

**NIST GCR 05-875**

# **Research Investigation for Determination of Residential Sprinkler Performance**

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**NIST**

**National Institute of Standards and Technology**  
Technology Administration, U.S. Department of Commerce



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# **Research Investigation for Determination of Residential Sprinkler Performance**

Prepared for  
*U.S. Department of Commerce  
Building and Fire Research Laboratory  
National Institute of Standards and Technology  
Gaithersburg, MD 20899-8660*

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Technology Administration  
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## **Notice**

**This report was prepared for the Building and Fire Research Laboratory of the National Institute of Standards and Technology under project number 03NK26622, US354. The statement and conclusions contained in this report are those of the authors and do not necessarily reflect the views of the National Institute of Standards and Technology or the Building and Fire Research Laboratory.**

*RESEARCH INVESTIGATION  
FOR DETERMINATION OF RESIDENTIAL  
SPRINKLER PERFORMANCE*

*Prepared by  
Underwriters Laboratories Inc.  
Project 03NK26622, US354  
for*

*U.S. National Institute of Standards  
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*February 20, 2004*

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## EXECUTIVE SUMMARY

A total of 22 fire tests were conducted to generate data and information relative to the performance of specific residential sprinklers when a total flow of 1.4 times the Listed flow rate of one sprinkler was supplied to the system. The flow rate provided to the system was maintained at this value regardless of whether one or two sprinklers operated. The fire scenarios used in this test series were similar to those described in UL1626 except that 7 of the tests were conducted with the simulated furniture fuel package located along a wall centered between two sprinklers.

In each of the 15 tests involving the corner fire scenario, only one sprinkler operated which limited the room temperatures as follows:

- a) The maximum temperature 3 inches (76 mm) below the ceiling described in this report did not exceed 600°F (316°C).
- b) The maximum temperature 5-1/4 feet (1.60 m) above the floor did not exceed 200°F (93°C), nor more than 130°F (54°C) for more than any continuous 2-minute period.
- c) The maximum ceiling material temperature 1/4 inch (6 mm) behind the finished ceiling surface did not exceed 500°F (260°C).

In each of the 7 tests conducted with the fire source located between two sprinklers, at least two sprinklers operated which resulted in a flow provided to each operated sprinkler of approximately 0.7 times the Listed flow. General observations for these 7 tests are as follows:

- In two of the fire tests (Tests 16 and 18), the third sprinkler in the room did not operate and the two operating sprinklers limited the room temperatures as described in the above Items a, b, c.
- In four of the fire tests (Tests 19-22), the third sprinkler (not connected to the water supply) near the doorway and most remote from the fire source operated, but the two sprinklers discharging water limited the room temperatures as described in the above Items a, b, and c.
- In one of the fire tests (Test 17), the third sprinkler operated and the test was terminated at 2 minutes and 29 seconds due to the lack of fire control and imminent flashover conditions.

A summary of the test results are presented in Table 5 (page 19) and Table 6 in (page 20) of this report.

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## **1 INTRODUCTION**

### ***1.1 General***

This test Report describes a Special Service Investigation conducted for U.S. National Institute of Standards and Technology to investigate the performance of a selected residential sprinklers when subjected to tests provided with a total water flow of approximately 1.4 times the UL listed rate and subjected to fire test scenarios similar to those described in the Standard for Residential Sprinklers for Fire-Protection Service, UL 1626, Third Edition.

#### **Note**

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### ***1.2 Purpose***

The sole purpose of this Special Service Investigation was to develop data relative to the performance of residential sprinklers in specific room fire test scenarios. This information is intended to be used in assessing the level of protection provided by residential sprinklers with a total water flow provided to the sprinkler system of 1.4 times the UL listed flow rate, regardless if one or two sprinklers are operating in the system. The data developed is to be used by U.S. National Institute of Standards and Technology (NIST).

## **2. TEST FACILITY**

The fire tests were conducted in Underwriters Laboratories large-scale fire test facility located in Northbrook, Illinois. The large-scale fire test facility used for this investigation includes three fire test areas that are used to develop data on the fire growth and suppressability characteristics of commodities, as well as the fire control/suppression characteristics of automatic water sprinkler systems. A schematic of the test facility is shown in Figure 1. The residential sprinkler fire tests were conducted in test rooms constructed inside the test cell designated as the "ADD Test Facility".

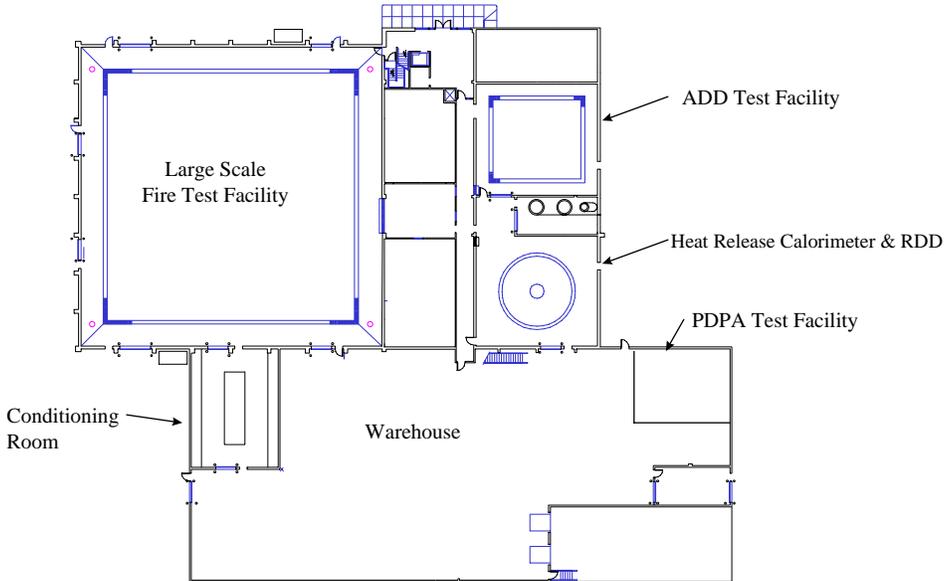


Figure 1. Test Facility

**3. TEST PARAMETERS**

Four different types of sprinklers were tested, designated in this report as sprinkler A, B, C and D. The tested sprinklers are UL listed and commercially available. Specific sprinkler information is presented in Table 1.

Table 1. Sprinkler Listing Data

<b>Sprinkler Designation</b>	<b>Type</b>	<b>Temperature Rating (° F)</b>	<b>K-factor</b>	<b>Listed Coverage Area L 3 W (ft.3 ft.)</b>	<b>Listed Flow Rate (gpm)</b>
A	Pendent or Recessed pendent	155	4.3	12 by12	12
				16 by 16	13
B	Flush Pendent	162	4.2	12 by12	13
				16 by 16	14
C	Recessed Pendent	155	4.9	12 by12	13
				16 by 16	13
D	Horizontal Sidewall	155	4.2	12 by12	12
				16 by 16	15

Twenty-two tests were performed. Tests 1 to 15, with the fire source located in the corner of the room, were performed as described in UL 1626 except for the water flow rate provided to the sprinklers. Tests 16 to 22 were conducted with the fire source located at the long-side wall between two sprinklers.

Different room layouts were constructed to accommodate the various sprinkler styles and test configurations. The sprinklers were installed as described in Table 2. Plan views of the test arrangements are presented in Figure 2 to Figure 7. The actual room dimensions relate to the sprinkler coverage area  $L \times W$ , which is described in Table 2.

Pendent sprinklers were tested with the sprinkler frame arms parallel to the short wall of the test enclosure or with the sprinkler frame arms rotated  $90^\circ$ , designated "parallel" or "perpendicular" respectively in Table 2. The flush pendent sprinklers had a design which incorporated three pins to retain the deflector upon operation. These sprinklers were tested with two deflector pins facing the short wall of the test enclosure close to the fire source, or with one deflector pin facing the short wall of the test enclosure close to the fire source, designated "2 pins to wall" or "1 pin to wall" respectively in Table 2.

The water flow rate for one operating sprinkler was set to 1.4 times the listed flow rate. The total flow rate through the operating sprinklers in the room was maintained at this flow rate regardless if one or two sprinklers operated as designated in Table 2. The third sprinkler was not connected to the water supply.

The sprinkler orientation (sprinkler frame arms parallel or perpendicular to the short wall of the test enclosure) visually observed to provide the lowest water density discharge over the fuel package was used in the tests with fire source located between two sprinklers. These visual observations were made before each fire test while discharging water at 0.7 times the rated flow through a single sprinkler or 1.4 times the rated flow through two sprinklers.

The general test parameters are presented in Table 2.

Table 2. Test Parameters

Test No	Sprinkler Code	Sprinkler Type	Deflector to Ceiling (in.)	Orientation to Short Wall	Coverage Area, W 3 L (ft.3ft.)	Flow Rate (gpm)	Fire Source Location
1	A	Recessed Pendent	*	Parallel	12 by 12	16.8	Corner
2	A	Recessed Pendent	*	Parallel	16 by 16	18.2	Corner
3	A	Recessed Pendent	*	Perpendicular	16 by 16	18.2	Corner
4	A	Pendent	4	Parallel	12 by 12	16.8	Corner
5	A	Pendent	4	Parallel	16 by 16	18.2	Corner
6	A	Pendent	4	Perpendicular	16 by 16	18.2	Corner
7	B	Flush Pendent	-	1 pin to wall	12 by 12	18.2	Corner
8	B	Flush Pendent	-	1 pin to wall	16 by 16	19.6	Corner
9	B	Flush Pendent	-	2 pins to wall	16 by 16	19.6	Corner
10	C	Recessed Pendent	*	Perpendicular	12 by 12	18.2	Corner
11	C	Recessed Pendent	*	Parallel	16 by 16	18.2	Corner
12	C	Recessed Pendent	*	Perpendicular	16 by 16	18.2	Corner
13	D	HSW	4	Far Wall	12 by 12	16.8	Corner
14	D	HSW	4	Far Wall	16 by 16	21.0	Corner
15	D	HSW	4	Near Wall	16 by 16	21.0	Corner
16	A	Recessed Pendent	*	Parallel	12 by 12	16.8	Between two
17	D	HSW	4	Far Wall	16 by 16	21.0	Between two
18	D	HSW	4	Near Wall	16 by 16	21.0	Between two
19	A	Recessed Pendent	*	Parallel	16 by 16	18.2	Between two
20	C	Recessed Pendent	*	Parallel	16 by 16	18.2	Between two
21	B	Flush Pendent	-	1 pin to wall	16 by 16	19.6	Between two
22	A	Pendent	4	Parallel	16 by 16	18.2	Between two

\* Recessed to the maximum permitted by the escutcheon which was approximately 3/4 in.

## 4 TEST METHOD

The tests 1 to 15 were conducted according to UL1626 - *Residential Sprinklers for Fire-Protection Service*, Paragraph 28 - Fire Tests. Tests 15 to 22 were generally conducted according to UL1626 except that a modified fuel package configuration was located centered between two sprinklers against one of the long walls of the test enclosure.

### 4.1 Test Room

The tests were conducted in a test room with an approximately 7 feet 11 inch (2.41 m) high ceiling, having nominal dimensions described in Figure 2 to Figure 7 as follows:

- |          |  |
|----------|--|
| Figure 2 | Pendent and recessed pendent sprinklers with fire source location in the corner.                         |
| Figure 3 | Pendent and recessed pendent sprinklers with fire source location between two sprinklers.                |
| Figure 4 | Horizontal sidewall sprinklers positioned on far wall with fire source location in corner.               |
| Figure 5 | Horizontal sidewall sprinklers positioned on far wall with fire source location between two sprinklers.  |
| Figure 6 | Horizontal sidewall sprinklers positioned on near wall with fire source location in corner.              |
| Figure 7 | Horizontal sidewall sprinklers positioned on near wall with fire source location between two sprinklers. |

The dimensions W (coverage width) and L (coverage length) in the figures, can be found in Table 2.

### 4.2 Instrumentation

The instrumentation used in the testing consisted of the following devices:

- 1/16-in. diameter, Type K inconel sheathed thermocouples. 36 thermocouples were used to measure air temperature in various locations in the room and ceiling tile temperature above the fire. The locations of the thermocouples are specified in Table 3.
- Bristol Babcock Model 250815B210 pressure transducers in a 0-30 psi range was used to measure the water pressure in the main supply pipe of the sprinkler system.
- Fischer Porter model 1475EN090L Mag X – 1 inch magnetic flow meter in the 0-60 gpm range was used to measure the water flow rate in the main supply pipe.
- Two Siemens Oxymat 6 paramagnetic oxygen analyzers were used to measure the oxygen concentration near the center of the room. Chemical agents were used to remove CO<sub>2</sub> and H<sub>2</sub>O from the gas line.
- Stopwatches were used to record sprinkler operation times.
- Camera was used to take photos of the test setup before test and the damage of the fuel packages after test.
- Two Digital video cameras was used to record the fire growth and fire suppression during fire test. One camera was positioned in the most distant doorway and the second camera was positioned behind a window located on the long side wall, opposite the fuel package.

Table 3. Thermocouple locations

Thermocouple Number	Location
1*	Embedded in the ceiling tile directly above the wood crib,
2*	Aligned with sprinkler #1, 8 inches (0.20 m) from center line, 5 feet, 3 inches (1.60 m) above floor
3*	Aligned with sprinkler #1, 8 inches (0.20 m) from center line, 3 inches (76 mm) below ceiling
4	Aligned with sprinkler #2, 8 inches (0.20 m) from center line, 3 inches (76 mm) below ceiling
5	Adjacent to sprinkler #3
6*	In center of room, 3 inches (76 mm) below ceiling
7	Adjacent to sprinkler #1
8	Adjacent to sprinkler #2
9	In TC tree 8 inches (0.20 m) from center of room, 1 inch (0.03 m) below ceiling
10	In TC tree 8 inches (0.20 m) from center of room, 2 inch (0.05 m) below ceiling
11	In TC tree 8 inches (0.20 m) from center of room, 3 inch (0.08 m) below ceiling
12	In TC tree 8 inches (0.20 m) from center of room, 4 inch (0.10 m) below ceiling
13	In TC tree 14 inches (0.36 m) from center of room, 5 inch (0.13 m) below ceiling
14	In TC tree 8 inches (0.20 m) from center of room, 6 inch (0.15 m) below ceiling
15	In TC tree 8 inches (0.20 m) from center of room, 7 inch (0.18 m) below ceiling
16	In TC tree 8 inches (0.20 m) from center of room, 8 inch (0.20 m) below ceiling
17	In TC tree 8 inches (0.20 m) from center of room, 9 inch (0.23 m) below ceiling
18	In TC tree 8 inches (0.20 m) from center of room, 10 inch (0.25 m) below ceiling
19	In TC tree 8 inches (0.20 m) from center of room, 11 inch (0.28 m) below ceiling
20	In TC tree 8 inches (0.20 m) from center of room, 12 inch (0.30 m) below ceiling
21	In TC tree 8 inches (0.20 m) from center of room, 13 inch (0.33 m) below ceiling
22	In TC tree 8 inches (0.20 m) from center of room, 14 inch (0.36 m) below ceiling
23	In TC tree 8 inches (0.20 m) from center of room, 15 inch (0.38 m) below ceiling
24	In TC tree 8 inches (0.20 m) from center of room, 16 inch (0.41 m) below ceiling
25	In TC tree 8 inches (0.20 m) from center of room, 17 inch (0.43 m) below ceiling
26	In TC tree 8 inches (0.20 m) from center of room, 18 inch (0.46 m) below ceiling
27	In TC tree 8 inches (0.20 m) from center of room, 19 inch (0.48 m) below ceiling
28	In TC tree 8 inches (0.20 m) from center of room, 20 inch (0.50 m) below ceiling
29	In TC tree 8 inches (0.20 m) from center of room, 21 inch (0.53 m) below ceiling
30	In TC tree 8 inches (0.20 m) from center of room, 22 inch (0.56 m) below ceiling
31	In TC tree 8 inches (0.20 m) from center of room, 23 inch (0.58 m) below ceiling
32	In TC tree 8 inches (0.20 m) from center of room, 25 inch (0.63 m) below ceiling
33	In TC tree 8 inches (0.20 m) from center of room, 28 inch (0.71 m) below ceiling
34	In TC tree 8 inches (0.20 m) from center of room, 31 inch (0.79 m) below ceiling
35	In TC tree 8 inches (0.20 m) from center of room, 34 inch (0.86 m) below ceiling
36	In TC tree 8 inches (0.20 m) from center of room, 48 inch (1.22 m) below ceiling

- Required according to UL1626.

