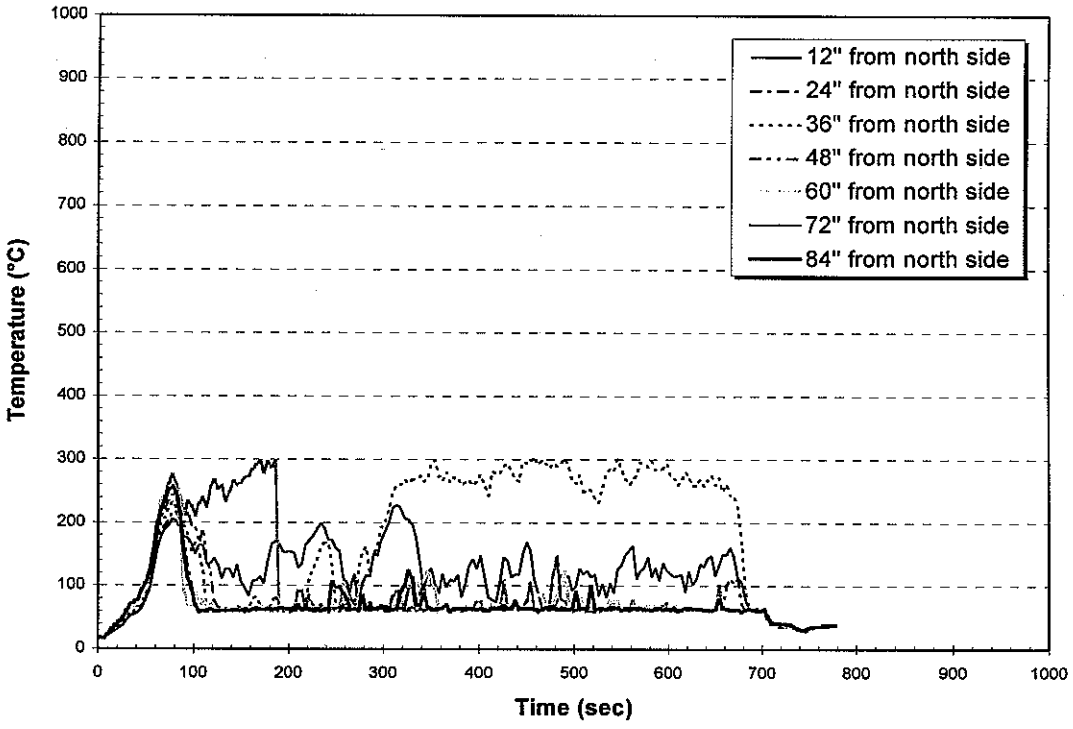


Figure B-100. Temperatures - Vent : Test 12

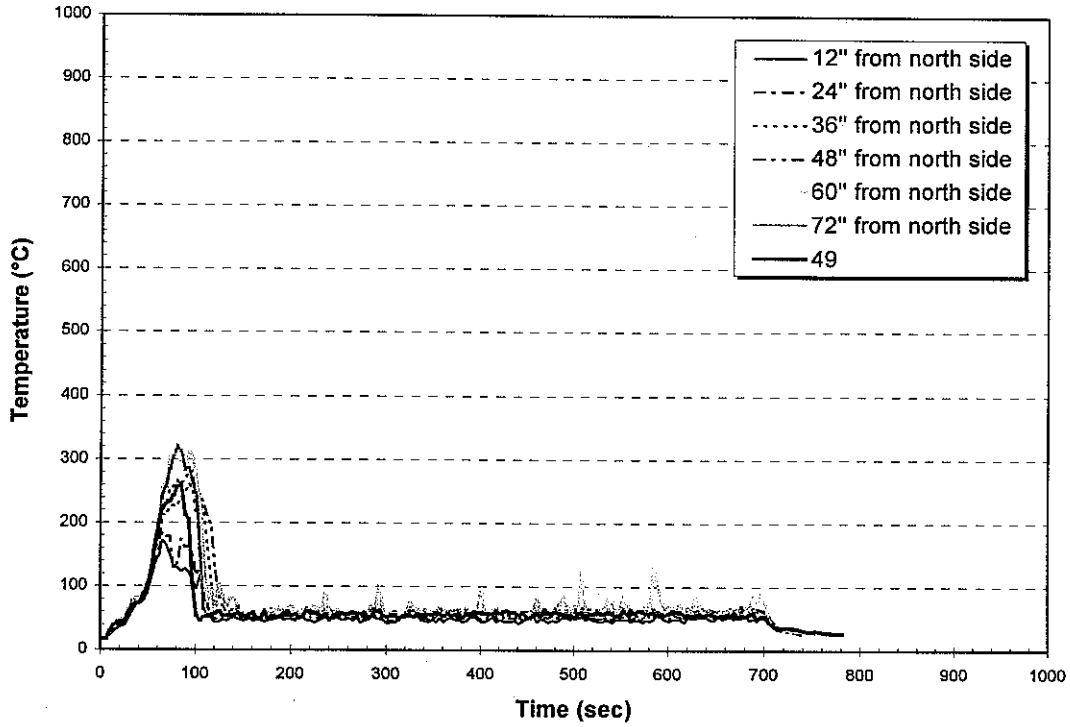


Figure B-101. Temperatures - Vent : Test 13

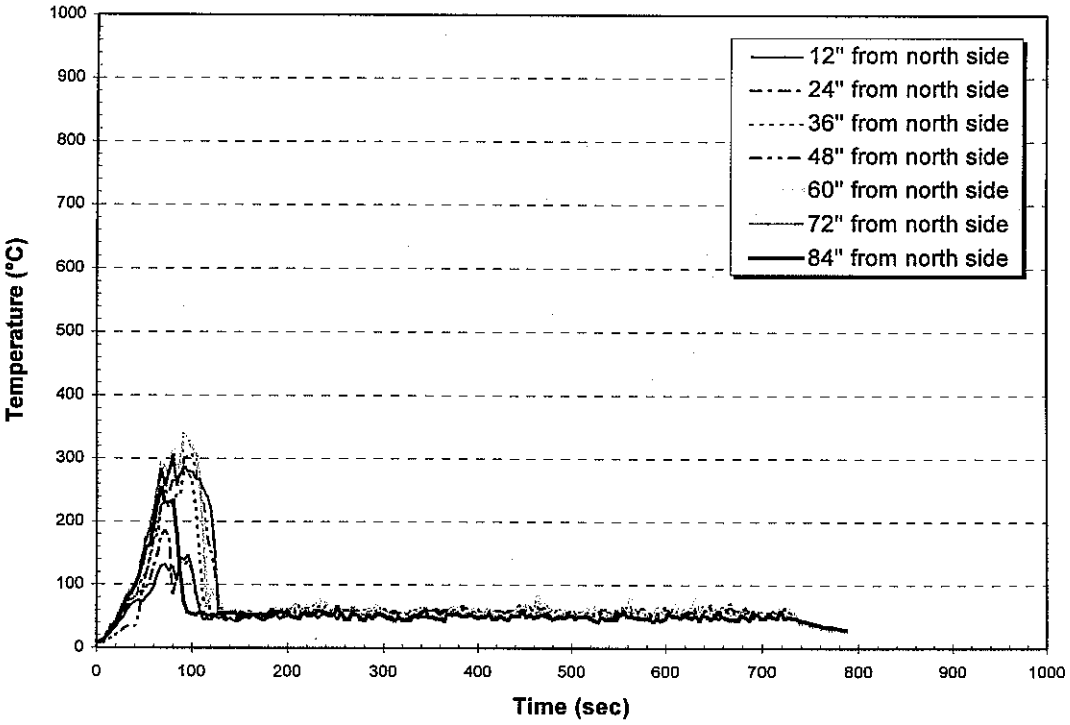


Figure B-102. Temperatures - Vent : Test 14

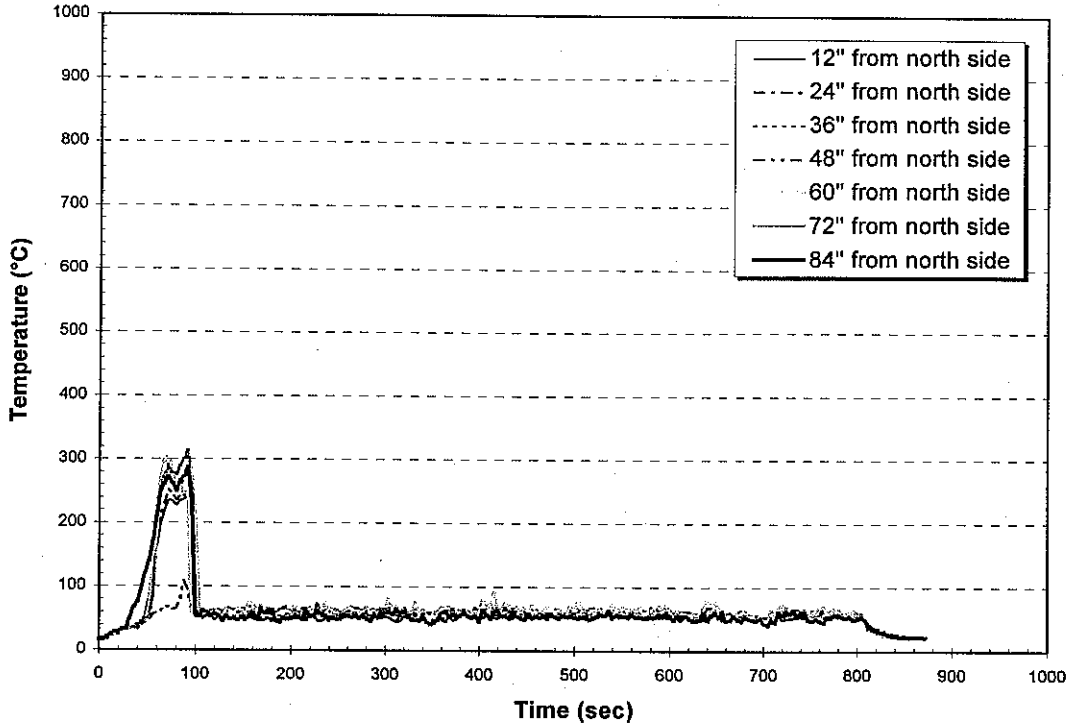


Figure B-103. Temperatures - Vent : Test 15

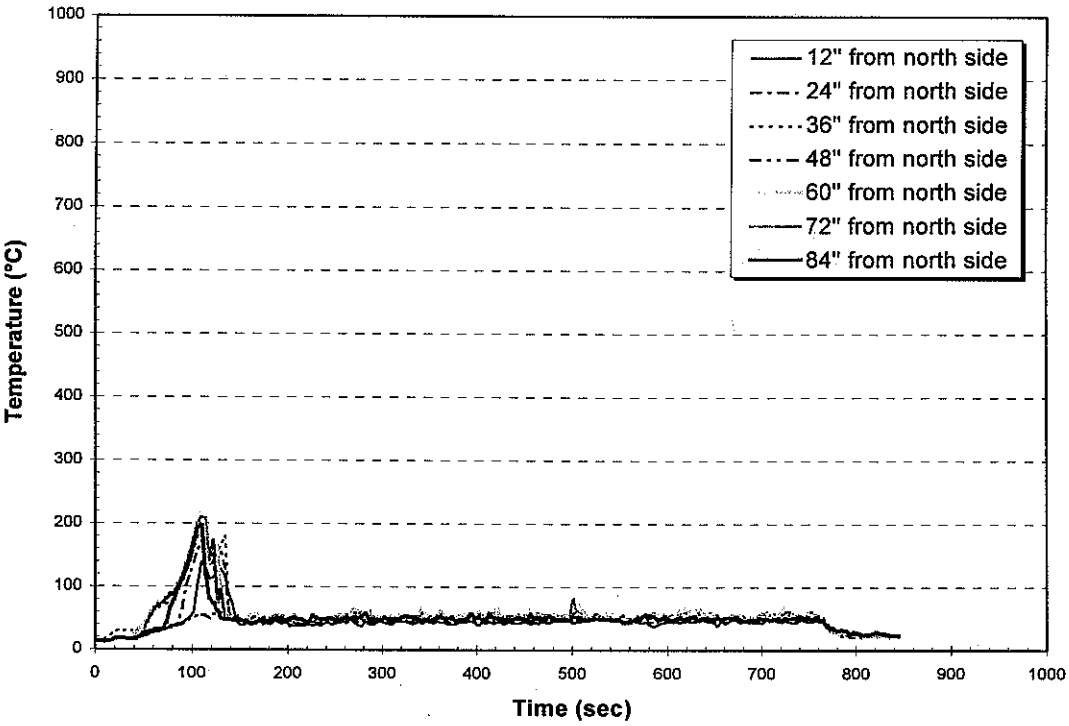


Figure B-104. Temperatures - Vent : Test 16

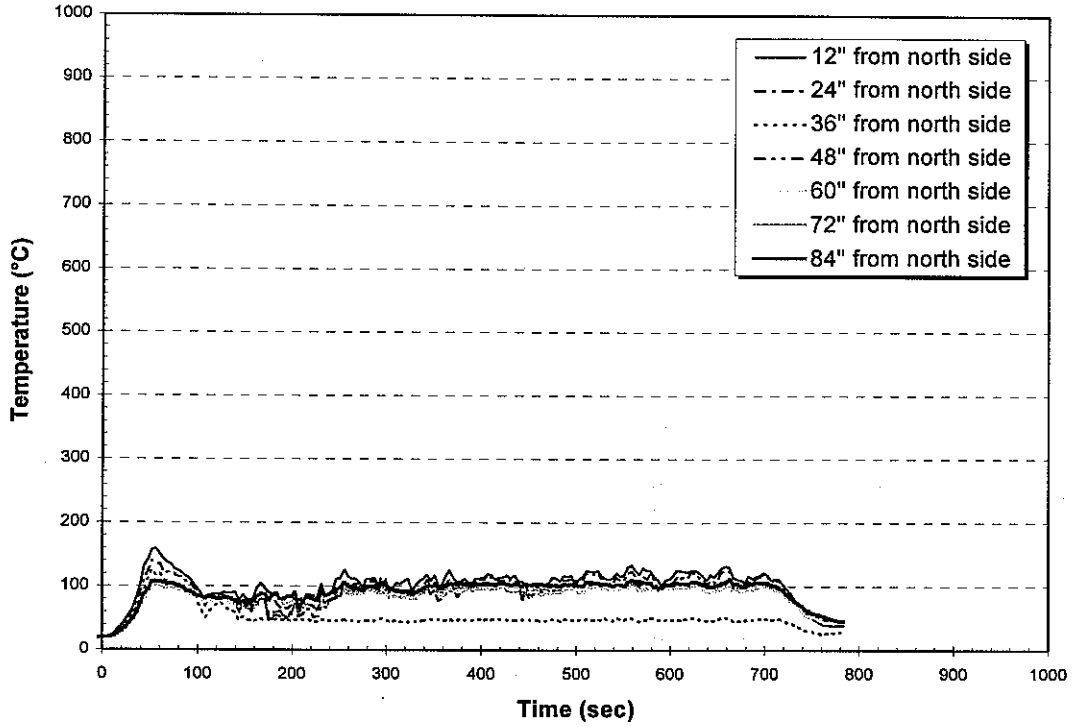


Figure B-105. Temperatures - Vent : Test 17