Thermocouple number 2, 3, 4 and 6 were shielded from sprinkler water impingement by aluminum tape attached to the thermocouple wire above the sensing element.

### 4.3 Test Procedure

For each test, three sprinklers were installed as described in Table 2. The location of the sprinklers are described in Table 4 and illustrated in Figure 2 to Figure 7. The sprinkler near the doorway furthest from the fire source was installed with the heat responsive element 2 inches (51 mm) below the ceiling for pendent sprinklers and for sidewall sprinklers, the deflector was 4 inches (102 mm) below the ceiling.

Table 4. Sprinkler Locations

Sprinkler	Location
Sprinkler #1	Closest to the corner of the fire according to UL1626.
Sprinkler #2	Second closest to the corner of the fire according to UL1626.
Sprinkler #3	Near the doorway furthest from the fire.

Two acoustical panels measuring 2 by 4 ft (0.61 by 1.22 m) were located in the 4 by 4 ft (1.22 by 1.22 m) area directly over the fire source. Covering the floor under the fire source were ¼ inch (13 mm) thick, 4 by 4 feet (1.22 by 1.22 m) noncombustible cement boards. Two 4 by 8 ft (1.22 by 2.44 m) sheets of 3 ply Douglas fir plywood panels, nominally ¼ inch (13 mm) thick, were placed on the test room walls behind the fire source. For the sidewall sprinkler near wall tests with the fire source location between two sprinklers, the plywood wall panels were extended to cover also the wall behind the sprinklers.

For each test, simulated furniture consisting of two pure polypropylene oxide polyol, polyether foam cushions having a density of 1.7 to 1.9 lb/ft<sup>3</sup> (27.23 to 30.44 kg/m<sup>3</sup>), measuring 32 by 30 inch (0.81 by 0.76 m) and 3 inch (76 mm) thick were used. Each foam cushion was glued to a 33 by 31 inch (0.84 by 0.79 m) nominal ½ inch (13 mm) thick plywood backing using an aerosol urethane foam adhesive. The simulated furniture assemblies were placed in steel frames to give support in a vertical orientation.

A nominal 12 by 12 by 6 inch tall (0.30 by 0.30 by 0.15 m) wood crib, two ¼ inch diameter by 6 inch long (6 by 152 mm) cotton wicks soaked in heptane and 8 oz (0.24 l) of heptane were also used as a part of the fuel package. The wood crib consisted of 1.5 by 1.5 by 12 inch (38 by 38 by 305 mm) long kiln dried spruce or fir lumber arranged in four alternate layers. The cotton wicks and heptane were used for a fire accelerant to ignite the simulated furniture pieces and wood crib, respectively.

The two wall panels, the simulated furniture and the wood crib were conditioned before the test as described in to UL1626.

Before ignition, the two sprinklers closest to the fire were pressurized with water with the water supply adjusted to discharge at the specified flow rate if activated. If two sprinklers operated, the total discharge from both sprinklers was maintained at the flow rate specified in Table 2. The third sprinkler at the doorway furthest from the fire was intended to monitor possible activation of the thermal element.

Before each test, the ambient room temperature was  $80 \pm 5^{\circ}\text{F}$  ( $27 \pm 3^{\circ}\text{C}$ ), measured 3 inches (76 mm) below the ceiling. All water from previous test were removed such there were no visible water on the floor, ceiling or walls.

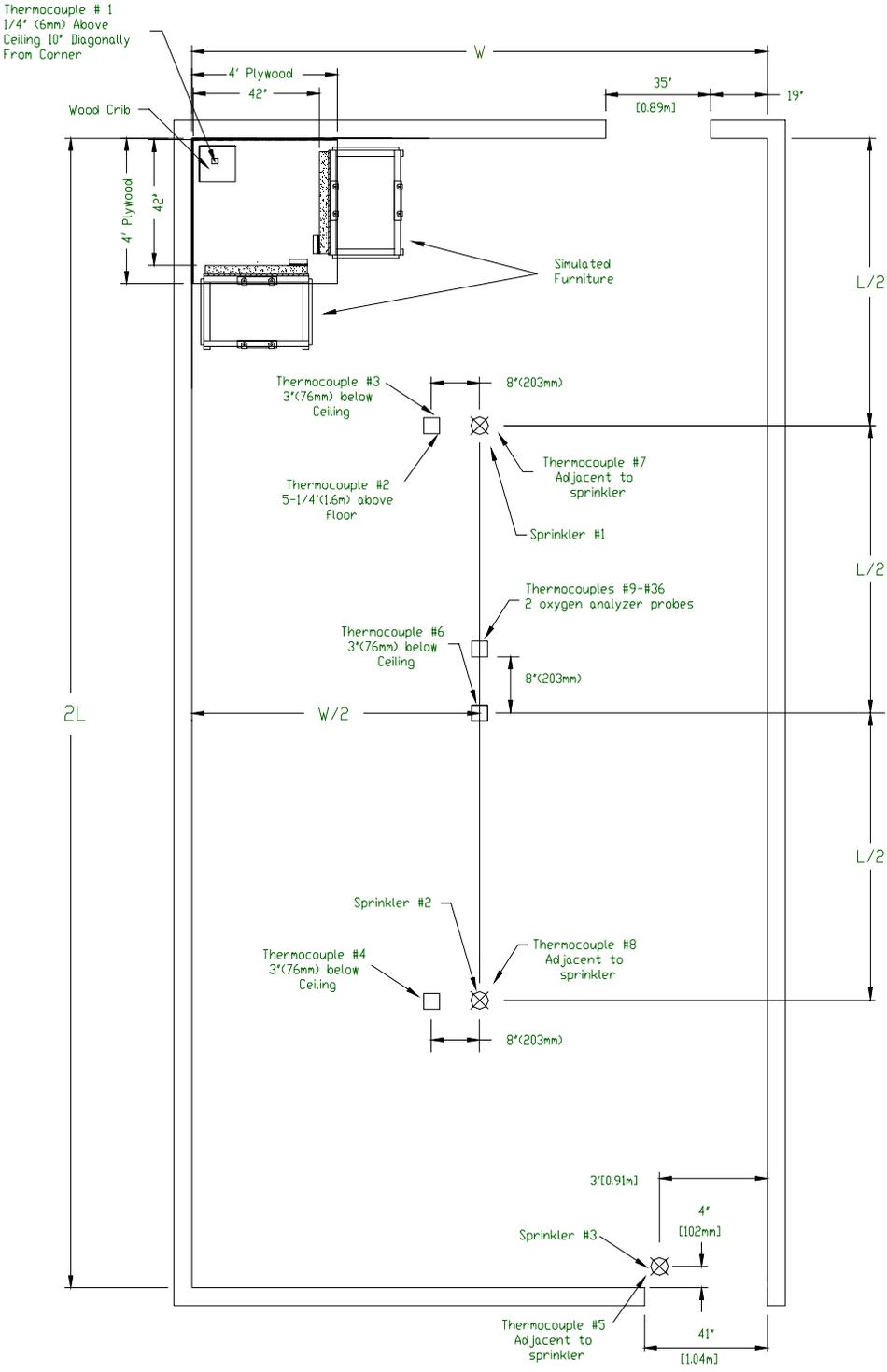
The heptane was placed in a  $1 \text{ ft}^2$  ( $0.093 \text{ m}^2$ ) pan containing 16 oz (4.7 dl) of water below the wood crib and then ignited. The cotton wicks which were placed at the edge of each simulated furniture piece, were immediately ignited following the wood crib.

Pictures showing the test room with fuel package arrangements are shown in Figure 8 to Figure 14.

The fire was allowed to burn for at least 10 min after the initial ignition, or longer if significant visible flames were observed.

After each test, a damage assessment was performed including photos of the remaining fuel package combustibles.

Following the test series, sprinklers with unactivated thermal elements were exposed to Operating Temperature (Bath) Test described in UL 1626.



L= Coverage length  
W= Coverage width

Figure 2. Plan view of room for Test Nos. 1-12. Pendent and recessed pendent sprinklers with the fire source located in the corner.

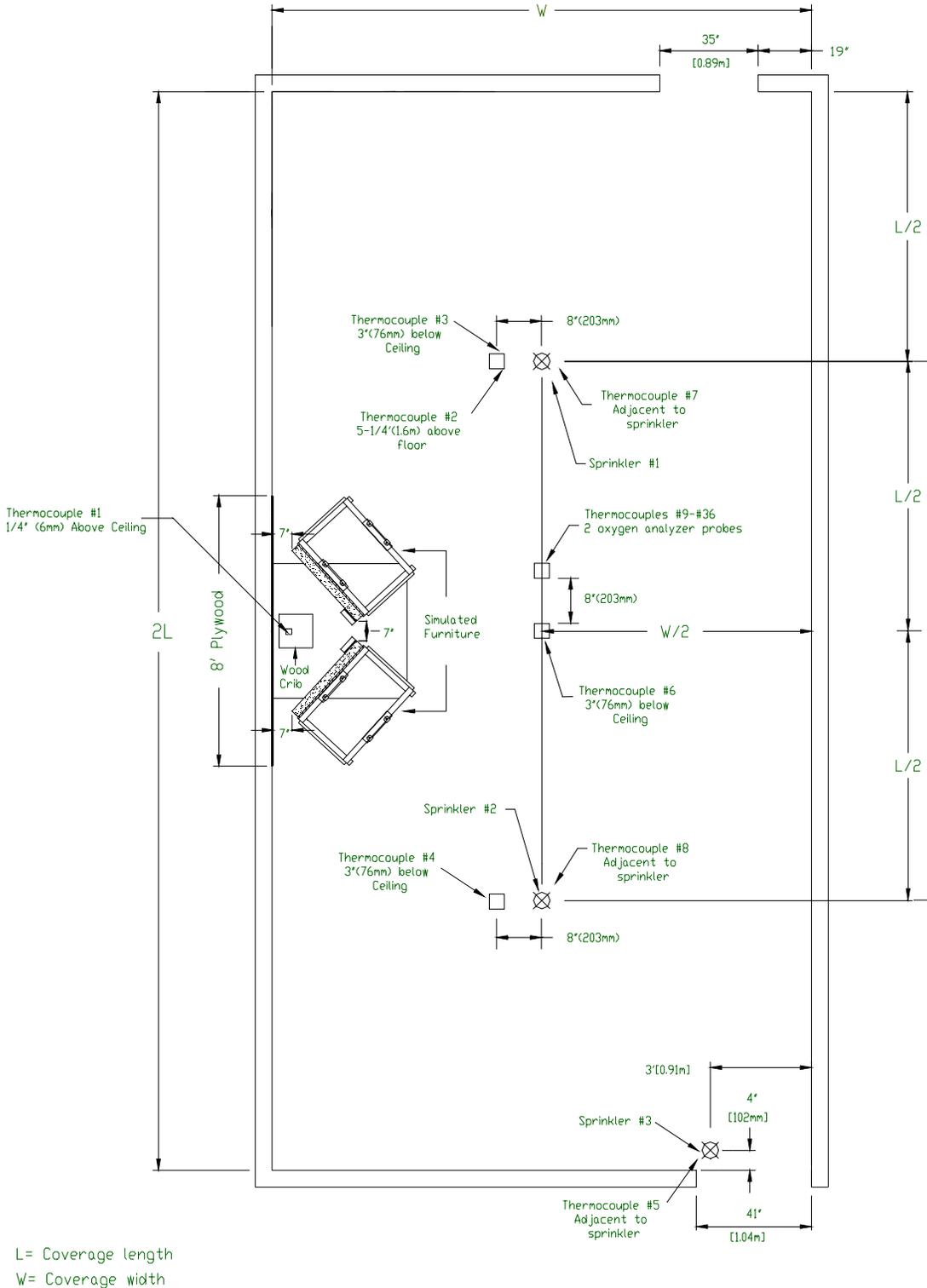
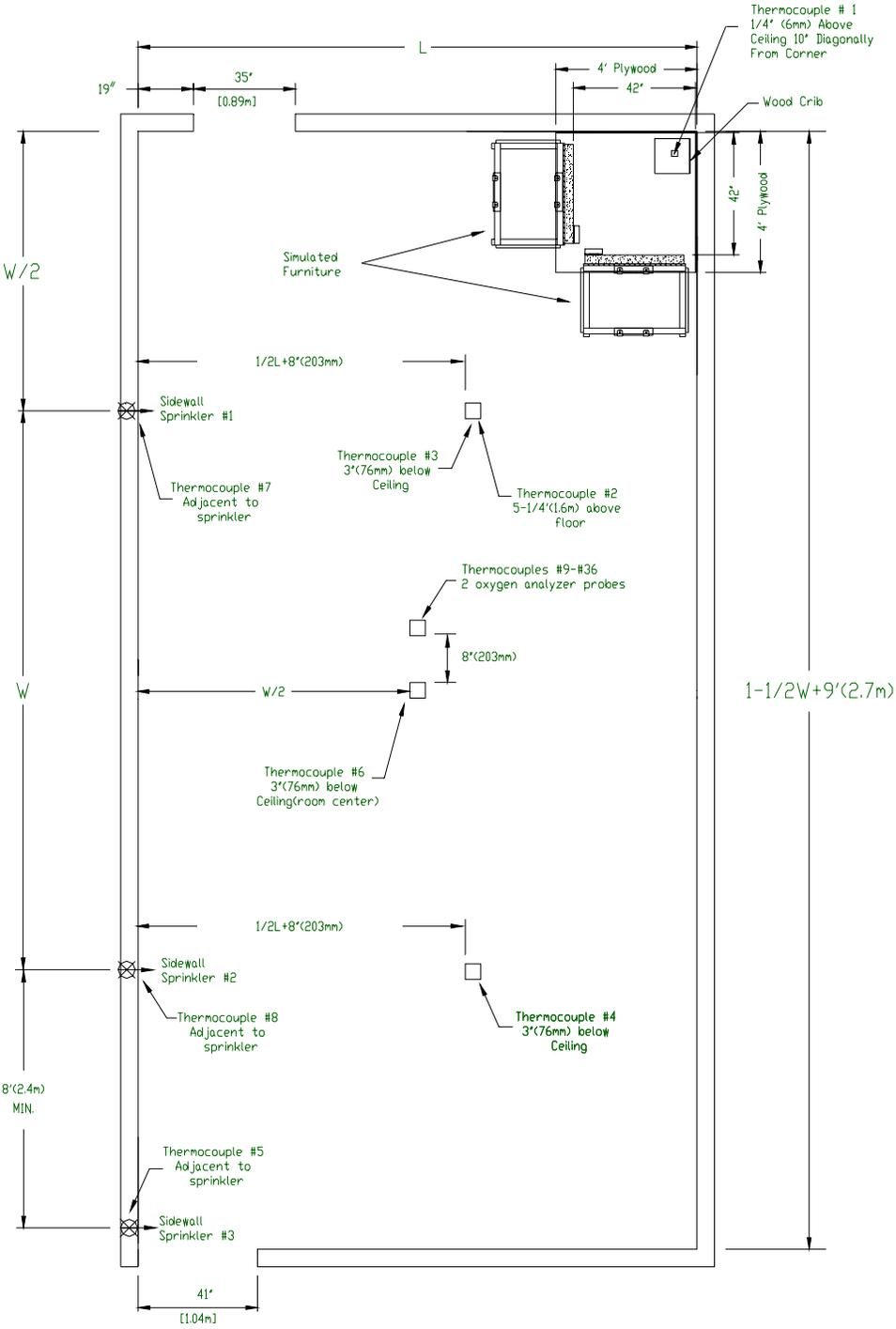
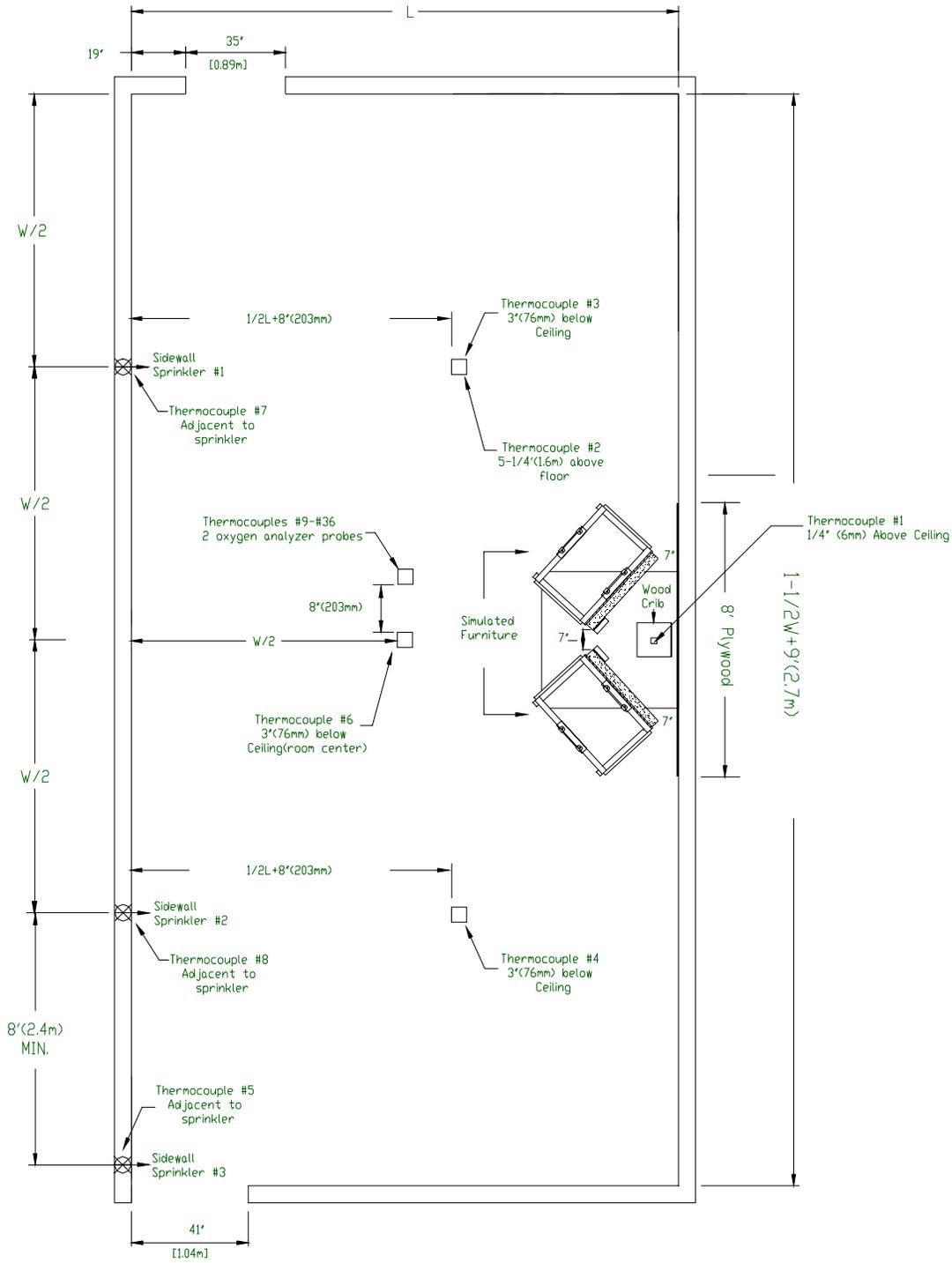


Figure 3. Plan view of room for Test Nos. 16 and 19-22. Pendent and recessed pendent sprinklers with the fire source located between two sprinklers.



L= Coverage length  
 W= Coverage width

Figure 4. Plan view of room for Test Nos. 13 and 14. Horizontal sidewall sprinklers positioned on far wall with the fire source located in the corner.



L= Coverage length  
W= Coverage width

Figure 5. Plan view of room for Test No. 17. Horizontal sidewall sprinklers positioned on far wall with the fire source located between two sprinklers.

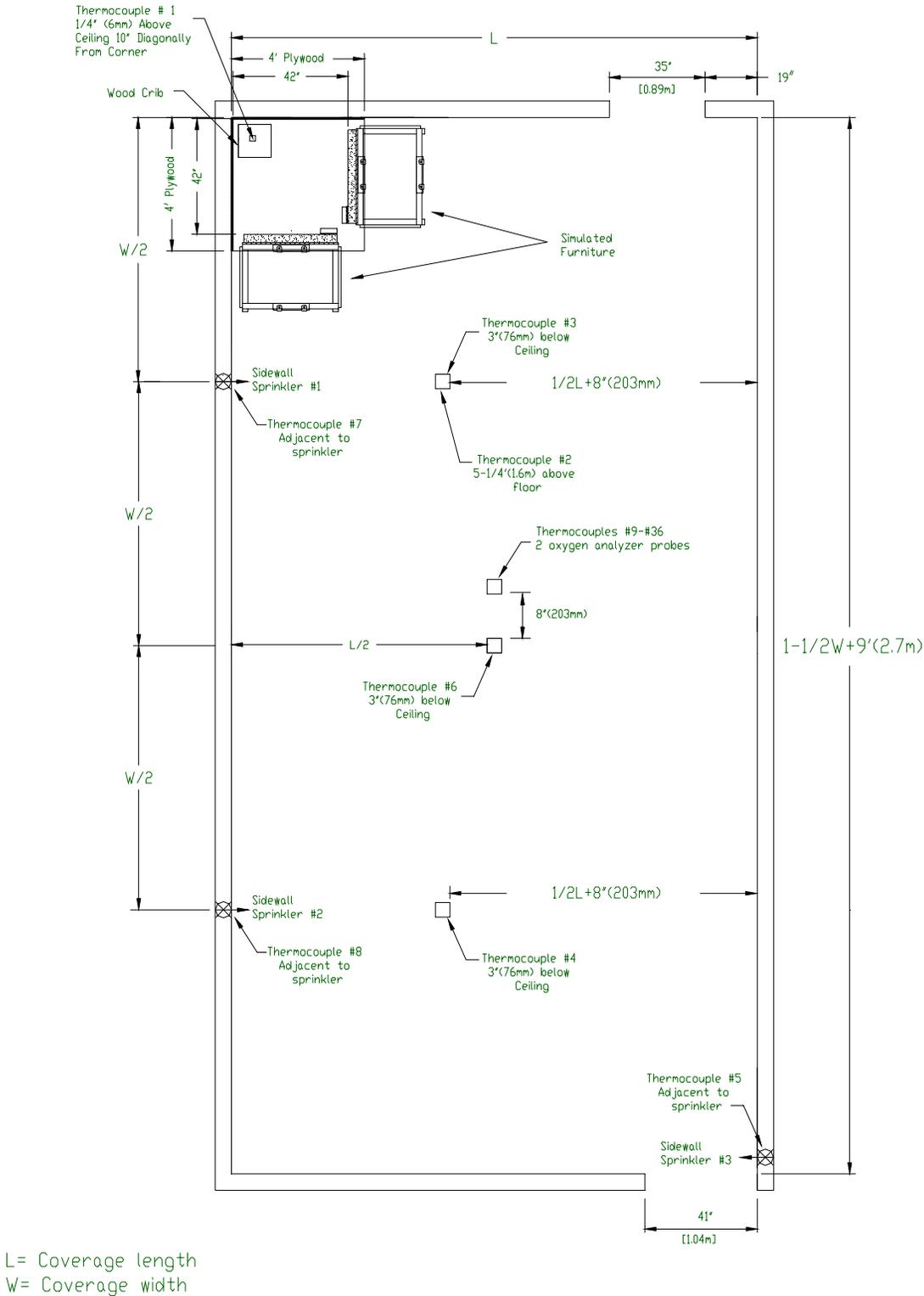


Figure 6. Plan view of room for Test No. 15. Horizontal sidewall sprinklers positioned on near wall with the fire source located in the corner.

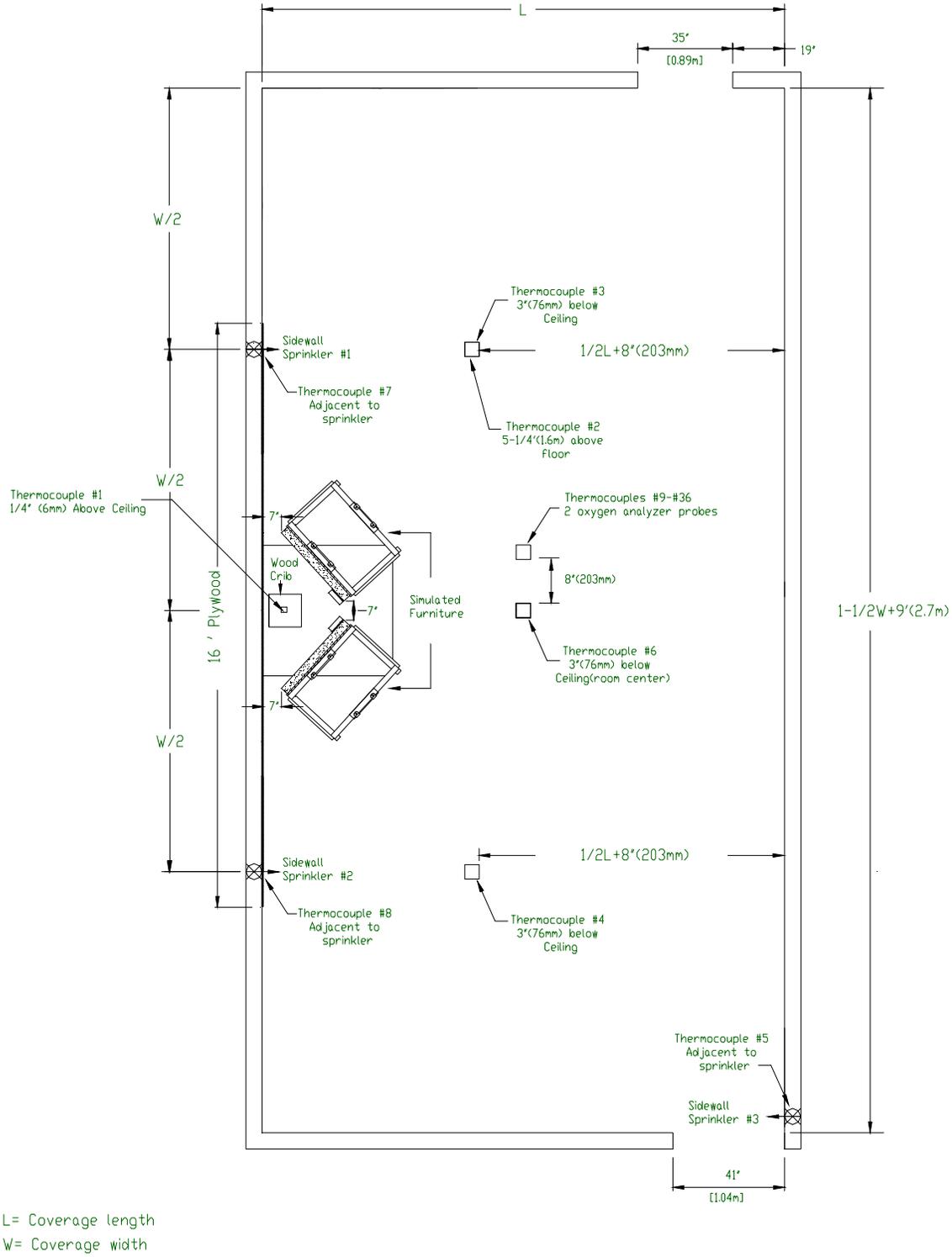


Figure 7. Plan view of room for Test No. 18. Horizontal sidewall sprinklers positioned on near wall with the fire source located between two sprinklers.



Figure 8. Test room for fire source located in the corner. (Test 3)



Figure 9. Fuel package arrangement for fire source located in the corner.



Figure 10. Close up view of fuel package arrangement for fire source located in the corner.



Figure 11. Cotton wicks position for fire source located in the corner.



Figure 12. Test room for fire source located between two sprinklers. (Test 19)



Figure 13. Fuel package arrangement for fire source located between two sprinklers.



Figure 14. Close up view of fuel package arrangement for fire source located between two sprinklers.

## 5 RESULTS

The results of each test are summarized in Table 5 for British units, and Table 6 for metric units. Graphs of temperatures recorded by thermocouple nos. 1, 2, 3, 4, 5, 6, 9, 19, 31, 34, and 36; and the results from the oxygen analyzers are presented in Appendix A. Data from the other thermocouples are not presented in this report, but were provided to the test sponsor.

The duration of all the tests was at least 10 minutes except for Test 17 which was terminated at 2 minutes and 29 seconds due to lack of fire control and imminent flashover conditions.

Post test photos illustrating different levels of fuel package combustion involvement are shown in Figure 15.

All sprinklers, which did not operate during the fire tests, functioned properly during the post test Operating Temperature (Bath) Tests. The thermal element activation was within  $\pm 3.5\%$  of its marked temperature rating.

Due to lodgement of water seal components at time of sprinkler activation, two tests were re-conducted. No lodgement occurred in the results presented in Table 5 and Table 6. The tests where lodgement occurred, Test 14L and Test 19L, are presented in Appendix B.

**Table 5. Summary of Results**

PARAMETERS							RESULTS									
Test No.	Test Code	Spklr Code	Spklr Type	Orient. to Short Wall	Fire Source Location	Coverage Area, W 3 L (ft.3ft.)	Operation Time (sec)			Max Temperature (°F)						Duration TC #2 over 130°F (sec)
							Sprinkler No.			Thermocouple Locations						
							1	2	3	1	2	3	4	5	6	
1	10130304	A	R. Pend.	Parallel	Corner	12 by 12	1:38	DNO	DNO	118	137	215	169	189	162	9
2	10210301	A	R. Pend.	Parallel	Corner	16 by 16	1:48	DNO	DNO	123	106	198	160	160	179	0
3	10210302	A	R. Pend.	Perpend.	Corner	16 by 16	2:09	DNO	DNO	119	116	189	170	159	186	0
4	10130302	A	Pendent	Parallel	Corner	12 by 12	1:18	DNO	DNO	122	107	161	154	176	163	0
5	10230302	A	Pendent	Parallel	Corner	16 by 16	1:49	DNO	DNO	133	104	177	175	158	203	0
6	10230301	A	Pendent	Perpend.	Corner	16 by 16	1:34	DNO	DNO	140	94	175	173	168	188	0
7	10140302	B	F. Pend	1 pin to w.	Corner	12 by 12	1:31	DNO	DNO	113	114	179	163	157	181	0
8	10220302	B	F. Pend	1 pin to w.	Corner	16 by 16	1:58	DNO	DNO	176	110	207	166	161	178	0
9	10220303	B	F. Pend	2 pin to w.	Corner	16 by 16	1:39	DNO	DNO	142	98	177	156	159	177	0
10	10140301	C	R. Pend	Perpend.	Corner	12 by 12	1:29	DNO	DNO	120	133	209	177	178	201	9
11	10210304	C	R. Pend	Parallel	Corner	16 by 16	1:48	DNO	DNO	130	108	193	197	170	192	0
12	10210306	C	R. Pend	Perpend.	Corner	16 by 16	1:48	DNO	DNO	159	118	195	185	169	193	0
13	10160301	D	HSW	F. Wall	Corner	12 by 12	1:28	DNO	DNO	121	127	209	182	169	192	0
14	10170302	D	HSW	F. Wall	Corner	16 by 16	1:45	DNO	DNO	125	108	157	179	168	182	0
15	10200303	D	HSW	N. Wall	Corner	16 by 16	1:21	DNO	DNO	123	94	134	123	127	129	0
16	10150301	A	R. Pend	Parallel	Between 2	12 by 12	1:14	1:08	DNO	118	135	198	187	196	310	16
17	10200301	D	HSW	F. Wall	Between 2	16 by 16	2:02	1:58	1:55	141	161	453	314	348	528	48
18	10200302	D	HSW	N. Wall	Between 2	16 by 16	1:19	1:24	DNO	136	113	176	221	174	262	0
19	10220306	A	R. Pend	Parallel	Between 2	16 by 16	1:15	1:20	1:48	136	114	206	194	268	351	0
20	10220301	C	R. Pend	Parallel	Between 2	16 by 16	1:34	1:27	2:02	127	140	198	213	251	345	50
21	10220304	B	F. Pend	1 pin to w.	Between 2	16 by 16	1:31	1:26	1:59	124	116	181	175	242	319	0
22	10230303	A	Pendent	Parallel	Between 2	16 by 16	1:31	1:35	2:14	161	138	160	178	283	382	69

TC location: 1 = Embedded in the ceiling tile directly above the wood crib.