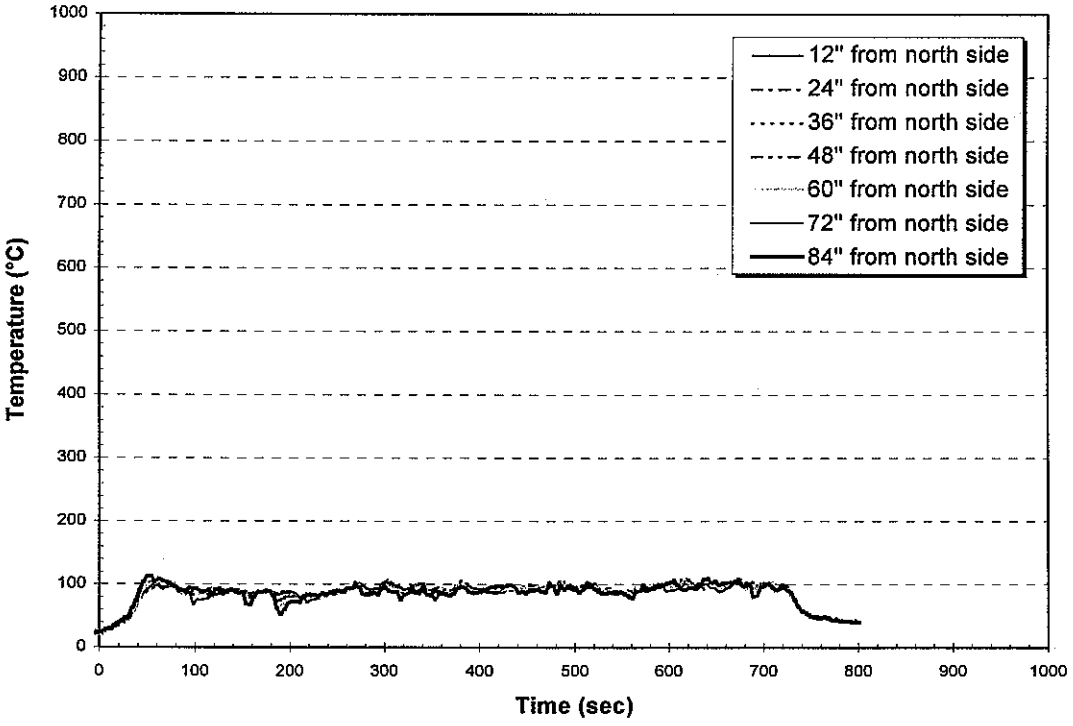


Figure B-106. Temperatures - Vent : Test 18

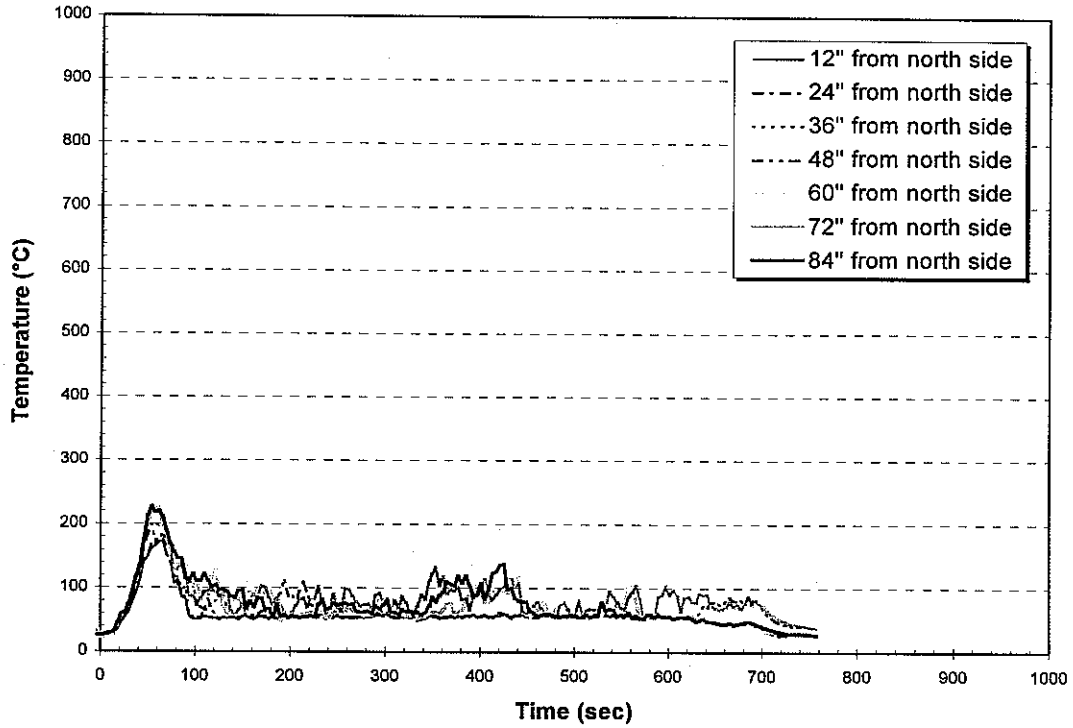


Figure B-107. Temperatures - Vent : Test 19

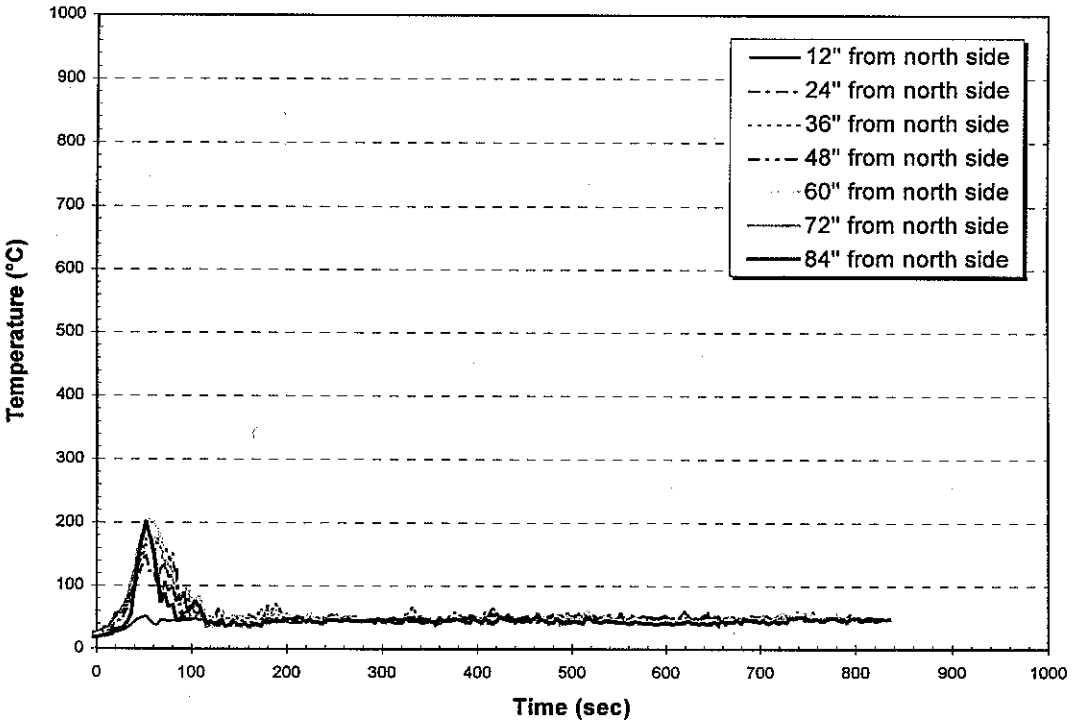


Figure B-108. Temperatures - Vent : Test 20

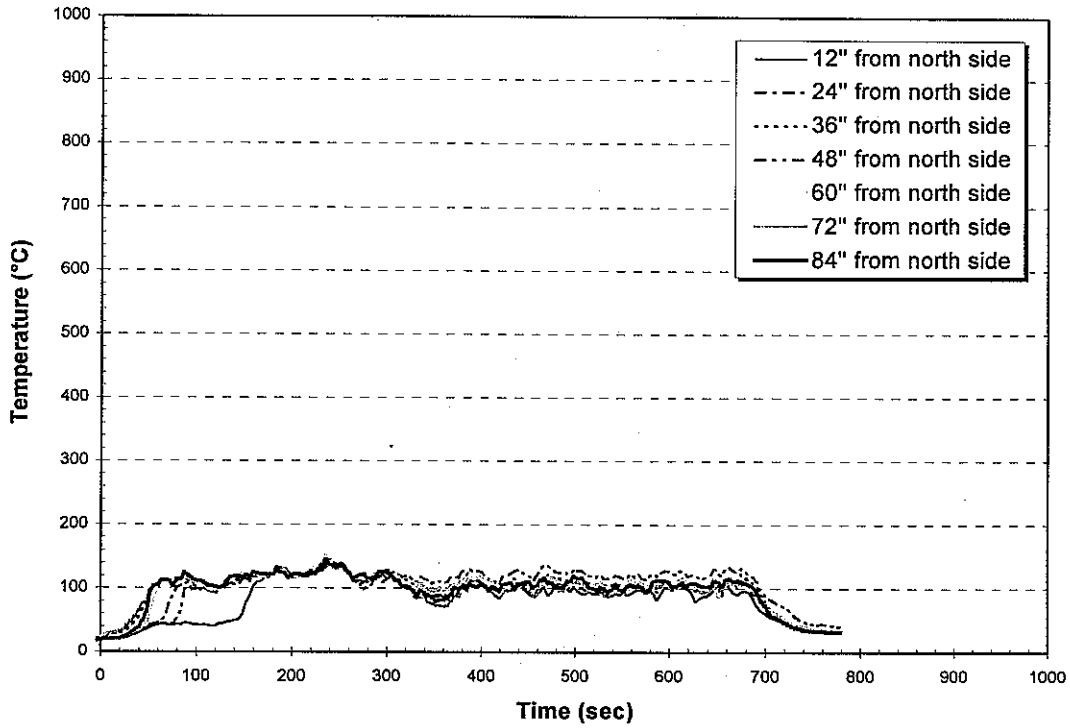


Figure B-109. Temperatures - Vent : Test 21

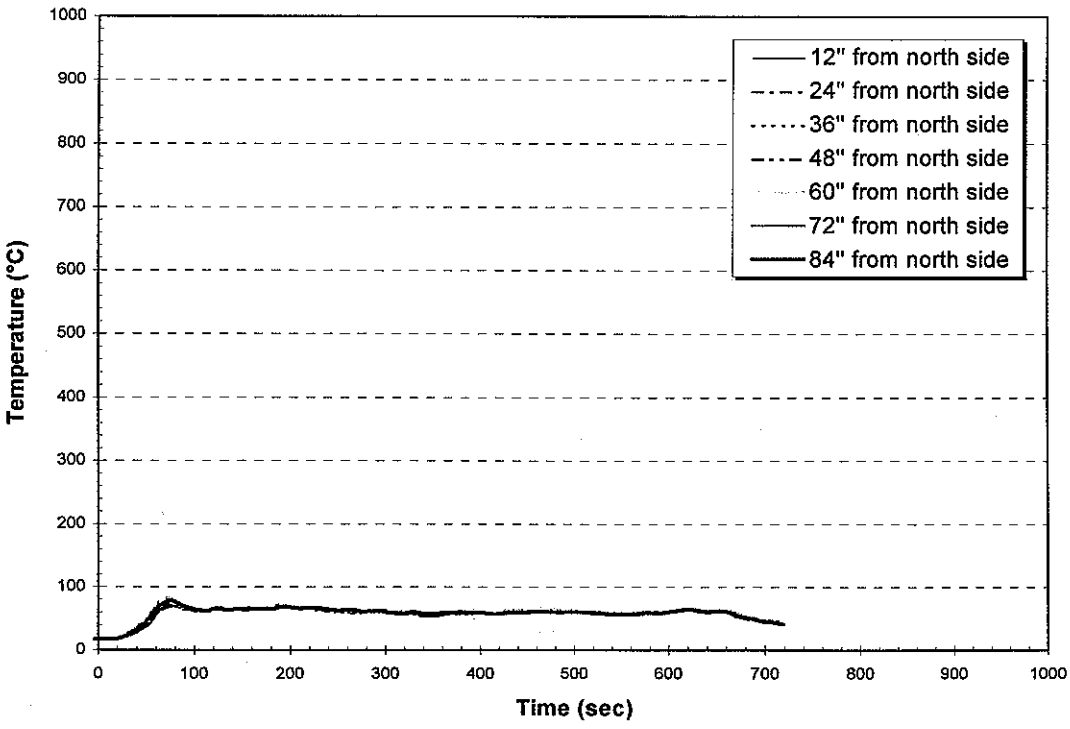


Figure B-110. Temperatures - Vent : Test 22

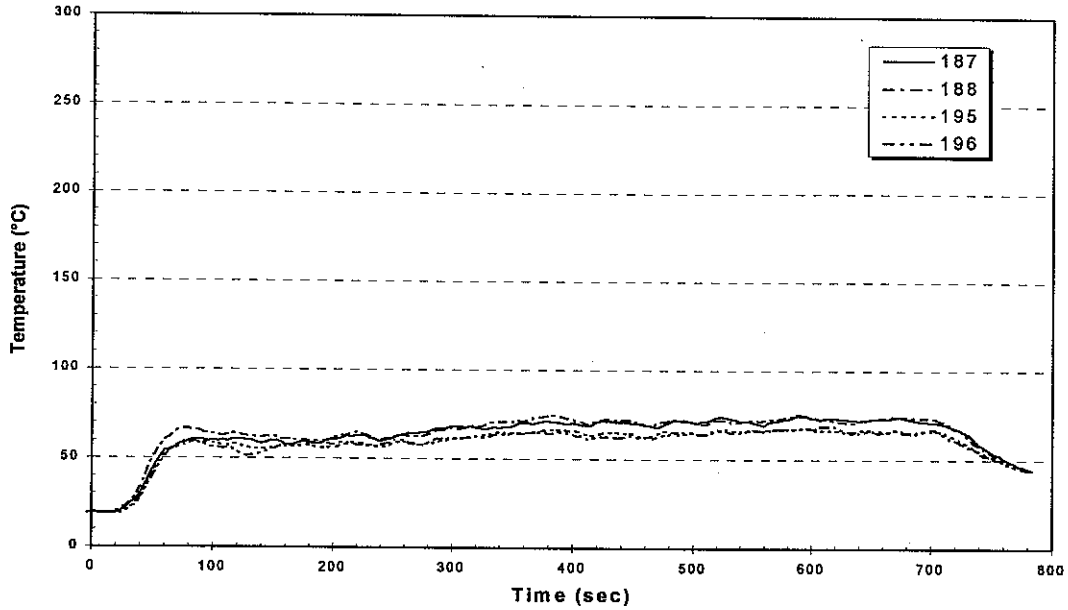


Figure C-1. Temperatures - Disk Thermocouples: Test 17