DNO = Did Not Operate

2 = Aligned with sprinkler #1, 8 inches from center line, 5 feet 3 inches above floor.

3 = Aligned with sprinkler #1, 8 inches from center line, 3 inches below ceiling

4 = Aligned with sprinkler #2, 8 inches from center line, 3 inches below ceiling.

5 = Adjacent to Sprinkler #3.

6 = In center of room, 3 inches below ceiling.

Table 6. Summary of Results (Metric Units)

PARAMETERS							RESULTS									
Test No.	Test Code	Spklr Code	Spklr Type	Orient. to Short Wall	Fire Source Location	Coverage Area, W 3 L (m3m)	Operation Time (sec)			Max Temperature (°C)						Duration TC #2 over 54°C (sec)
							Sprinkler No.			Thermocouple Locations						
							1	2	3	1	2	3	4	5	6	
1	10130304	A	R. Pend.	Parallel	Corner	3.7 by 3.7	1:38	DNO	DNO	48	58	102	76	87	72	9
2	10210301	A	R. Pend.	Parallel	Corner	4.9 by 4.9	1:48	DNO	DNO	51	41	92	71	71	82	0
3	10210302	A	R. Pend	Perpend.	Corner	4.9 by 4.9	2:09	DNO	DNO	48	47	87	77	71	86	0
4	10130302	A	Pendent	Parallel	Corner	3.7 by 3.7	1:18	DNO	DNO	50	42	72	68	80	73	0
5	10230302	A	Pendent	Parallel	Corner	4.9 by 4.9	1:49	DNO	DNO	56	40	81	79	70	95	0
6	10230301	A	Pendent	Perpend.	Corner	4.9 by 4.9	1:34	DNO	DNO	60	34	79	78	76	87	0
7	10140302	B	F. Pend	1 pin to w.	Corner	3.7 by 3.7	1:31	DNO	DNO	45	46	82	73	69	83	0
8	10220302	B	F. Pend	1 pin to w.	Corner	4.9 by 4.9	1:58	DNO	DNO	80	43	97	74	72	81	0
9	10220303	B	F. Pend	2 pin to w.	Corner	4.9 by 4.9	1:39	DNO	DNO	61	37	81	69	71	81	0
10	10140301	C	R. Pend	Perpend.	Corner	3.7 by 3.7	1:29	DNO	DNO	49	56	98	81	81	94	9
11	10210304	C	R. Pend	Parallel	Corner	4.9 by 4.9	1:48	DNO	DNO	54	42	89	92	77	89	0
12	10210306	C	R. Pend	Perpend.	Corner	4.9 by 4.9	1:48	DNO	DNO	71	48	91	85	76	89	0
13	10160301	D	HSW	F. Wall	Corner	3.7 by 3.7	1:28	DNO	DNO	49	53	98	83	76	89	0
14	10170302	D	HSW	F. Wall	Corner	4.9 by 4.9	1:45	DNO	DNO	52	42	69	82	76	83	0
15	10200303	D	HSW	N. Wall	Corner	4.9 by 4.9	1:21	DNO	DNO	51	34	57	51	53	54	0
16	10150301	A	R. Pend	Parallel	Between 2	3.7 by 3.7	1:14	1:08	DNO	48	57	92	86	91	154	16
17	10200301	D	HSW	F. Wall	Between 2	4.9 by 4.9	2:02	1:58	1:55	61	72	234	157	176	276	48
18	10200302	D	HSW	N. Wall	Between 2	4.9 by 4.9	1:19	1:24	DNO	58	45	80	105	79	128	0
19	10220306	A	R. Pend	Parallel	Between 2	4.9 by 4.9	1:15	1:20	1:48	58	46	97	90	131	177	0
20	10220301	C	R. Pend	Parallel	Between 2	4.9 by 4.9	1:34	1:27	2:02	53	60	92	101	122	174	50
21	10220304	B	F. Pend	1 pin to w.	Between 2	4.9 by 4.9	1:31	1:26	1:59	51	47	83	79	117	159	0
22	10230303	A	Pendent	Parallel	Between 2	4.9 by 4.9	1:31	1:35	2:14	72	59	71	81	139	194	69

TC location: 1 = Embedded in the ceiling tile directly above the wood crib.

DNO = Did Not Operate

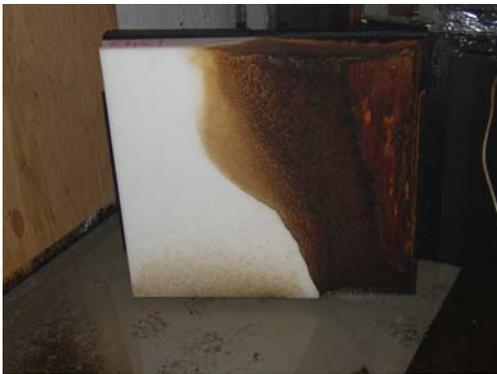
- 2 = Aligned with sprinkler #1, 0.20 m from center line, 1.60 m above floor.
- 3 = Aligned with sprinkler #1, 0.20 m from center line, 76 mm below ceiling
- 4 = Aligned with sprinkler #2, 0.20 m from center line, 76 mm below ceiling.
- 5 = Adjacent to Sprinkler #3.
- 6 = In center of room, 76 mm below ceiling.



Attachment of fire to plywood wall.  
(Test 6)



No visible attachment of fire to plywood wall. (Test 7)



Foam combustible partially consumed  
(Test 16)



Foam combustible partially consumed  
(Test 16)



Foam combustible consumed.  
(Test 3)



Foam combustible consumed.  
(Test 3)

Figure 15. Examples of involvement from plywood and foam combustibles.

## **SUMMARY**

In each of the 15 tests involving the corner fire scenario, only one sprinkler operated which limited the room temperatures as follows:

- a) The maximum temperature 3 inches (76 mm) below the ceiling 8 inches (0.20 m) from Sprinkler #1 did not exceed 600°F (316°C).
- b) The maximum temperature 5-1/4 feet (1.60 m) above the floor did not exceed 200°F (93°C), nor more than 130°F (54°C) for more than any continuous 2-minute period.
- c) The maximum ceiling material temperature 1/4 inch (6 mm) behind the finished ceiling surface did not exceed 500°F (260°C).

In each of the 7 tests conducted with the fire source located between two sprinklers, at least two sprinklers operated which resulted in a flow provided to each operated sprinkler of approximately 0.7 times the Listed flow. General observations for these 7 tests are as follows:

- In two of the fire tests (Tests 16 and 18), the third sprinkler in the room did not operate and the two operating sprinklers limited the room temperatures as described in the above Items a, b, c.
- In four of the fire tests (Tests 19-22), the third sprinkler (not connected to the water supply) near the doorway and most remote from the fire source operated, but the two sprinklers discharging water limited the room temperatures as described in above Items a, b, and c.
- In one of the fire tests (Test 17), the third sprinkler operated and the test was terminated at 2 minutes and 29 seconds due to the lack of fire control and imminent flashover conditions.

Prior to conducting the between two-sprinkler fire test scenario, visual observations of the sprinkler discharge characteristics were made while discharging water at 0.7 times the rated flow from one operating sprinkler to assist in selecting sprinklers for these tests. At 0.7 times the rated flow provided to the sprinkler, it was observed that the height of wall wetting was well below the 28 inches (71 cm) below the ceiling as referenced in UL1626 and in some cases, only the wall portion near the floor level was wetted.

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Reviewed By:

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***APPENDIX A***  
**Graphical Presentation of Data**

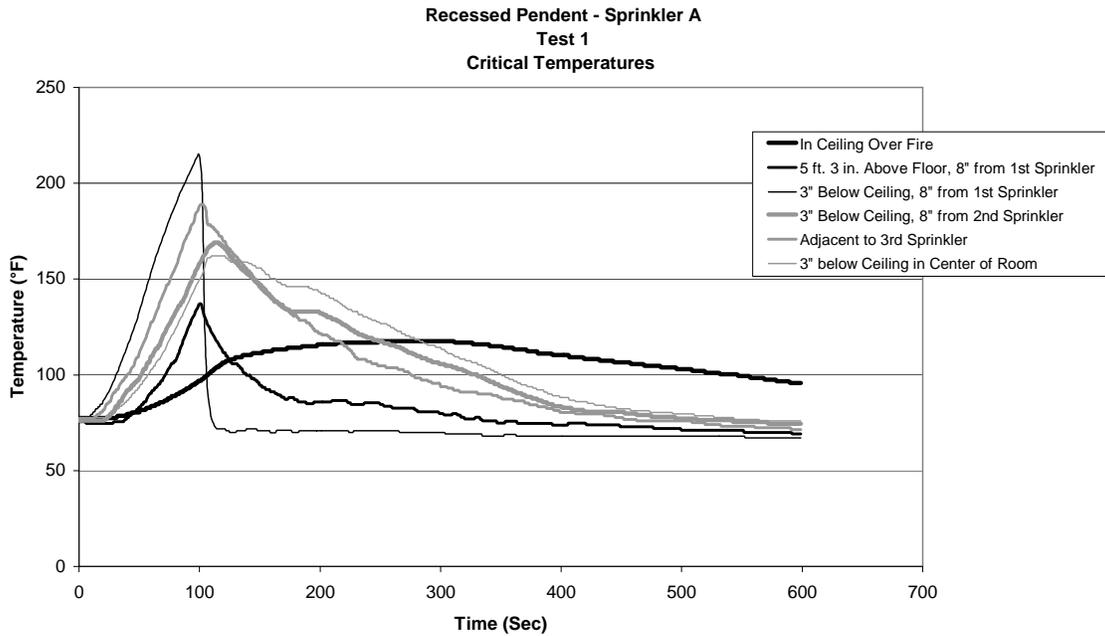


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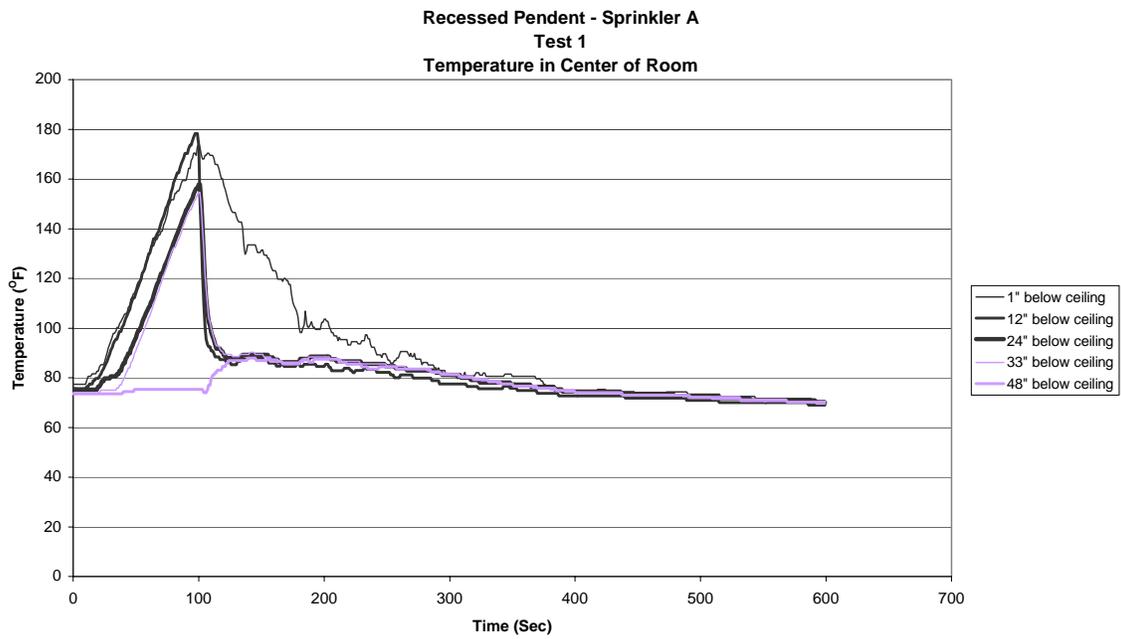


Figure A- 2

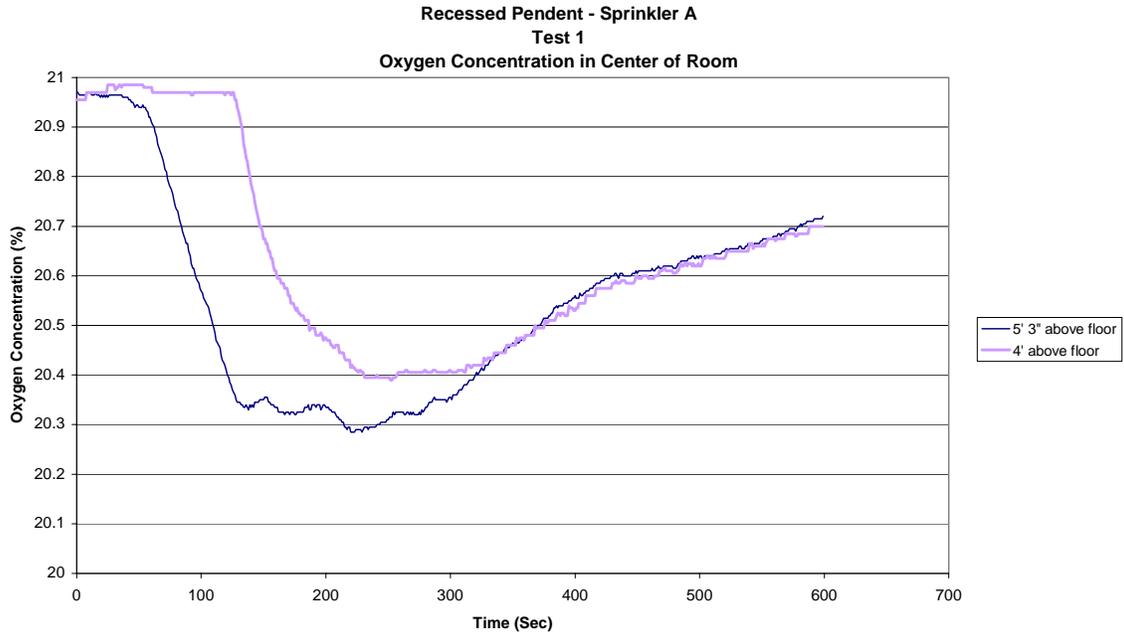


Figure A- 3

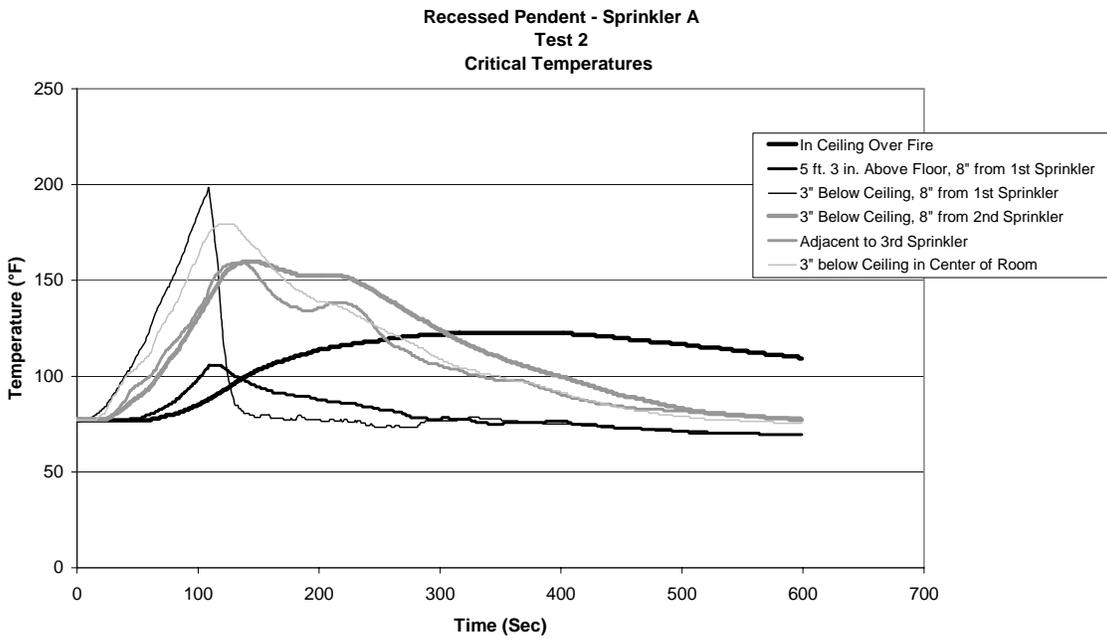


Figure A- 4

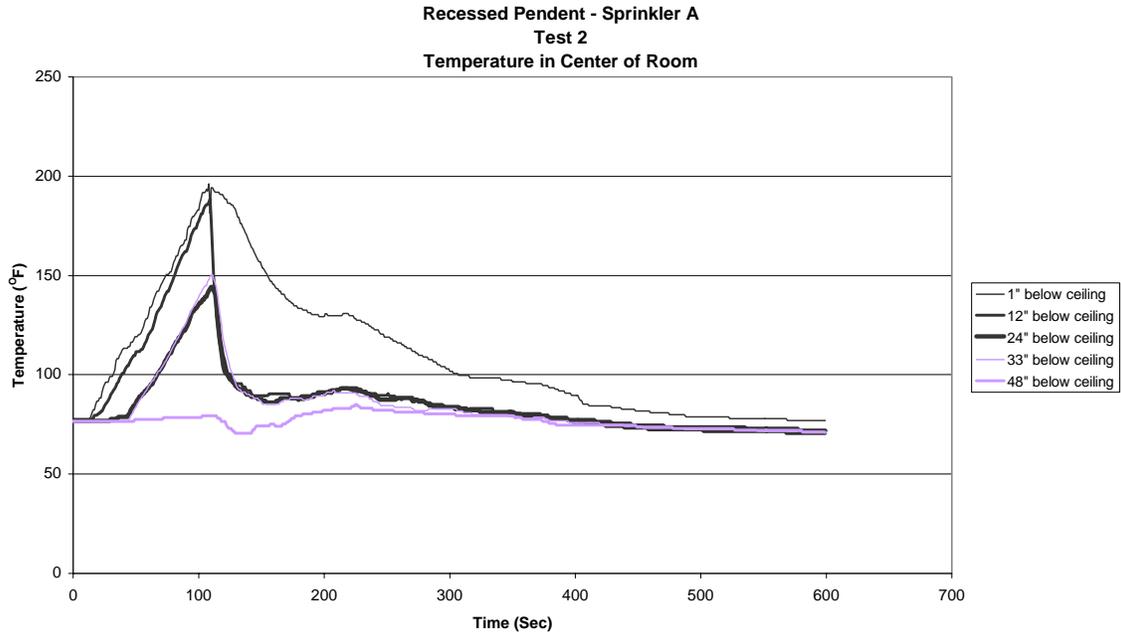


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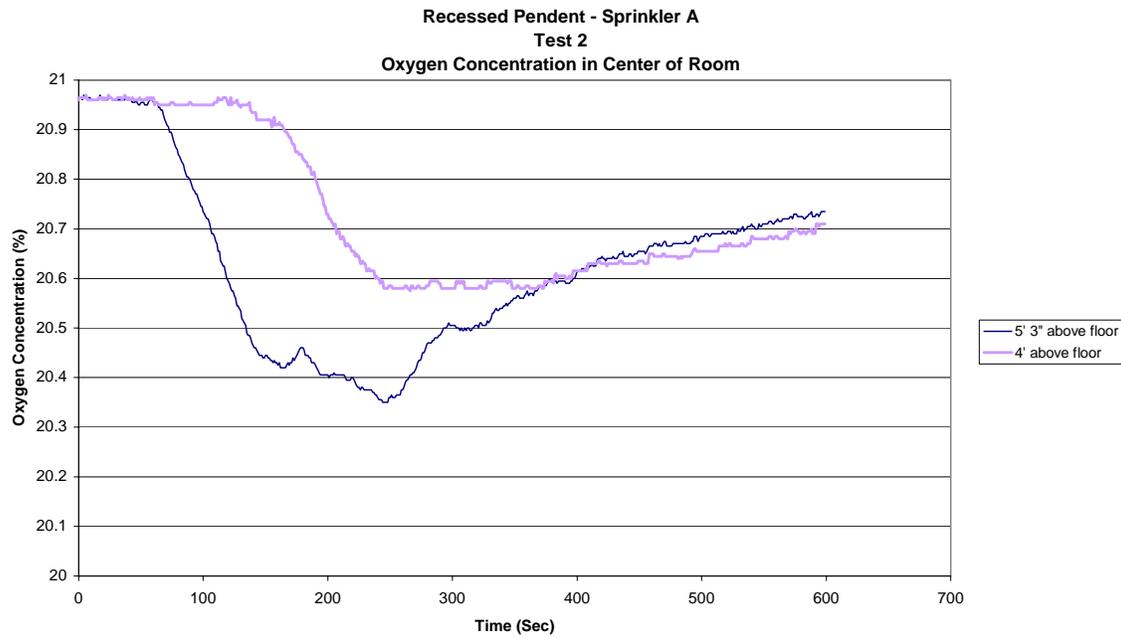
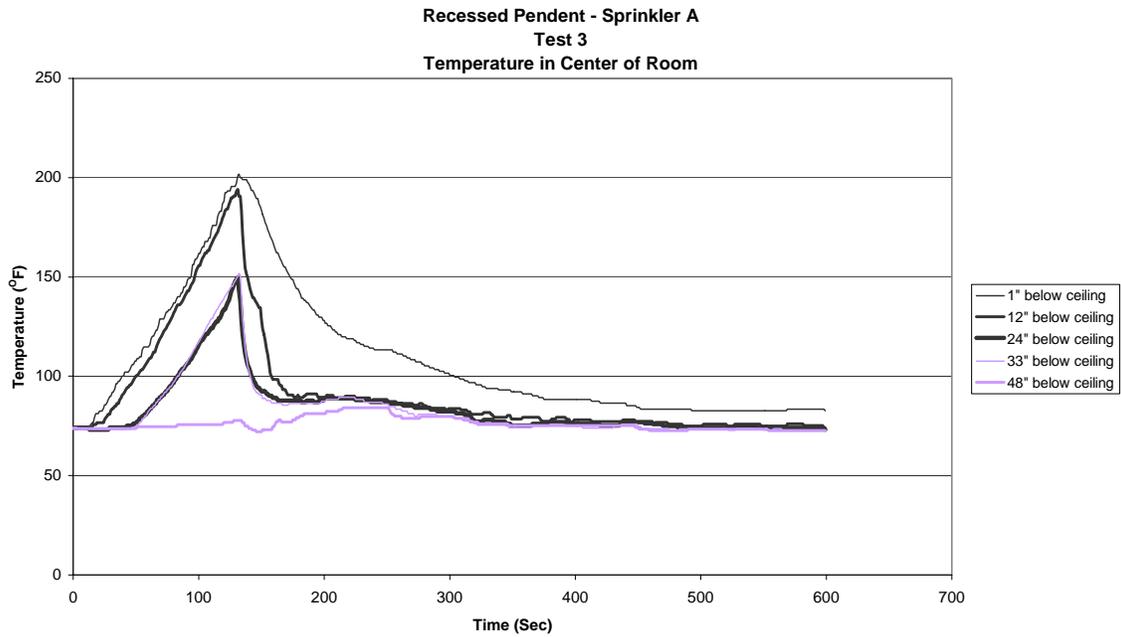
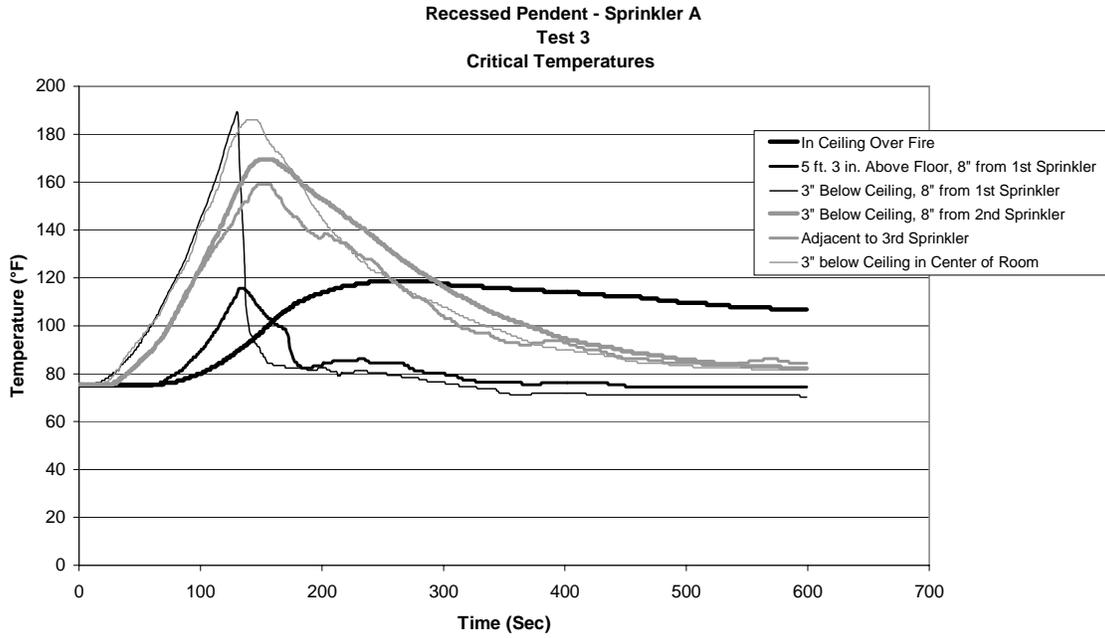


Figure A- 6



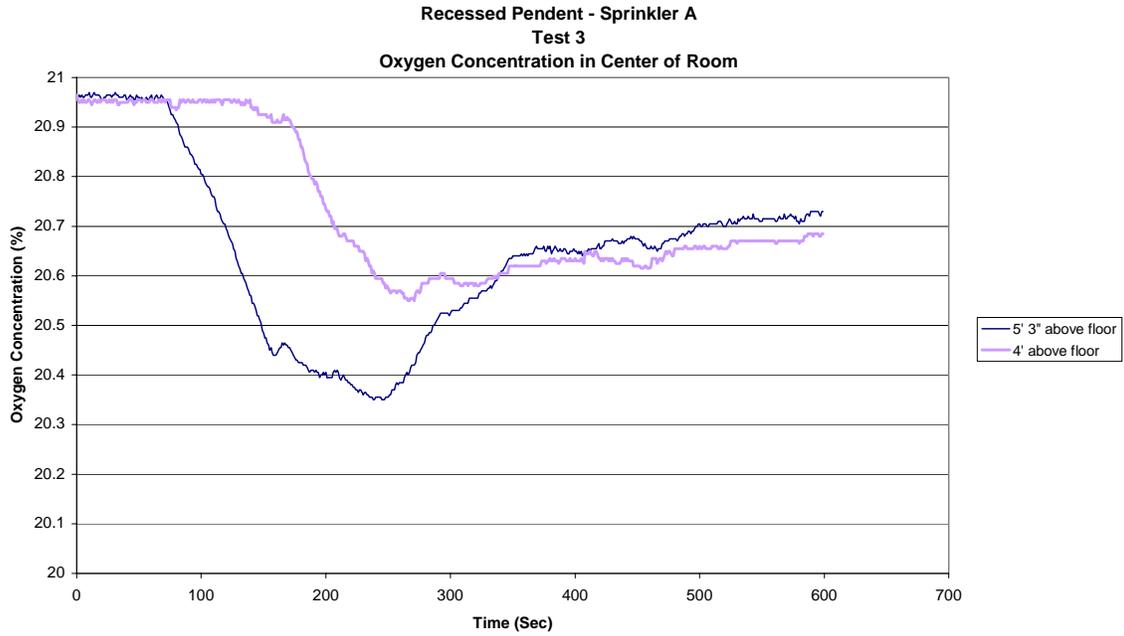


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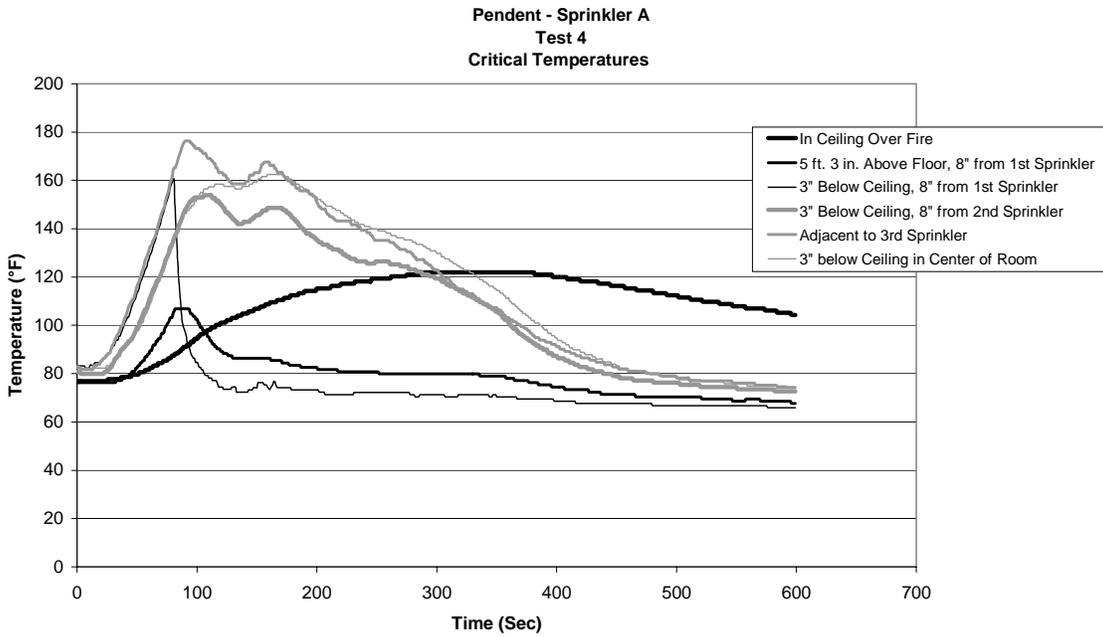