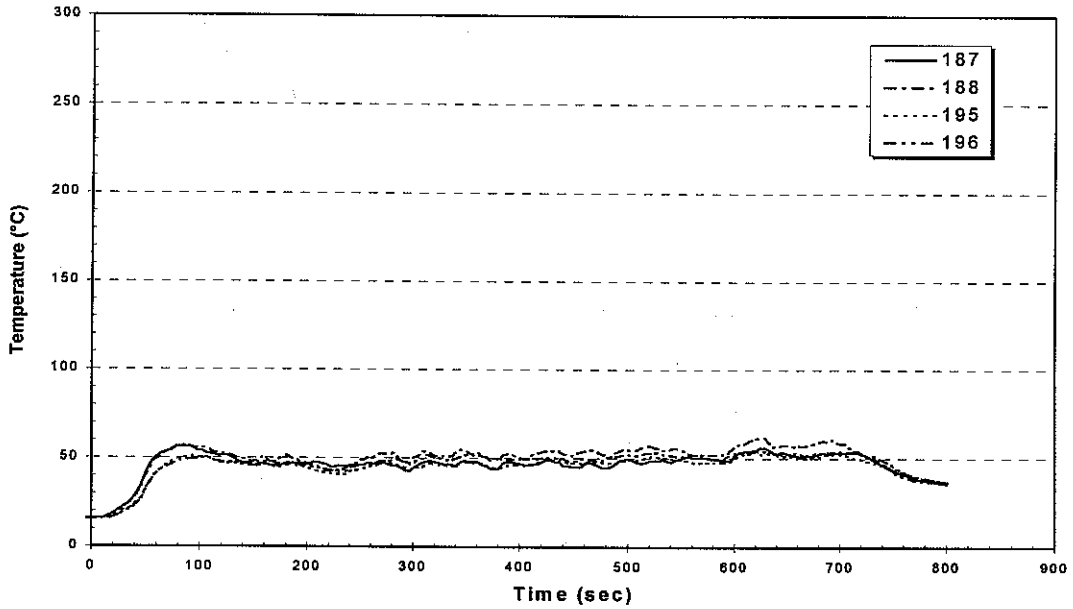


Figure C-2. Temperatures - Disk Thermocouples: Test 18

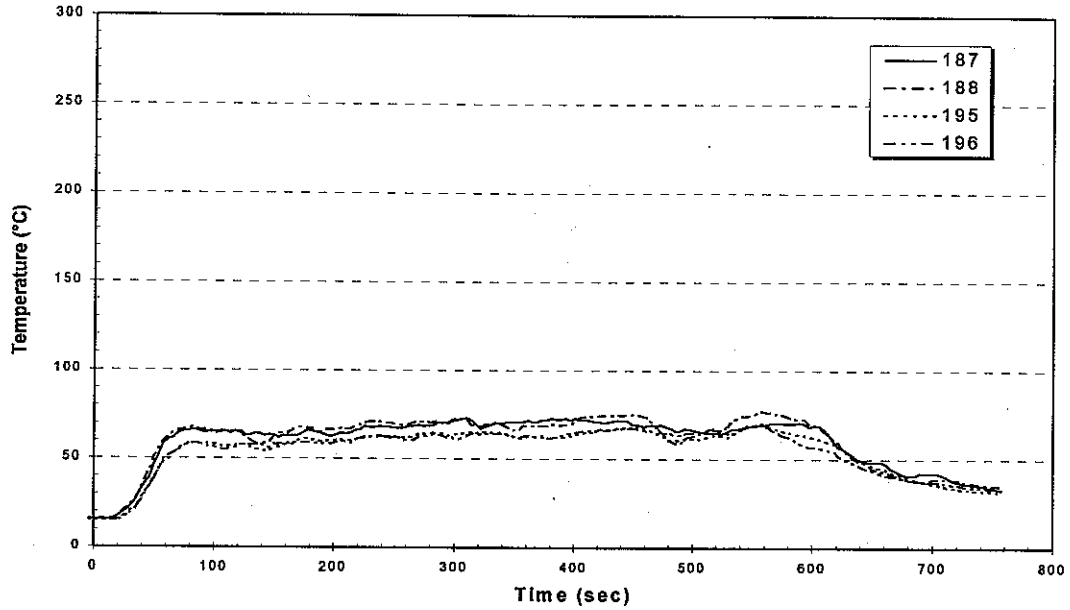


Figure C-3. Temperatures - Disk Thermocouples: Test 19

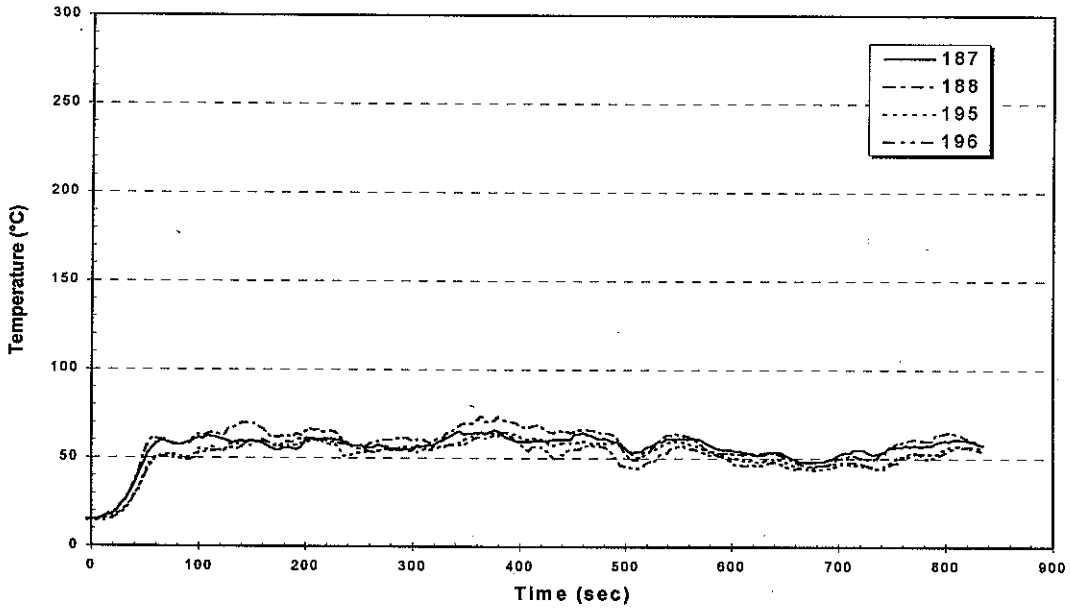


Figure C-4. Temperatures - Disk Thermocouples: Test 20

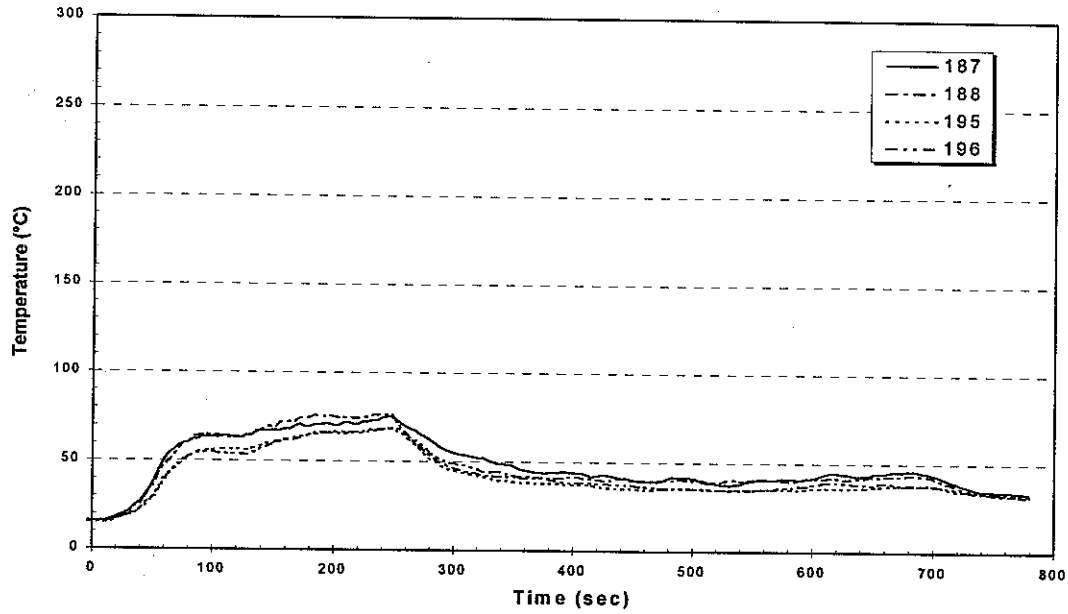


Figure C-5. Temperatures - Disk Thermocouples: Test 21

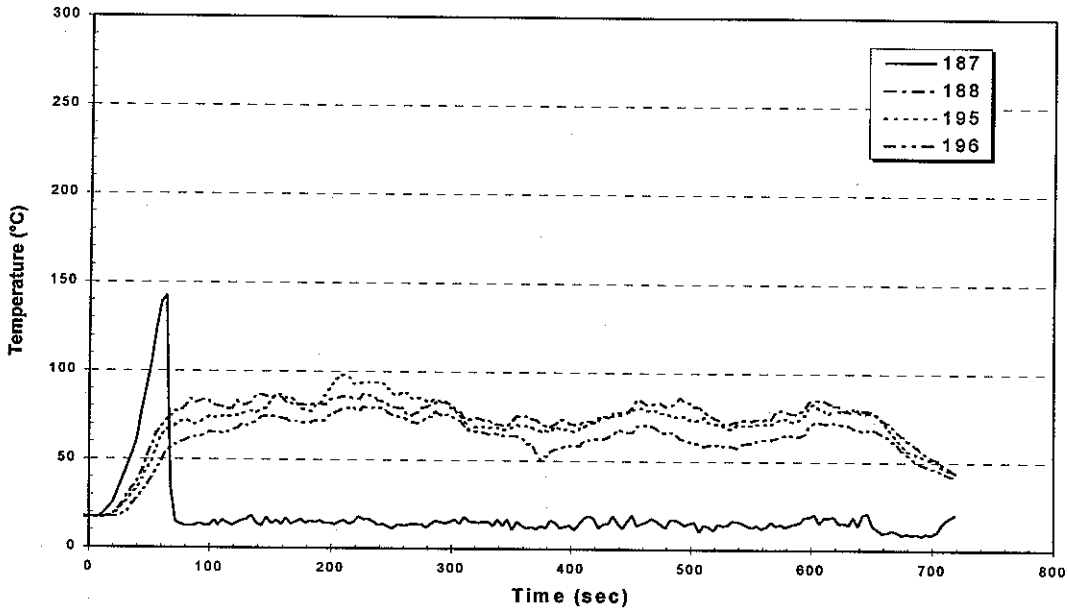


Figure C-6. Temperatures - Disk Thermocouples: Test 22

Appendix D - Gas Analysis Results:

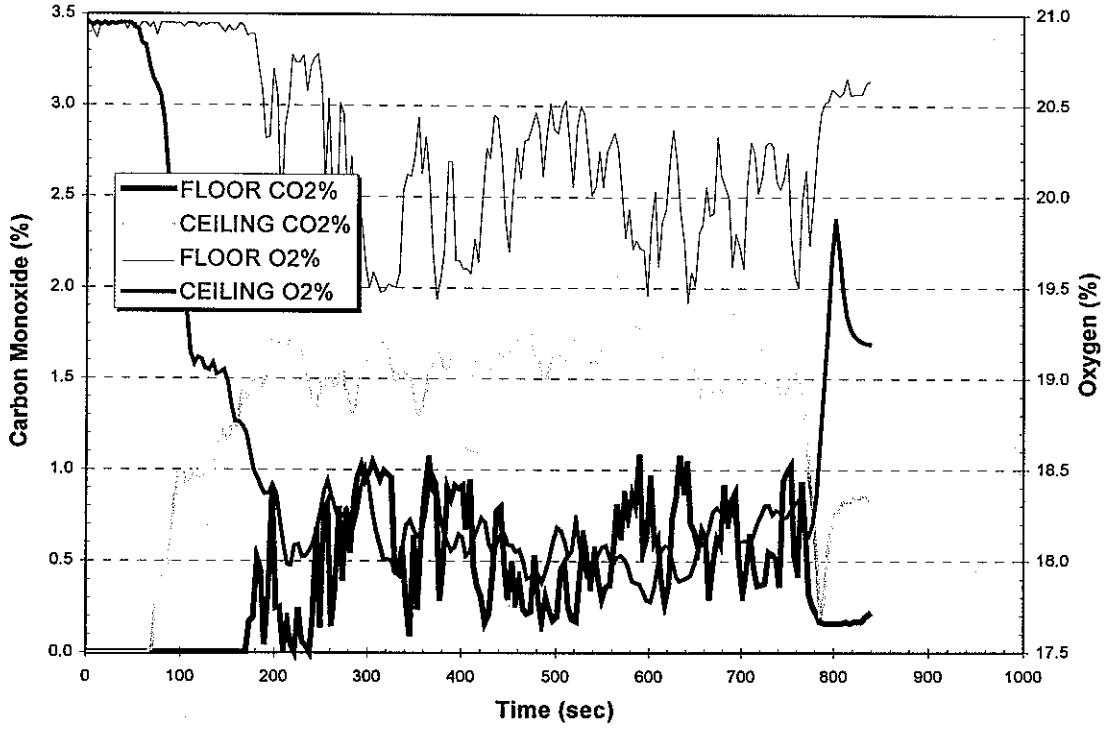


Figure D-1. Gas Concentrations : Test 1

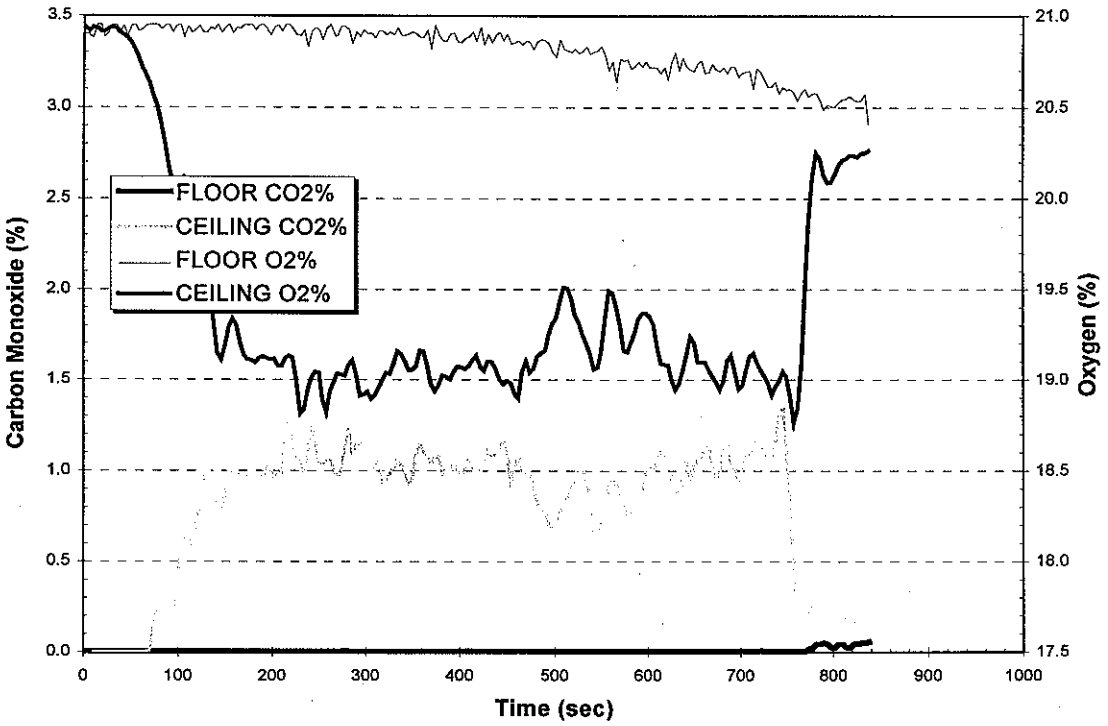


Figure D-2. Gas Concentrations : Test 2

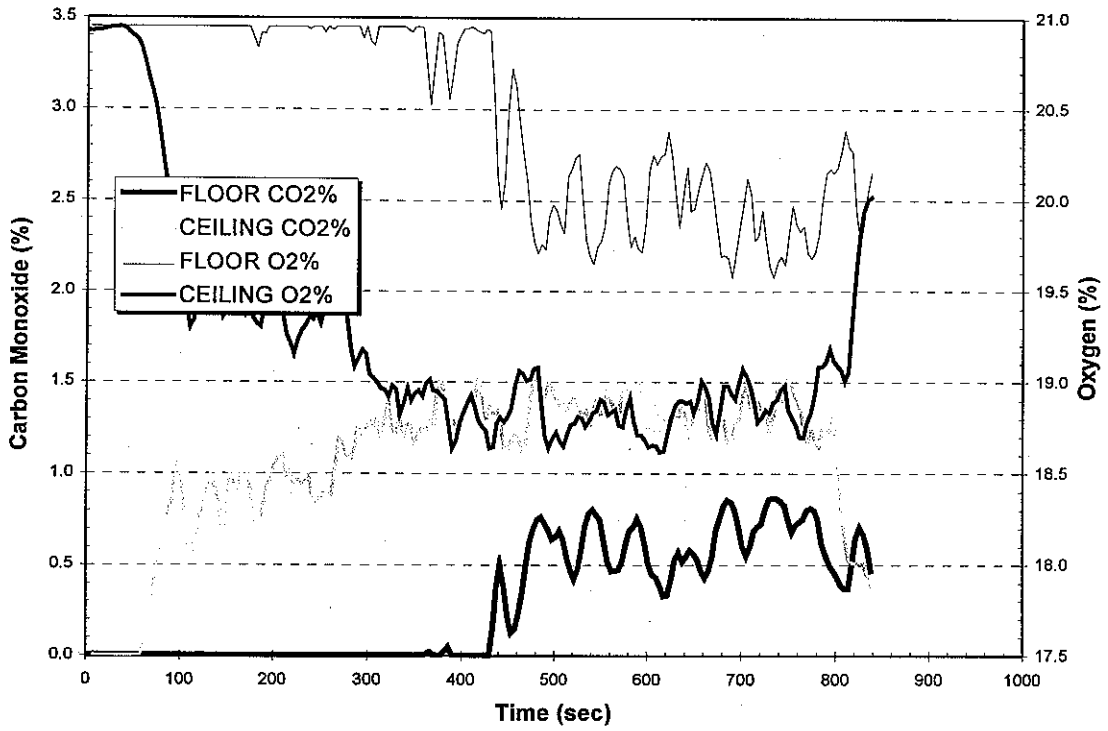


Figure D-3. Gas Concentrations : Test 3

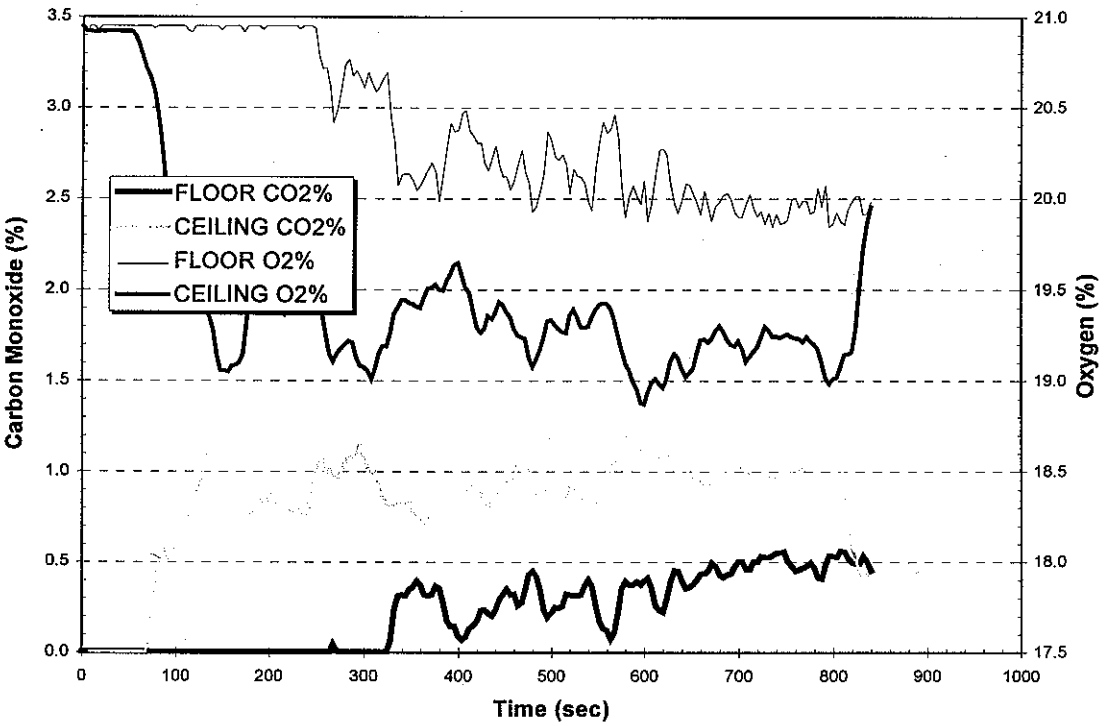


Figure D-4. Gas Concentrations : Test 4

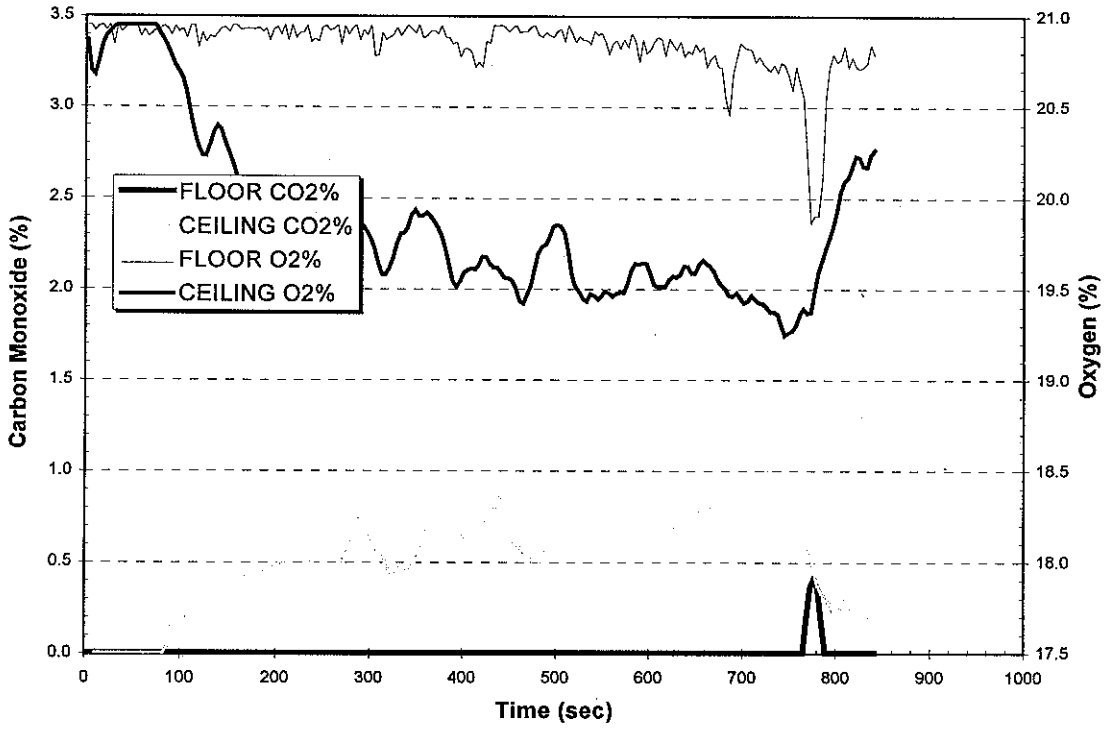


Figure D-5. Gas Concentrations : Test 5

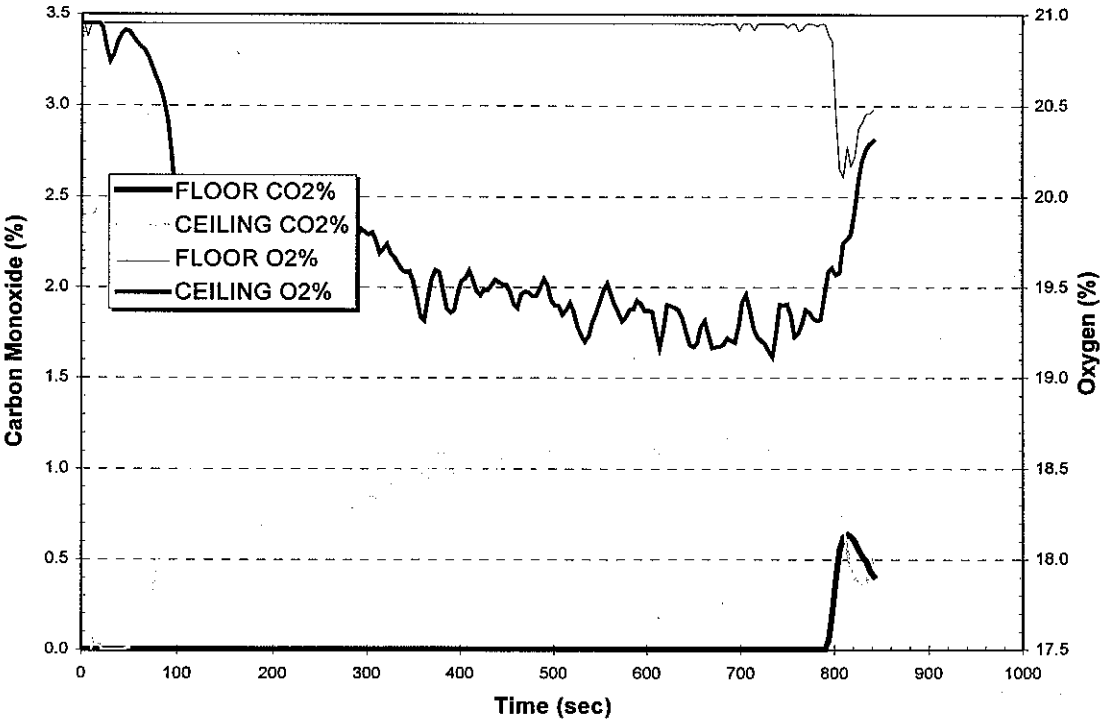


Figure D-6. Gas Concentrations : Test 6

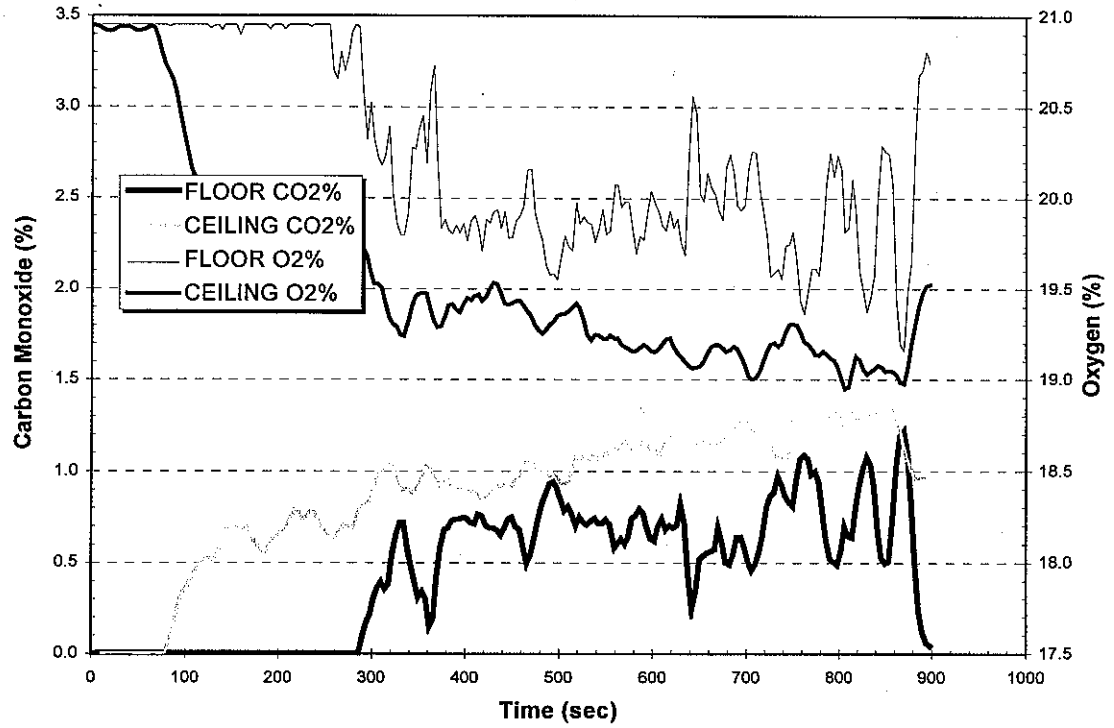


Figure D-7. Gas Concentrations : Test 7

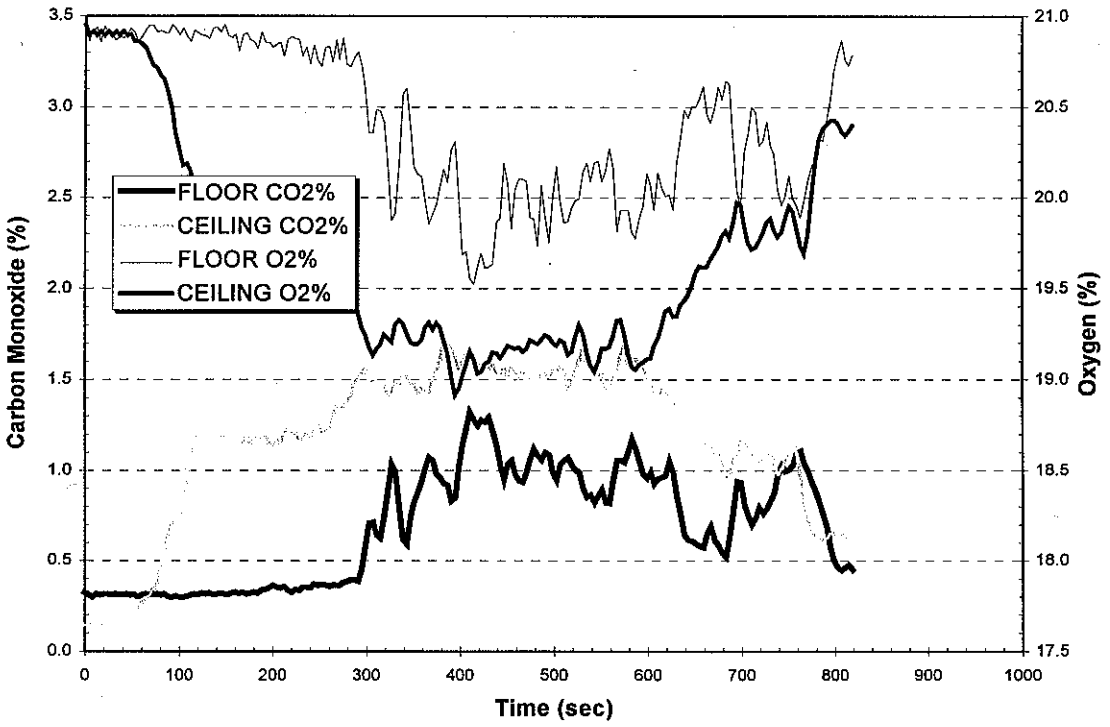


Figure D-8. Gas Concentrations : Test 8

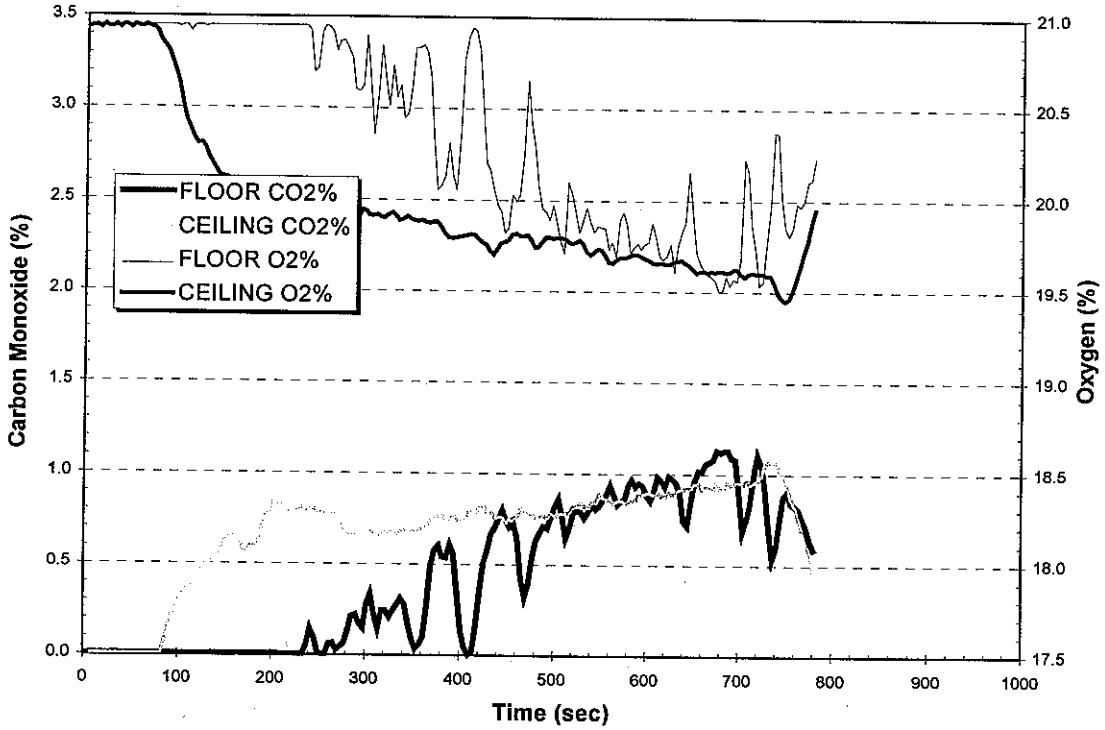


Figure D-9. Gas Concentrations : Test 9

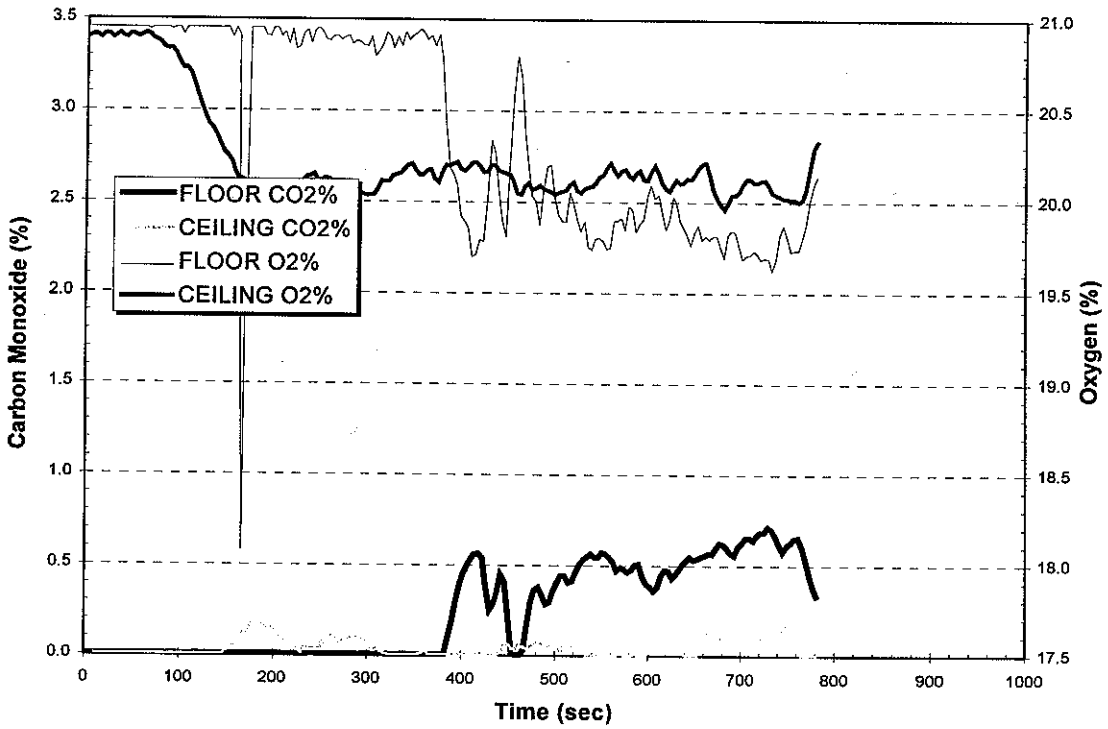