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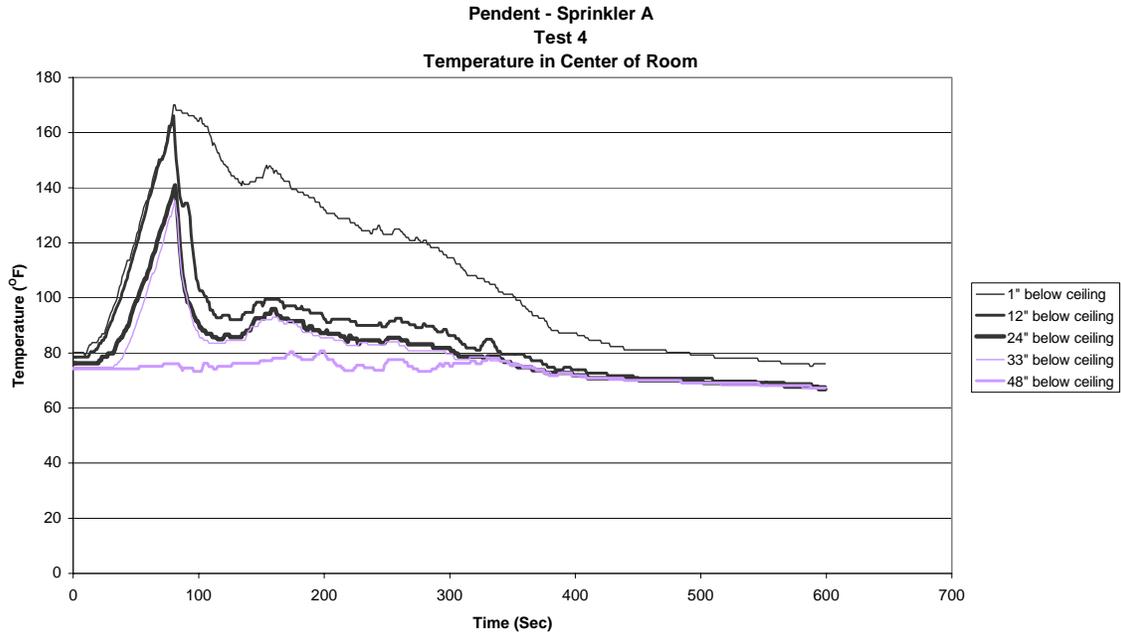


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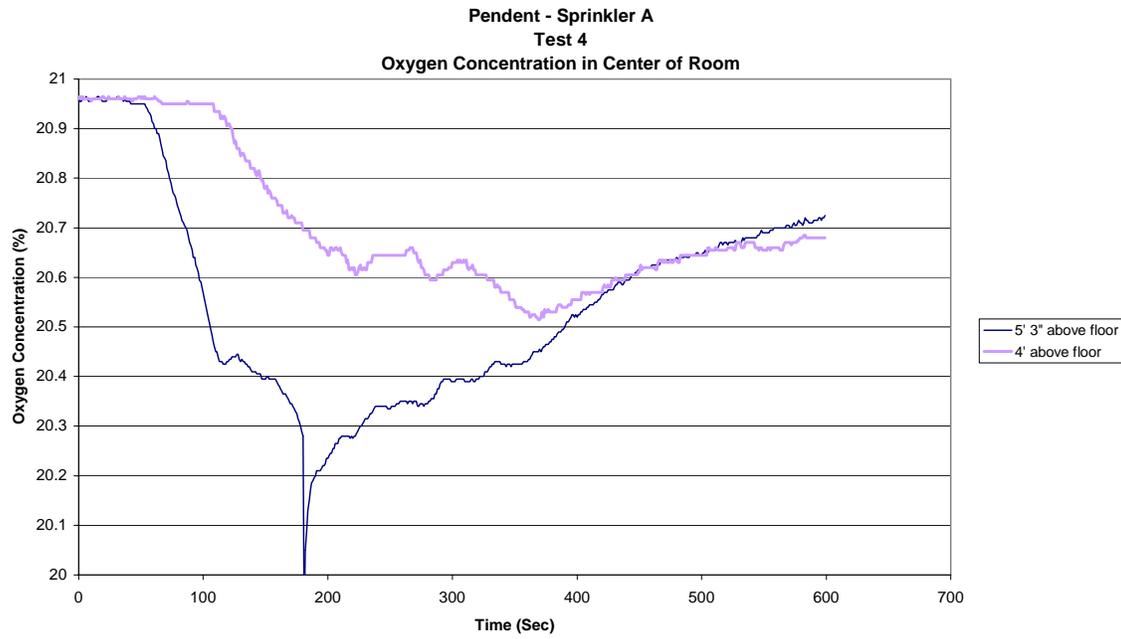


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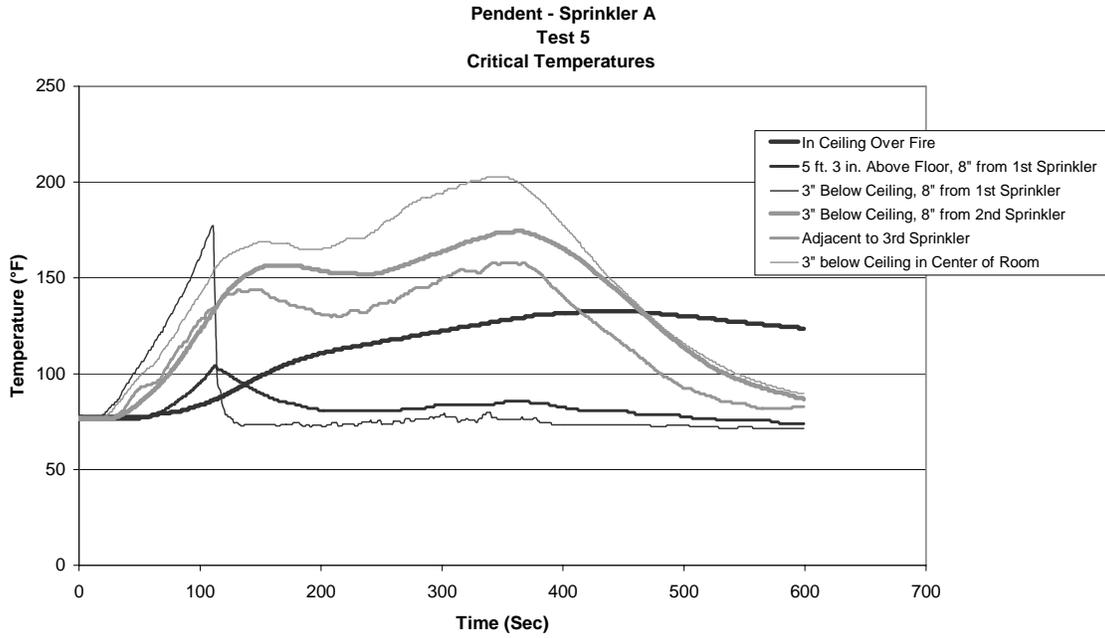


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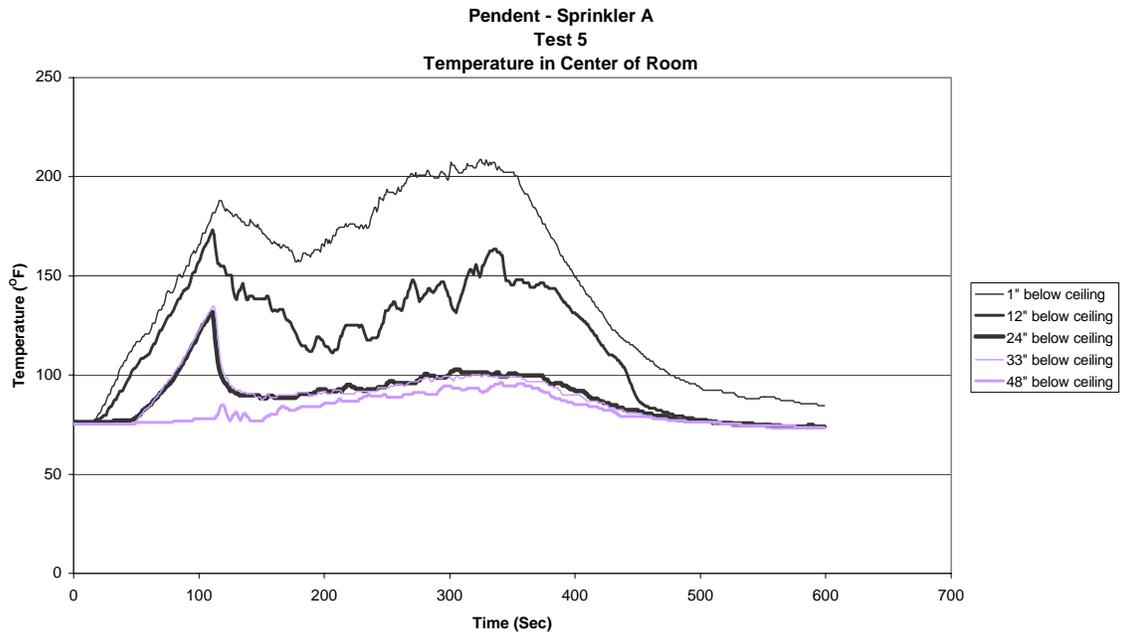


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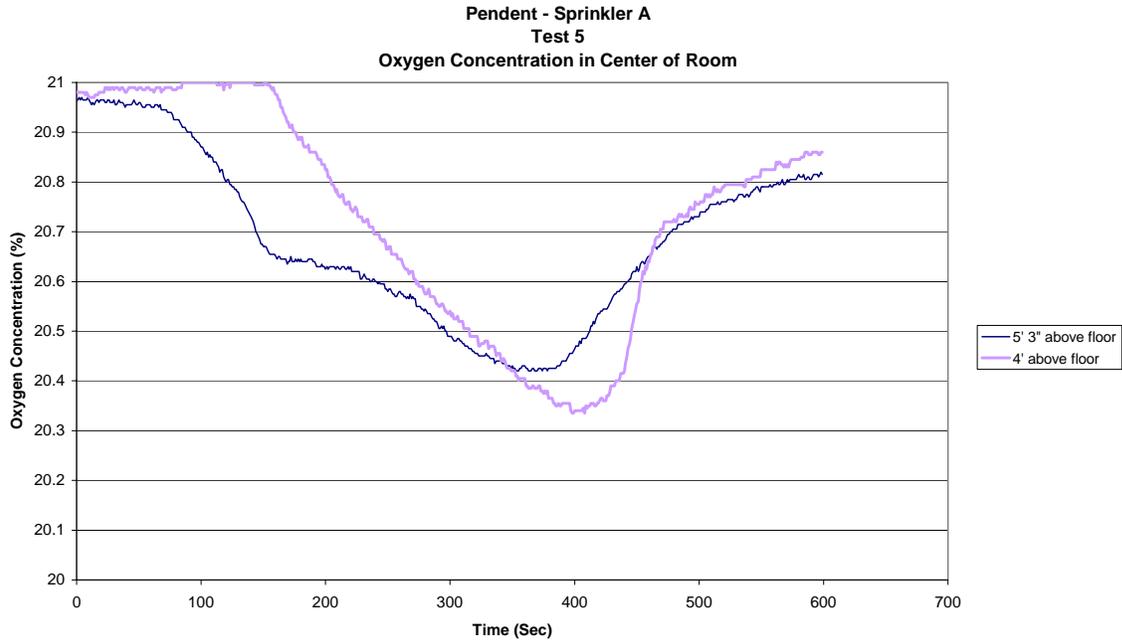


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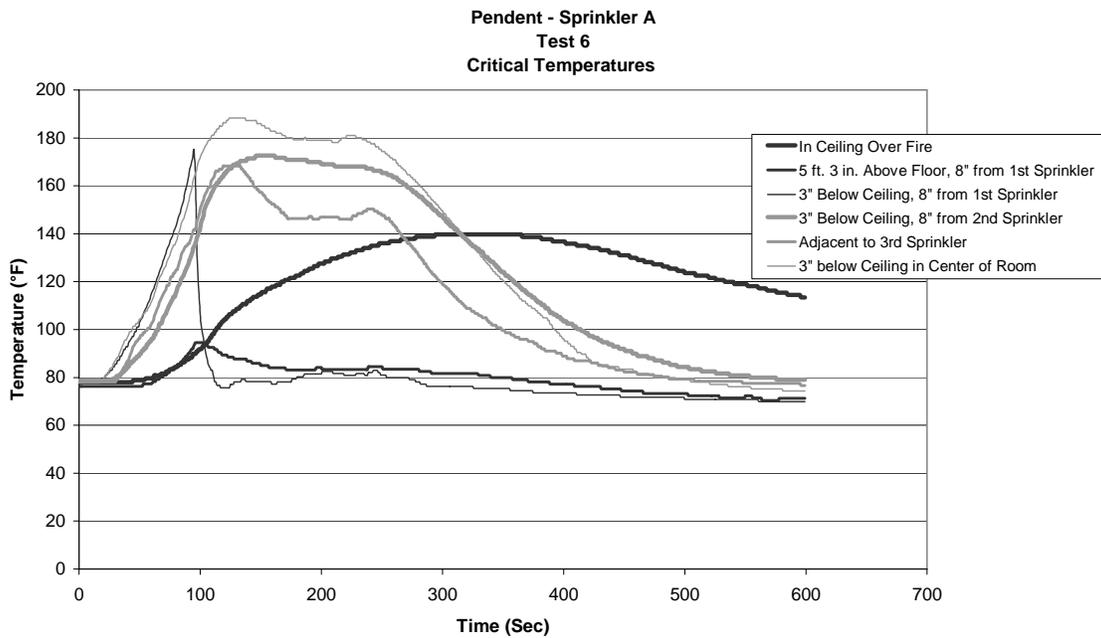


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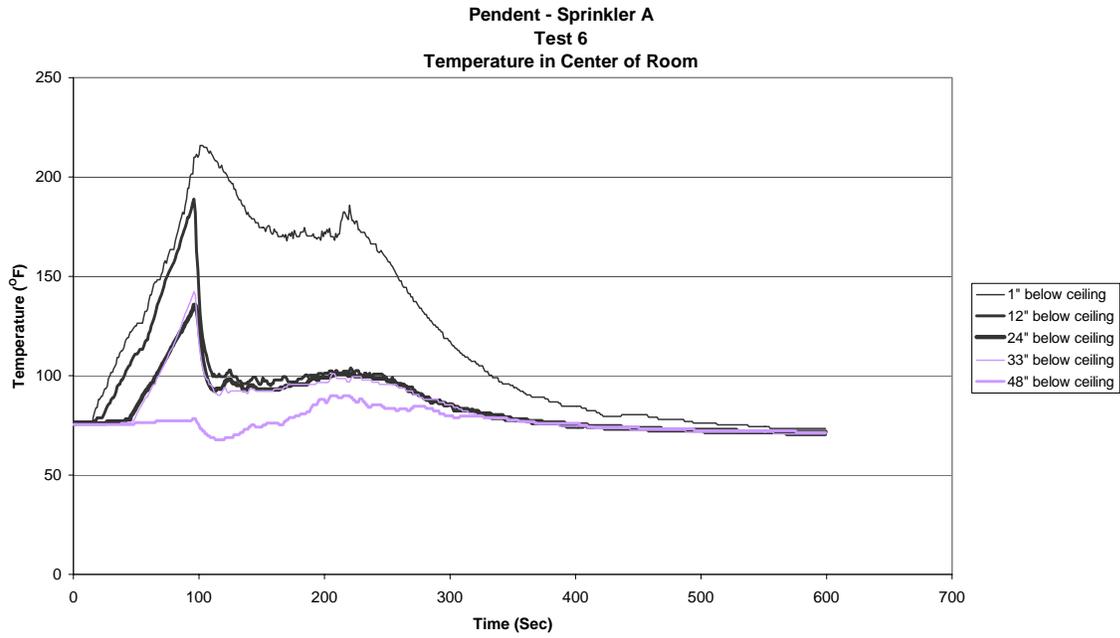