Figure D-10. Gas Concentrations : Test 10

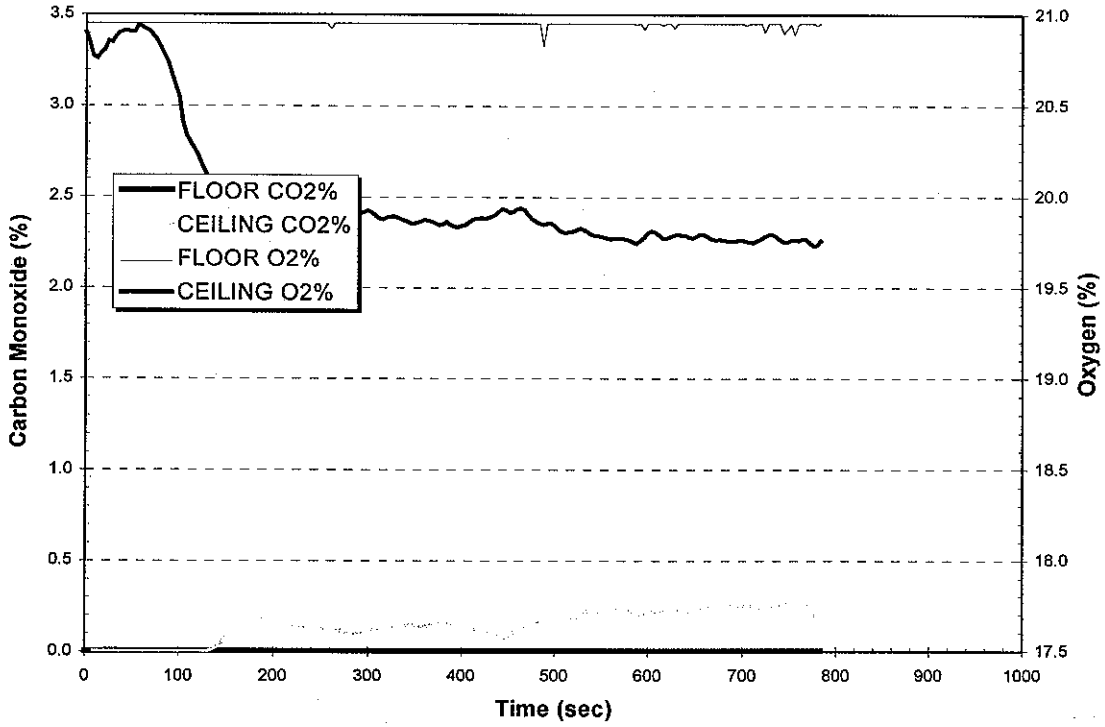


Figure D-11. Gas Concentrations : Test 11

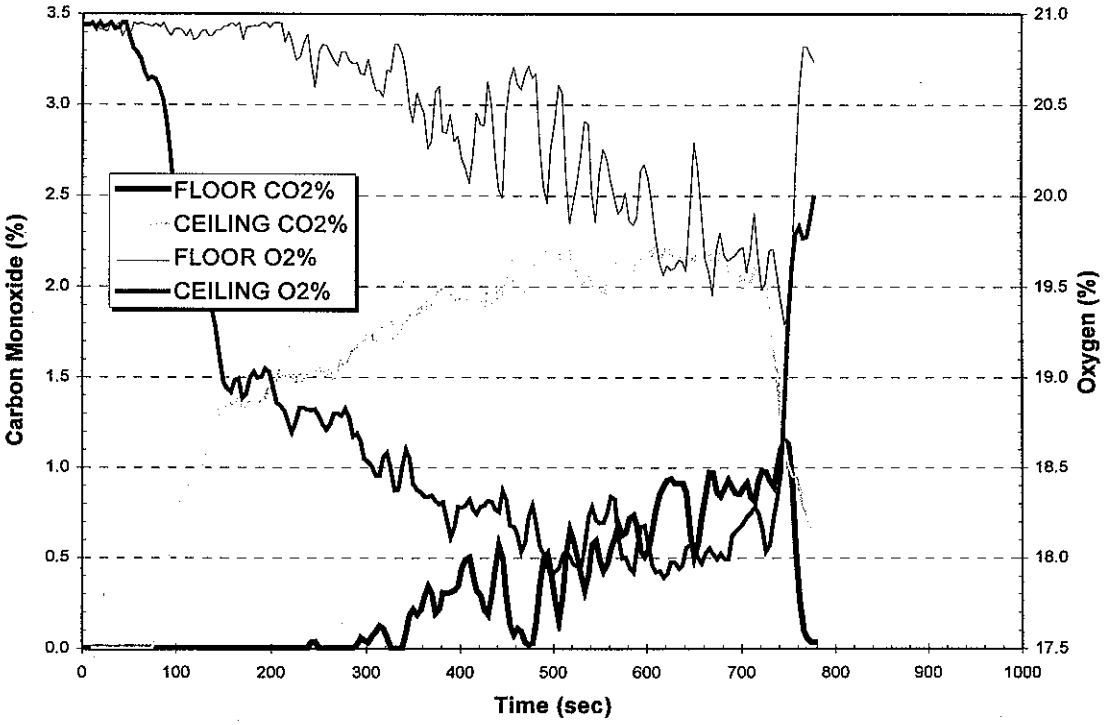


Figure D-12. Gas Concentrations : Test 12

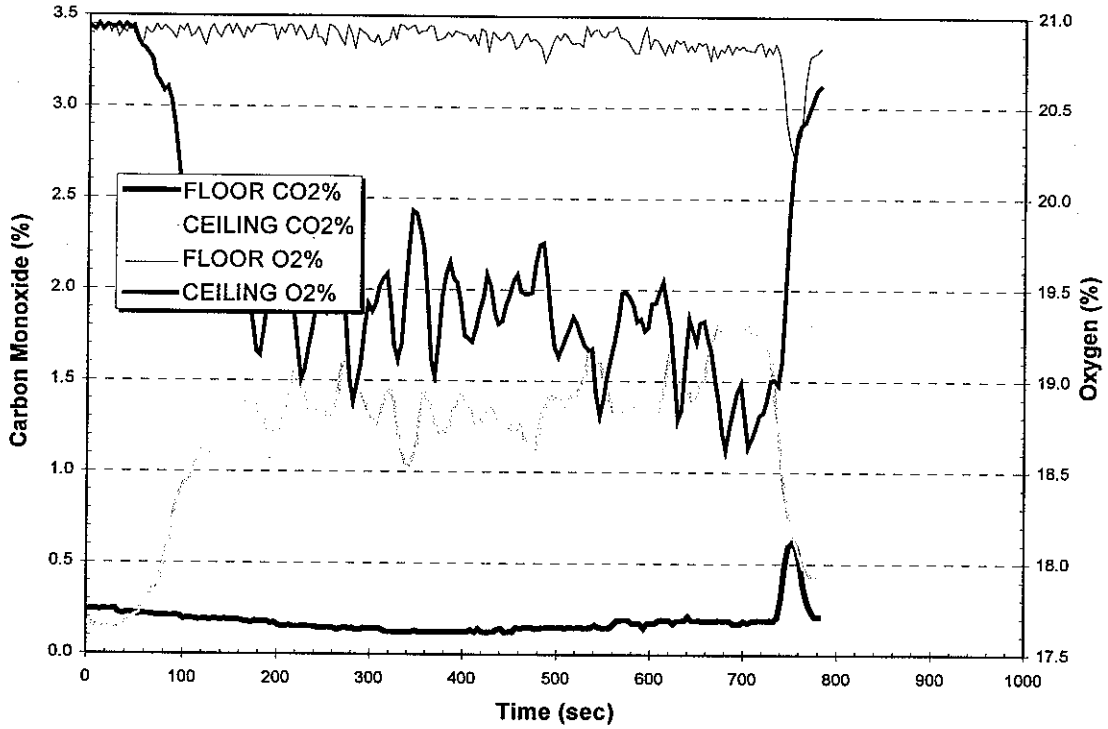


Figure D-13. Gas Concentrations : Test 13

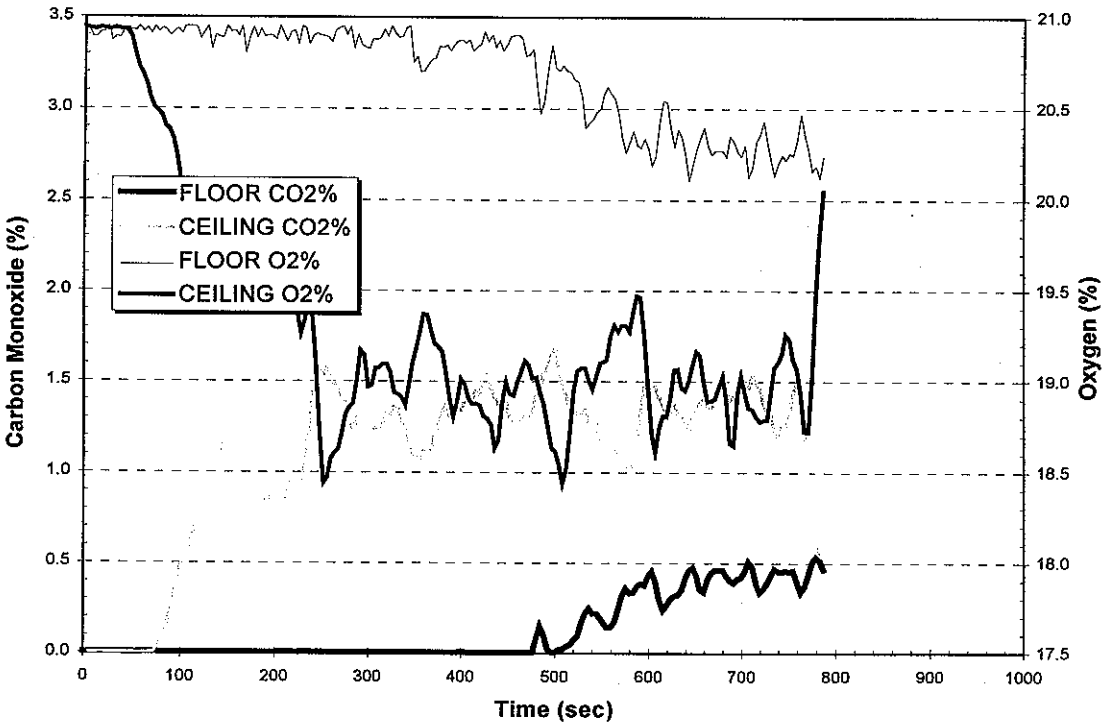


Figure D-14. Gas Concentrations : Test 14

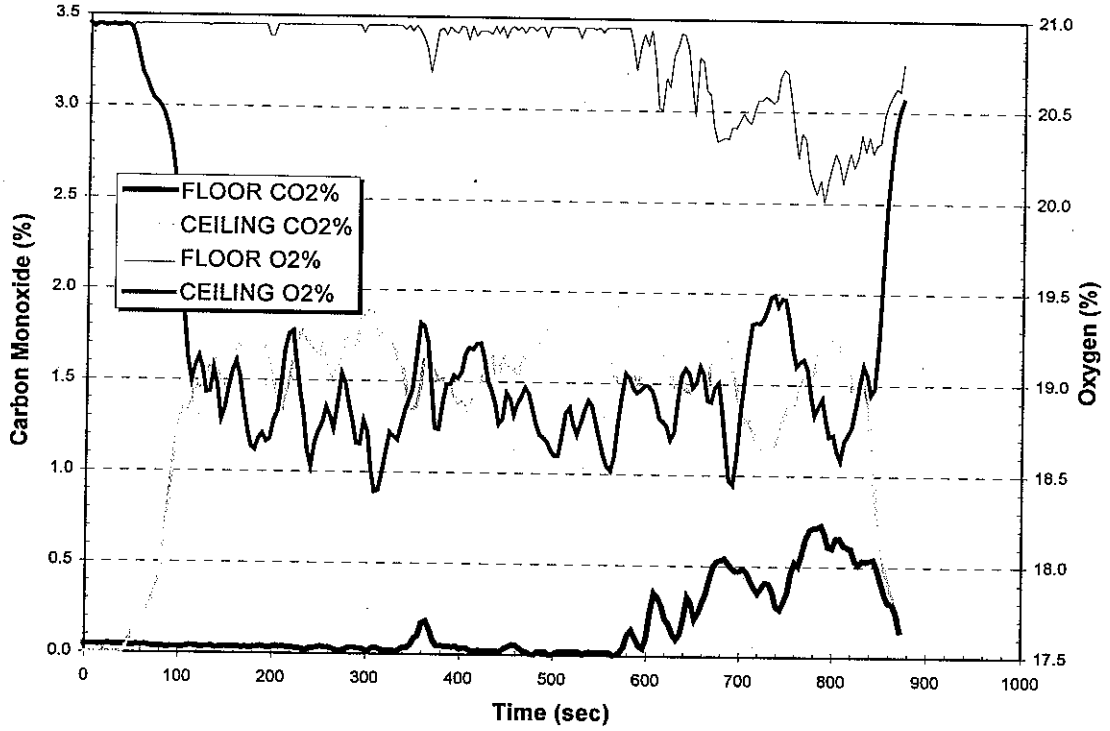


Figure D-15. Gas Concentrations : Test 15

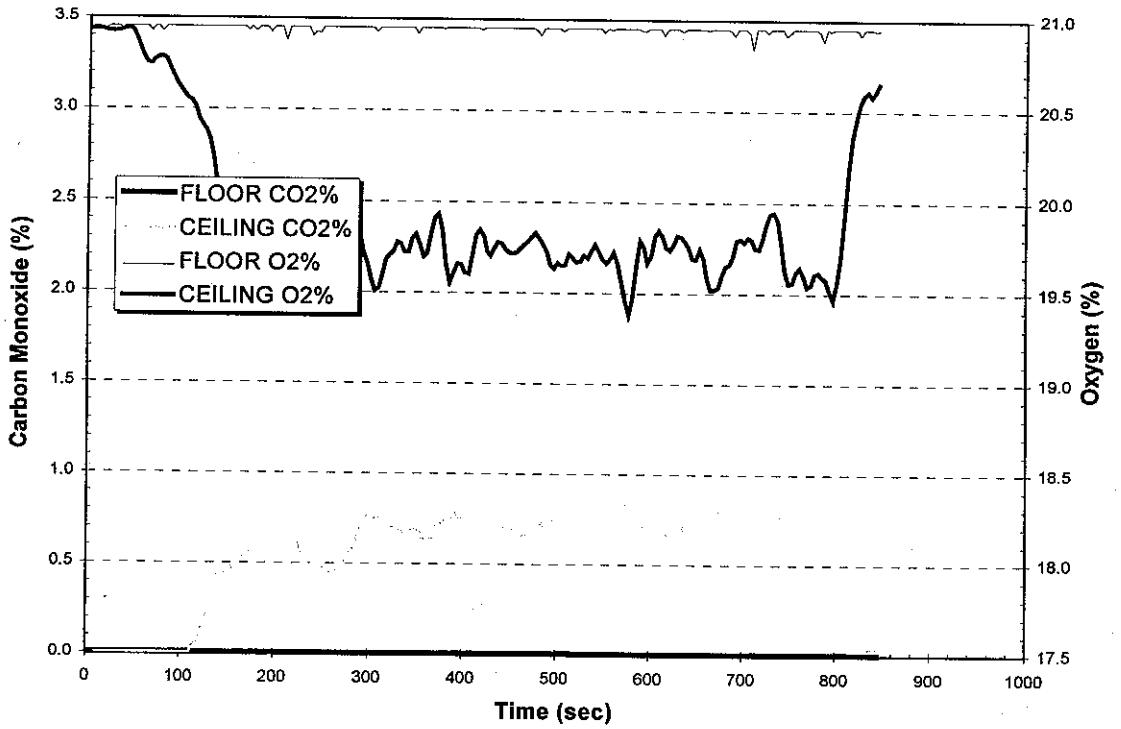


Figure D-16. Gas Concentrations : Test 16

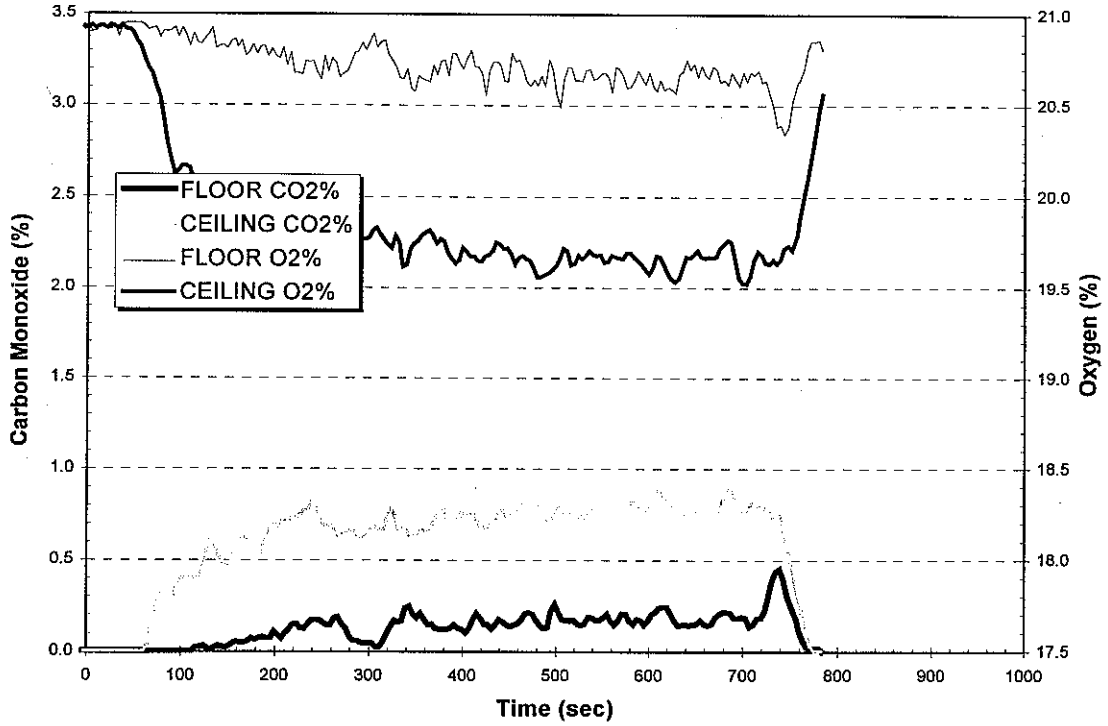


Figure D-17. Gas Concentrations : Test 17

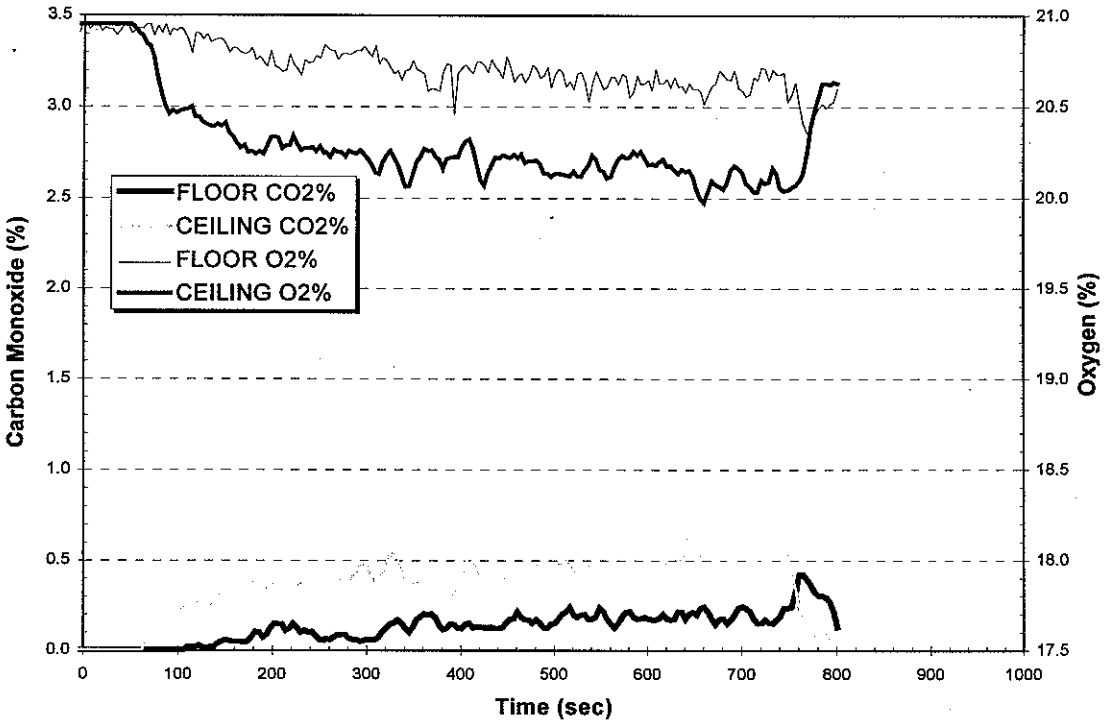


Figure D-18. Gas Concentrations : Test 18

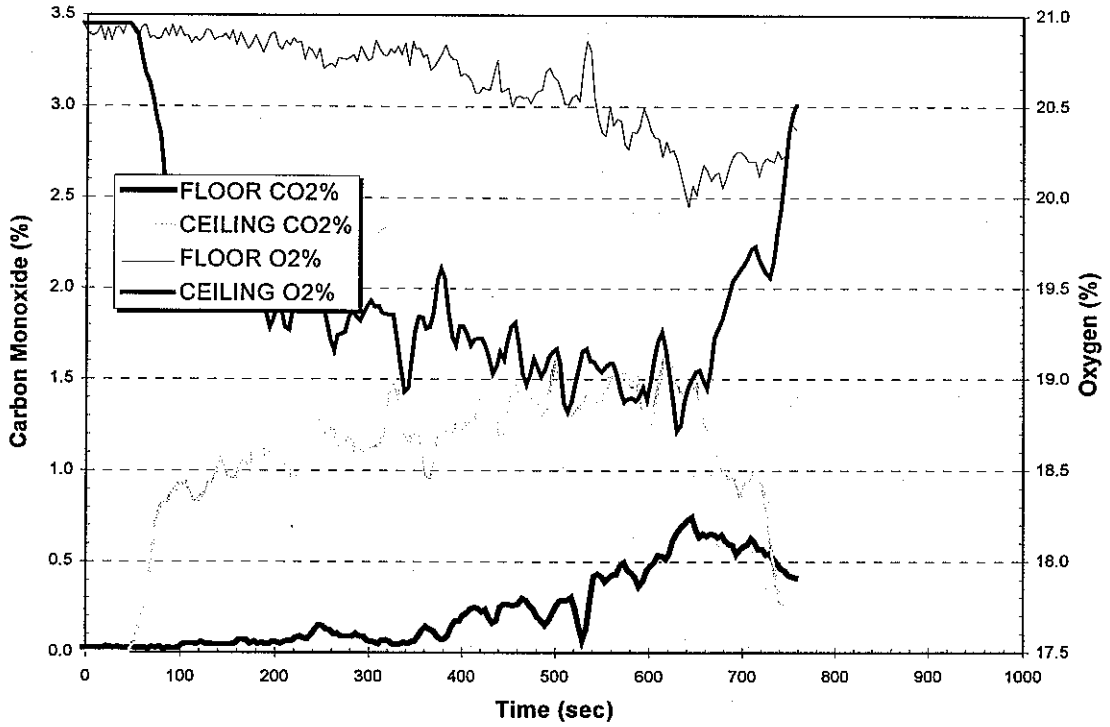


Figure D-19. Gas Concentrations : Test 19

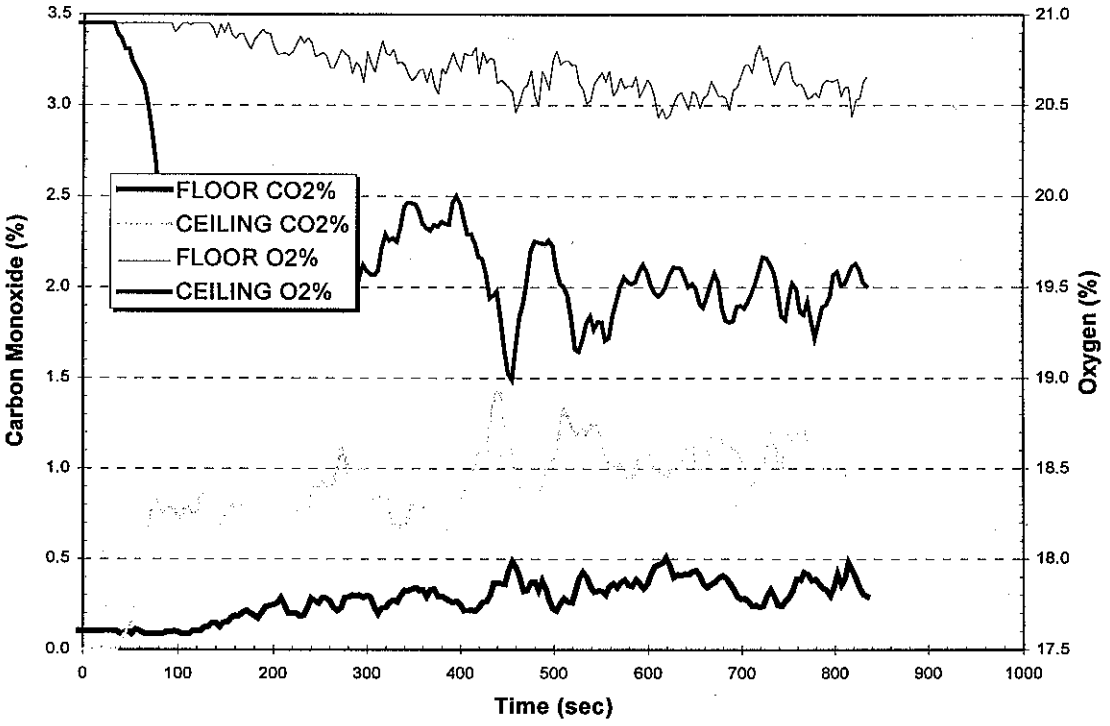


Figure D-20. Gas Concentrations : Test 20

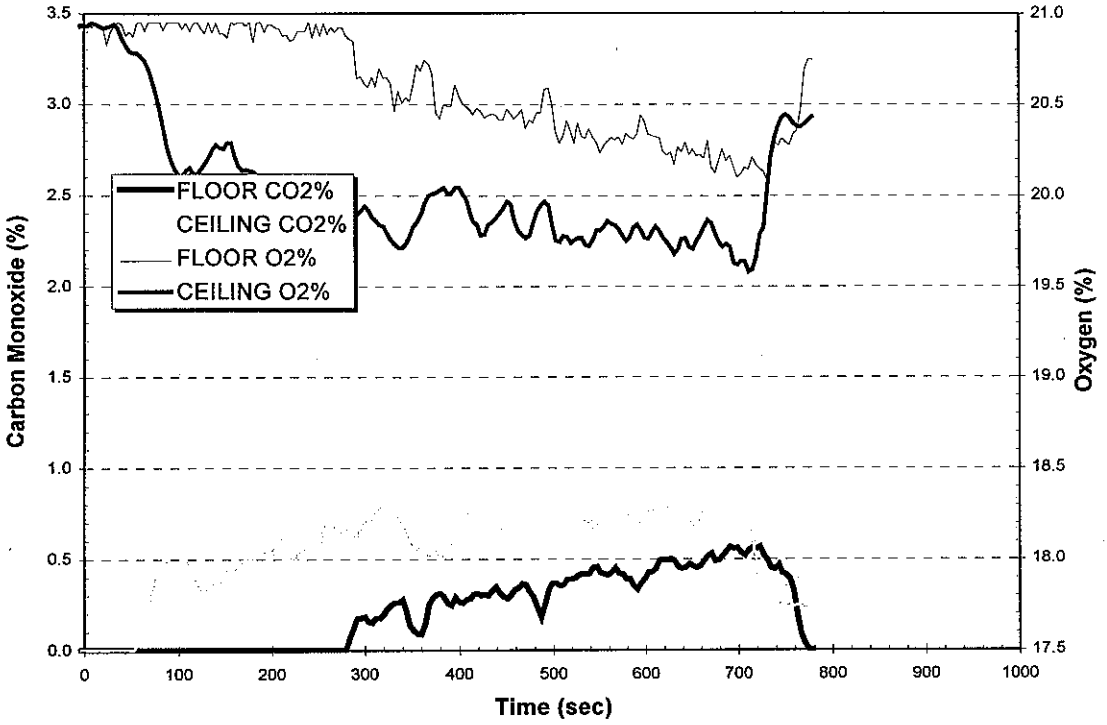


Figure D-21. Gas Concentrations : Test 21

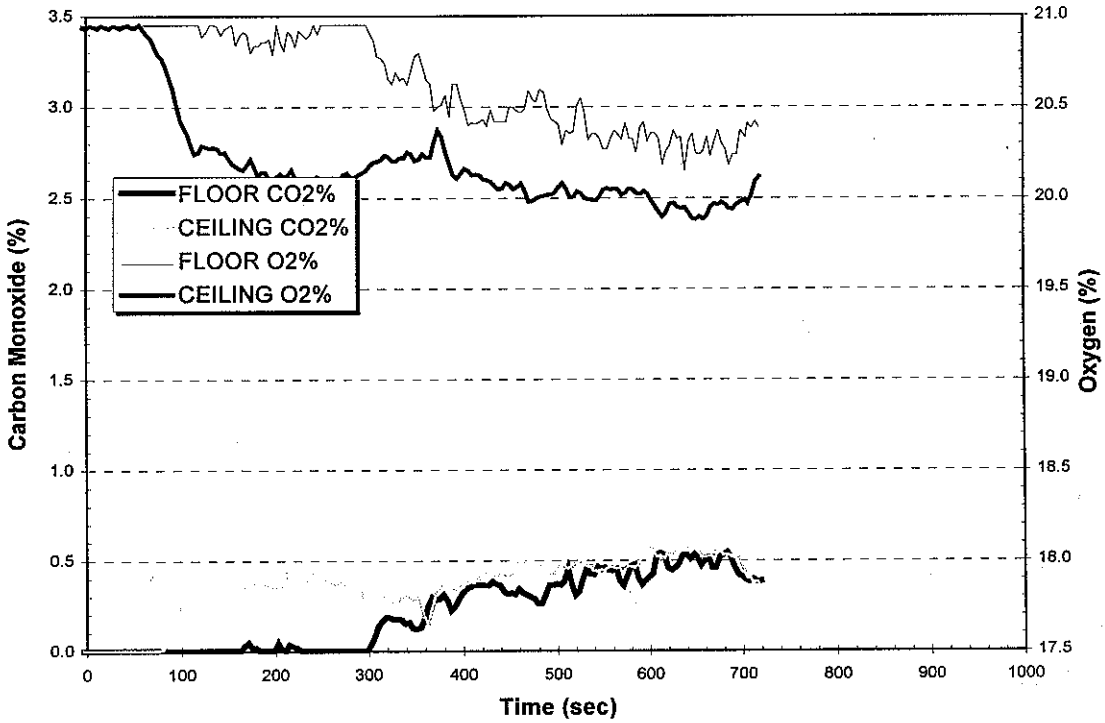


Figure D-22. Gas Concentrations : Test 22

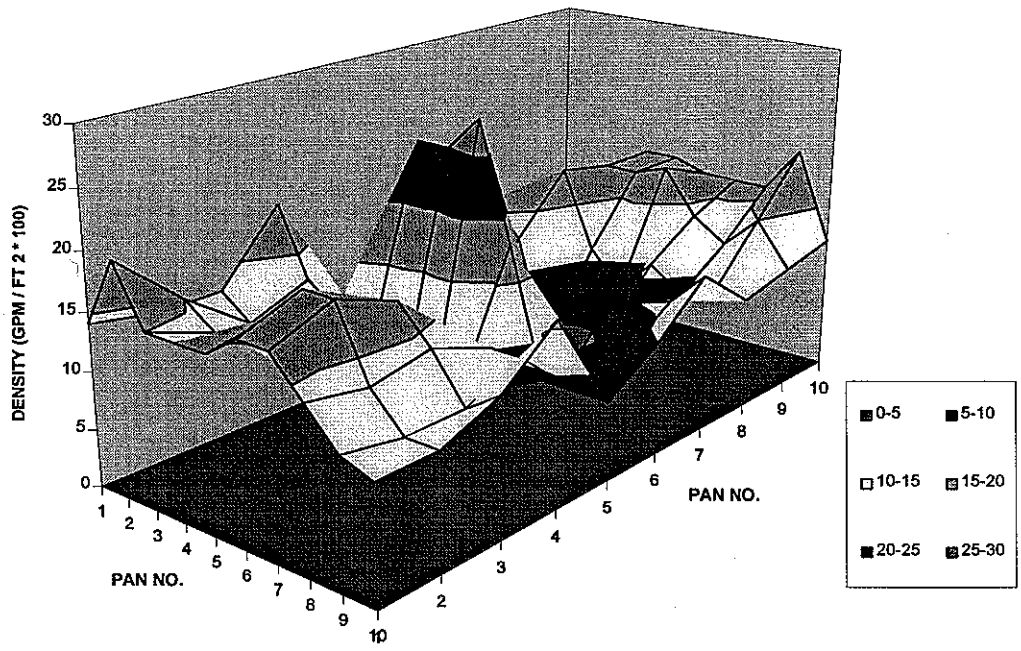
TEST 1

Test Date:	1/29/97	**Test Duration:**	10 min.
Sprinkler No.:	5	**Deflector Distance to CL of Pipe:**	5.75"
Orifice Size:	large	**Overspray:**	7.5 - 8.0'
Flowrate:	34 gpm	**Average Density (gpm / ft2):**	0.1226

Table F- 2 - Area Densities (gpm/ ft ^{2} * 100)

Pan No.	1	2	3	4	5	6	7	8	9	10
1	14	20	15	15	15	17	17	14	11	10
2	13	15	13	13	16	19	19	13	10	10
3	13	11	10	10	7	8	17	14	10	12
4	19	13	11	7	3	3	7	12	12	16
5	7	7	7	25	25	28	18	7	7	7
6	12	10	9	7	4	4	4	6	8	10