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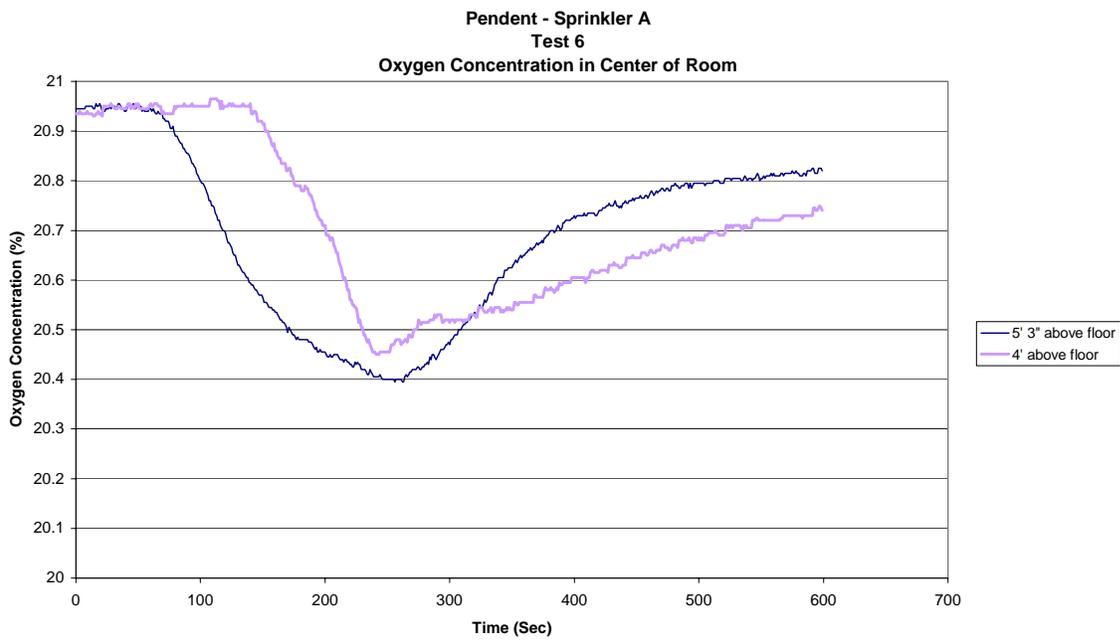


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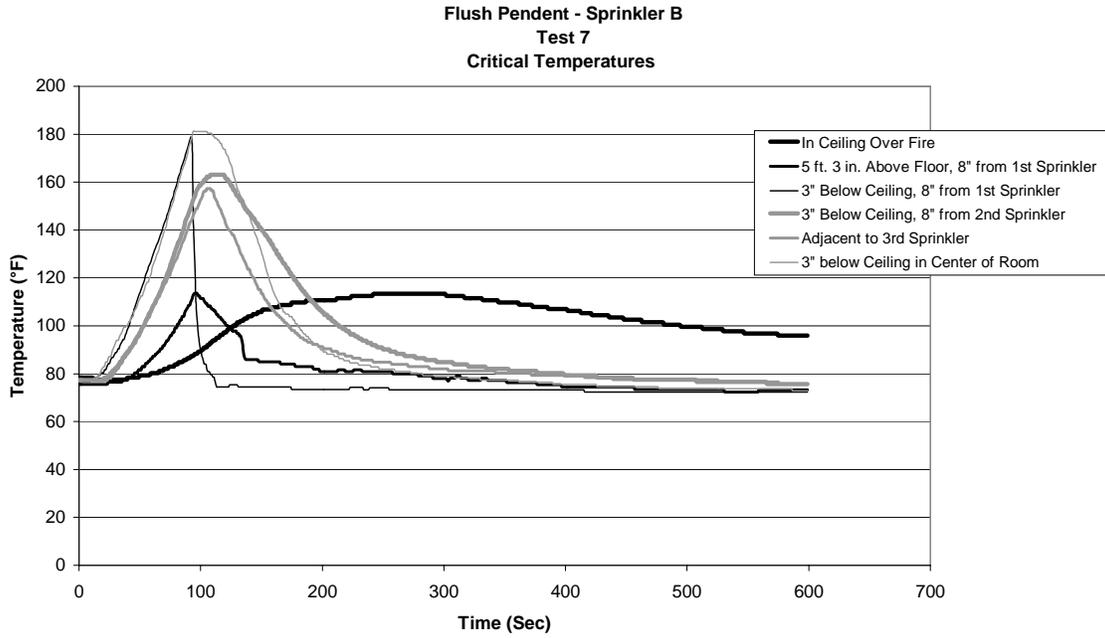


Figure A- 19

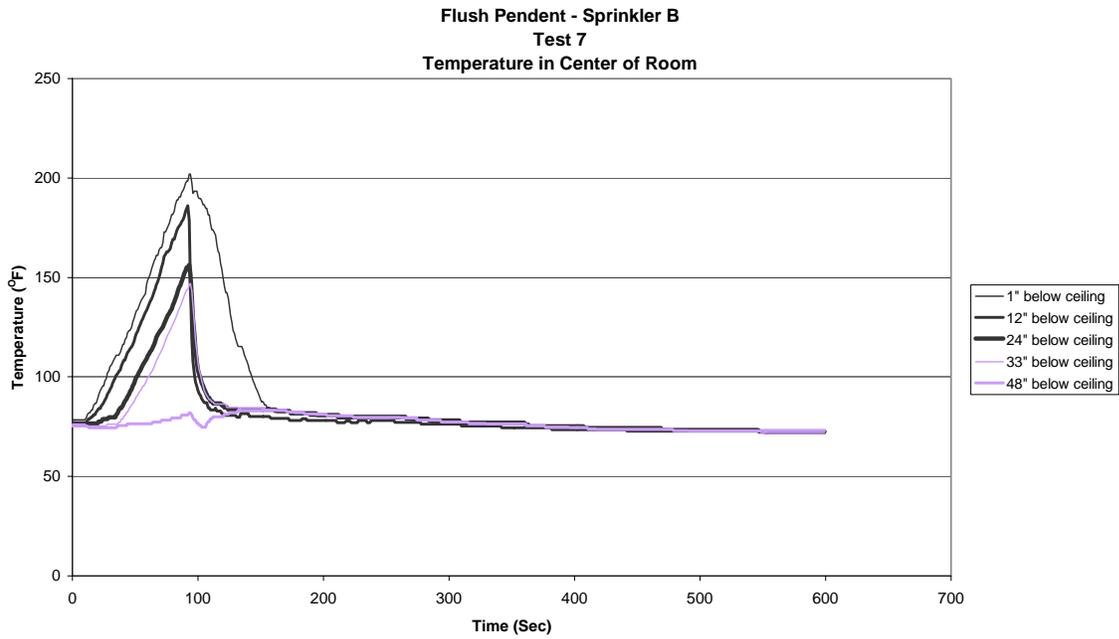


Figure A- 20

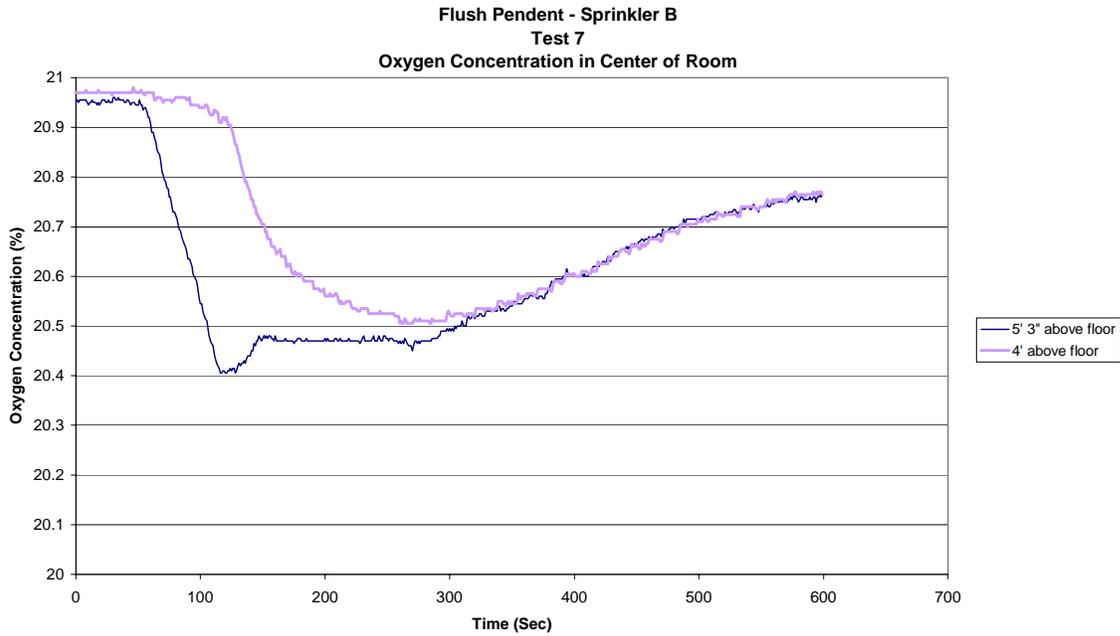


Figure A- 21

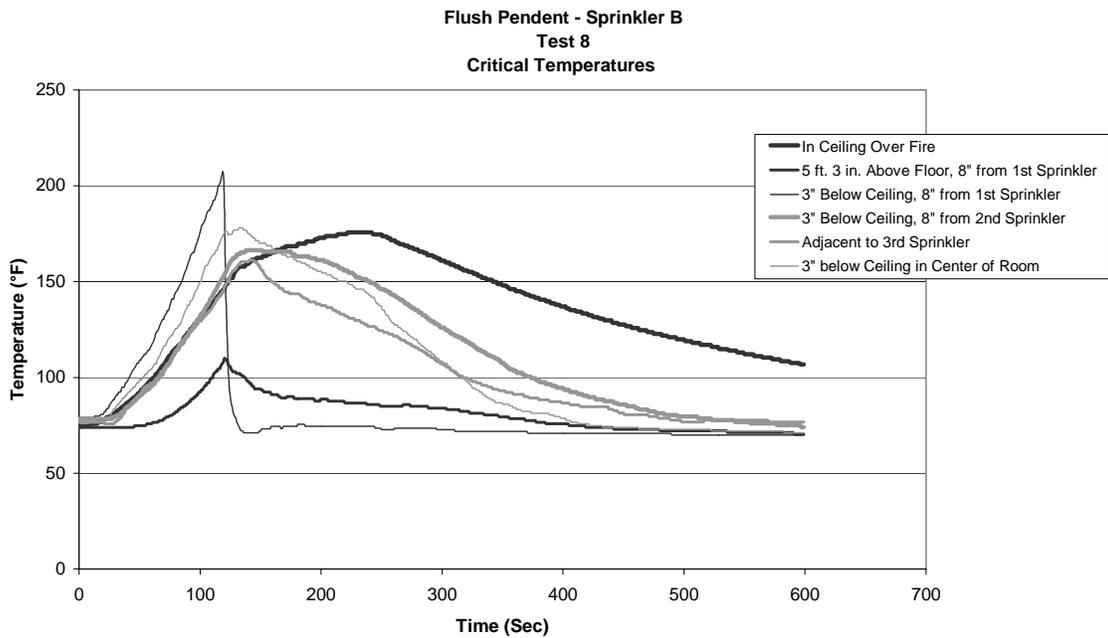


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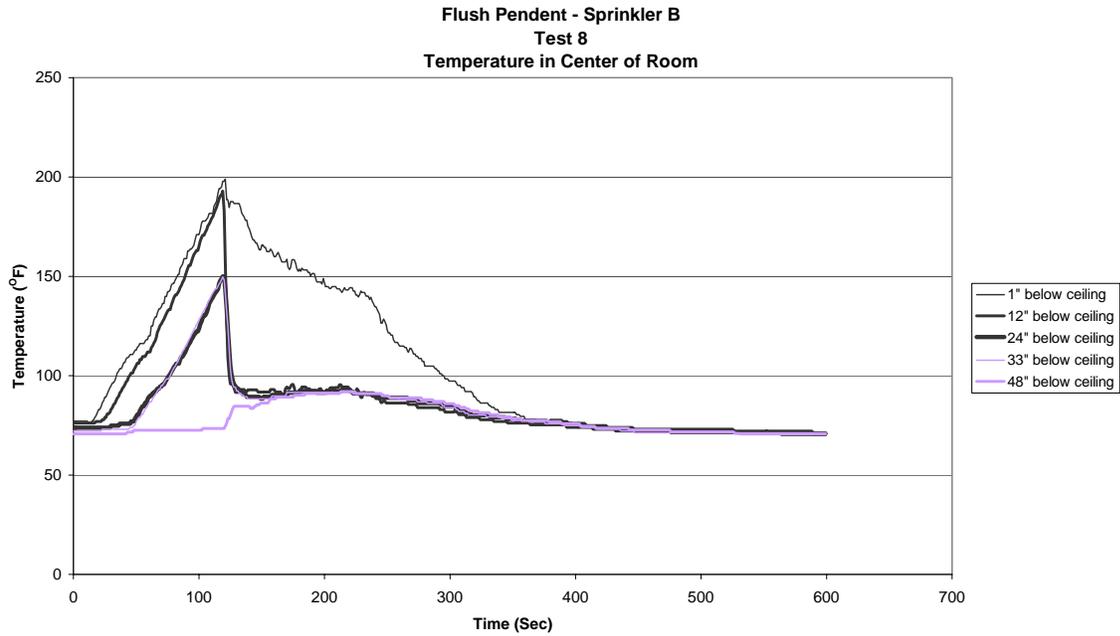


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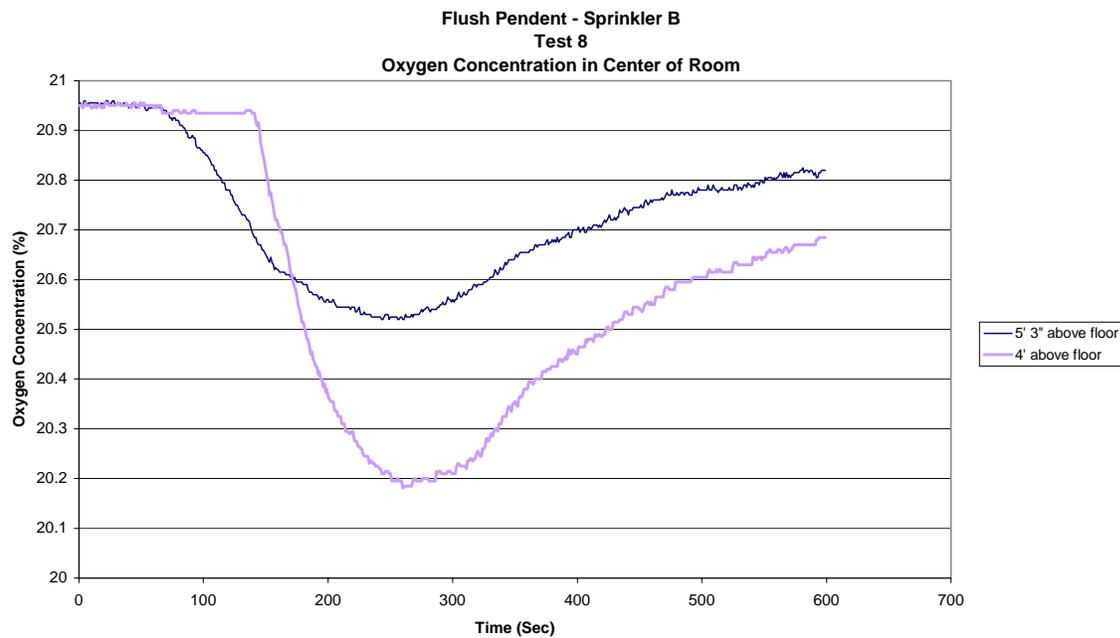