7	15	12	16	13	3	3	6	10	11	14
8	10	12	14	18	11	8	11	9	10	10
9	10	13	15	17	17	18	14	12	15	11
10	10	13	15	17	17	16	16	16	20	12

DISTRIBUTION TEST 1
LARGE ORIFICE, 34 GPM, OVERSPRAY = ~7.5 - 8.0 FT.



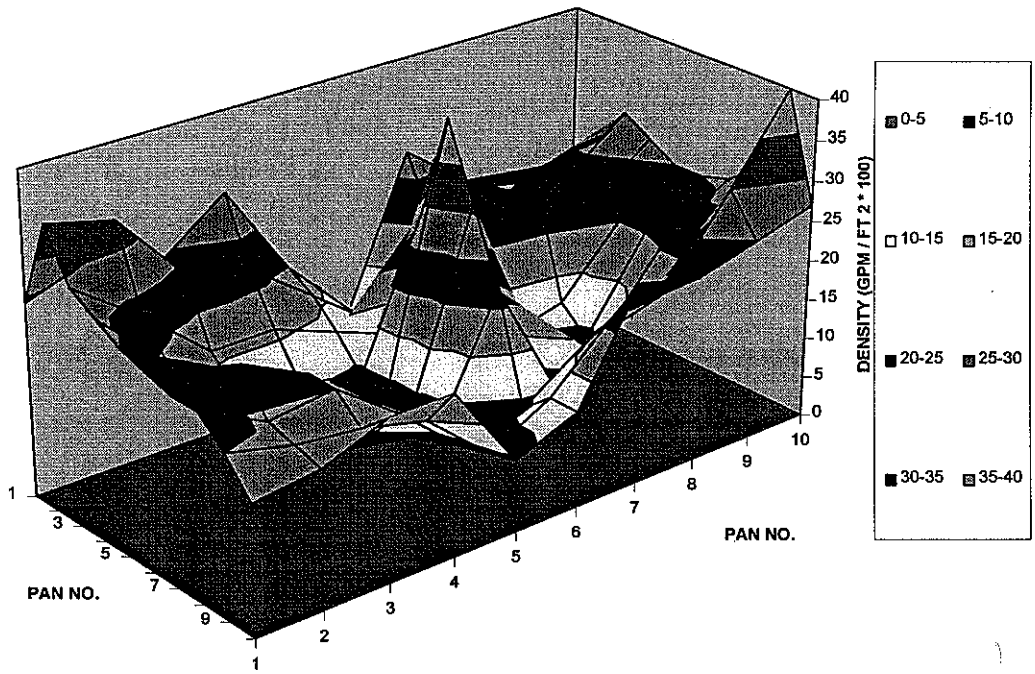
TEST 2

Test Date:	1/29/97	**Test Duration:**	10 min.
Sprinkler No.:	5	**Deflector Distance to CL of Pipe:**	5.75"
Orifice Size:	large	**Overspray:**	7.5 - 8.0'
Flowrate:	50 gpm	**Average Density (gpm / ft2):**	0.1925

Table F- 3 - Area Densities (gpm/ ft ^{2} * 100)

Pan No.	1	2	3	4	5	6	7	8	9	10
1	24	35	29	27	25	24	23	23	20	16
2	27	33	23	19	19	22	24	19	18	17
3	24	24	16	13	9	10	20	20	17	20
4	30	22	16	11	6	6	10	14	15	20
5	18	16	13	9	8	8	7	7	8	9
6	10	10	10	27	40	31	22	9	12	12
7	28	21	22	21	10	6	7	14	19	25
8	22	20	22	25	12	9	13	16	20	23
9	18	23	23	21	20	20	22	22	30	25
10	18	24	29	27	25	25	26	29	40	27

DISTRIBUTION TEST 2
LARGE ORIFICE, 50 GPM, OVERSPRAY = ~7.5 - 8.0 FT.



TEST 3

Test Date:	1/29/97	**Test Duration:**	10 min.
Sprinkler No.:	6	**Deflector Distance to CL of Pipe:**	5.75"
Orifice Size:	Extra Large	**Overspray:**	6.0'
Flowrate:	34 gpm	**Average Density (gpm / ft2):**	0.1856

Table F- 4 - Area Densities (gpm/ ft ^{2} * 100)

Pan No.	1	2	3	4	5	6	7	8	9	10
1	10	13	15	18	20	19	18	16	14	12
2	11	13	15	27	41	42	30	18	14	12
3	10	15	21	40	15	13	38	26	15	15
4	14	22	29	15	3	2	12	36	25	20
5	7	10	12	23	32	9	21	14	16	14
6	10	18	22	10	12	11	30	11	17	13
7	12	23	40	18	2	3	14	23	22	19
8	14	17	23	49	29	31	46	19	14	11
9	11	14	18	24	35	34	24	16	12	10
10	11	15	16	18	19	18	18	15	13	10

DISTRIBUTION TEST 3
EXTRA LARGE ORIFICE, 34 GPM, OVERSPRAY = ~6.0 FT.