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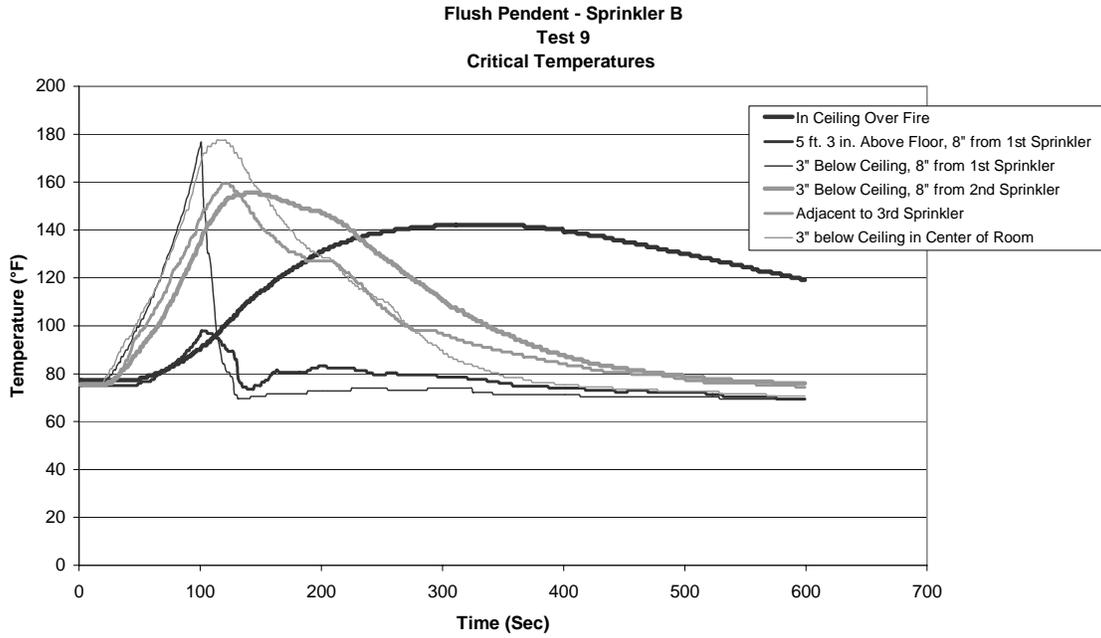


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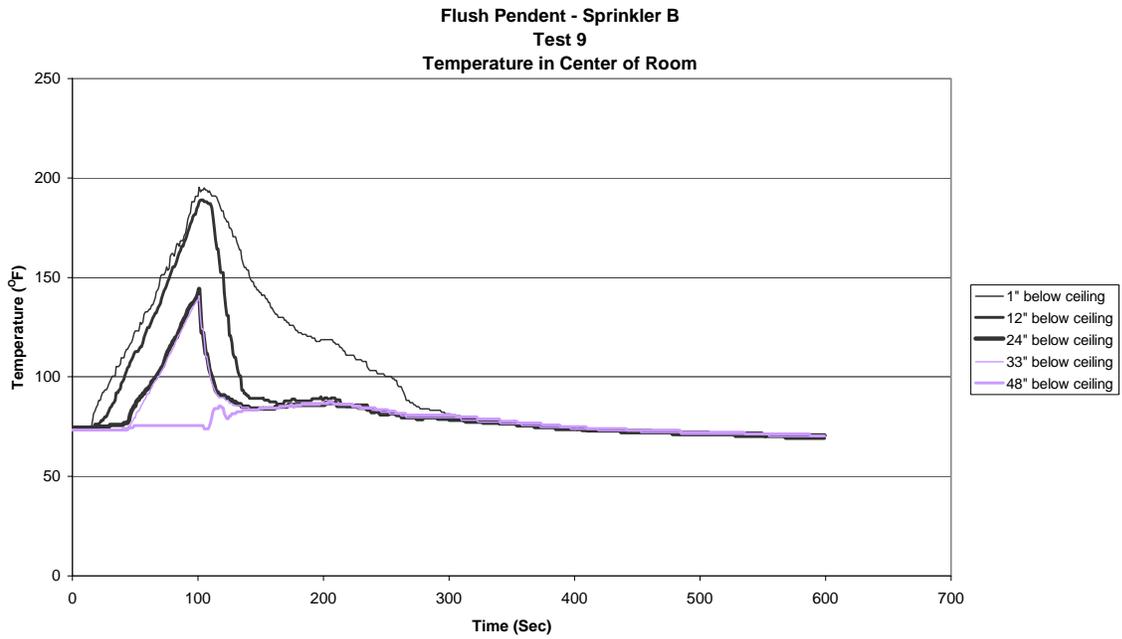


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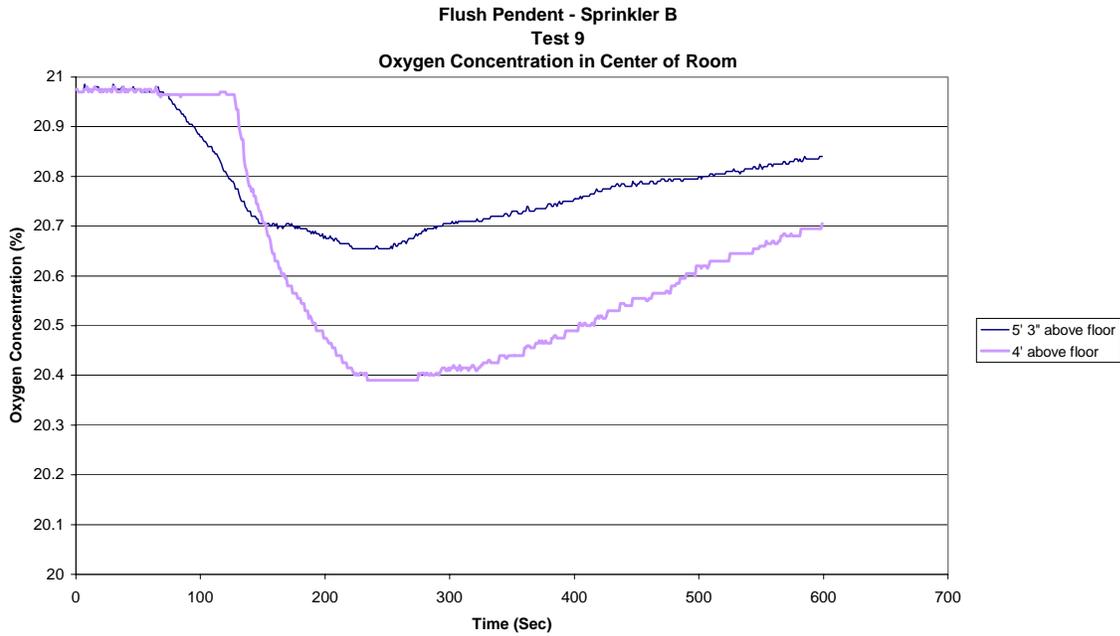


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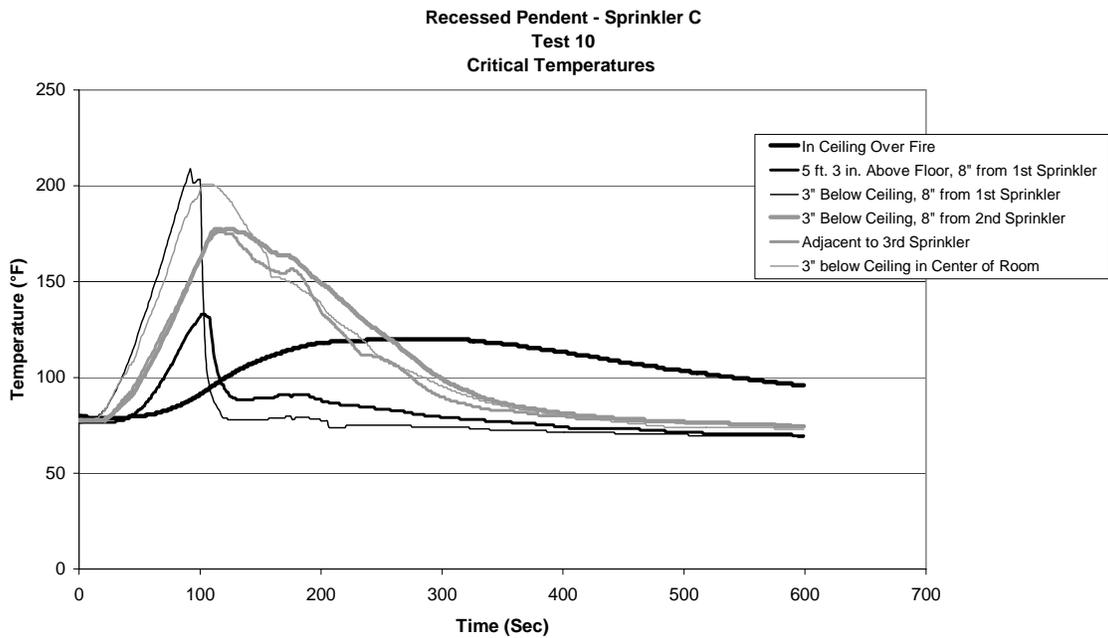


Figure A- 28

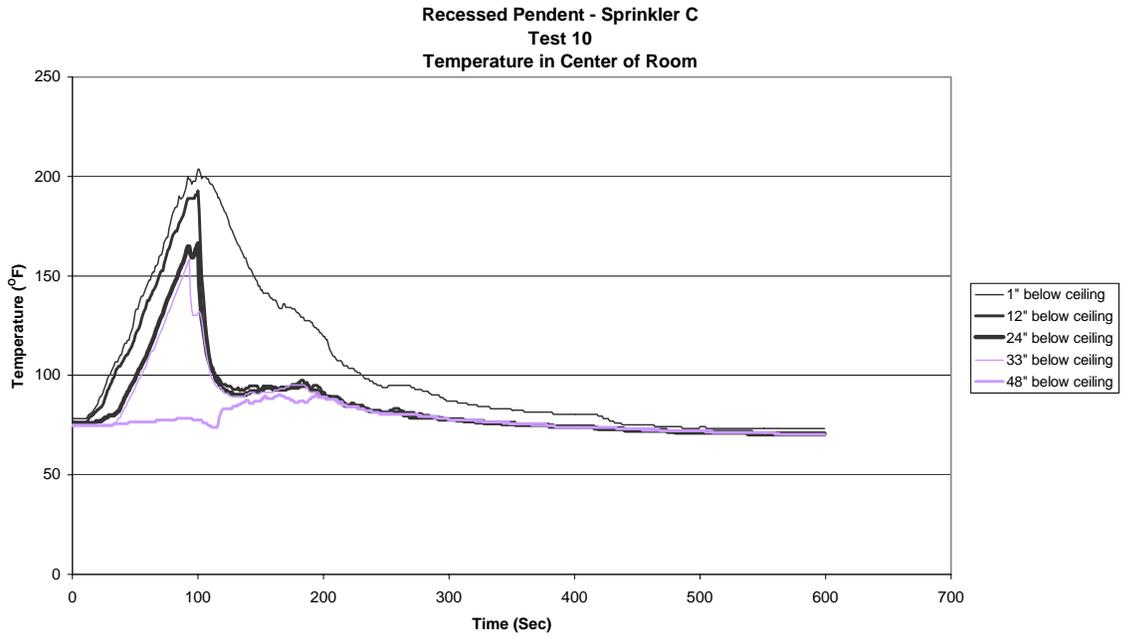


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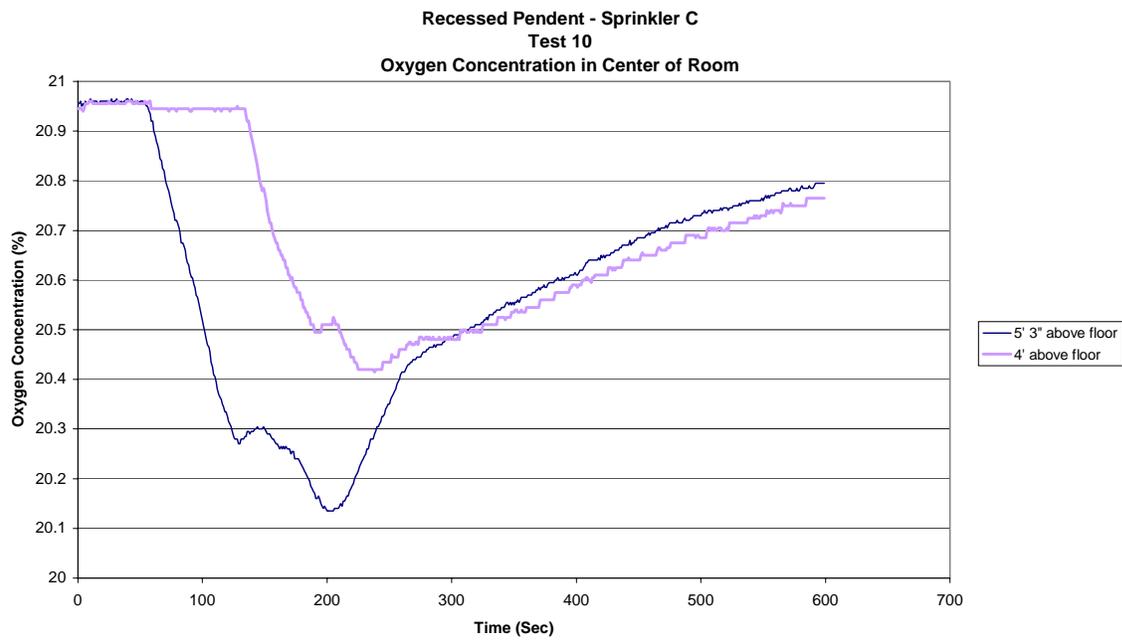


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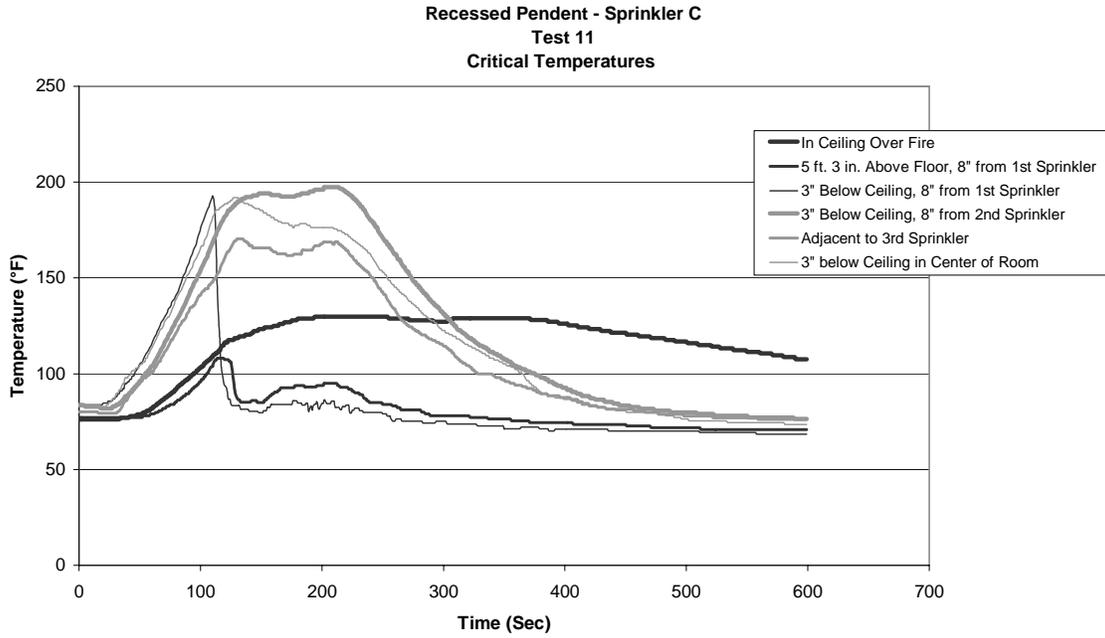


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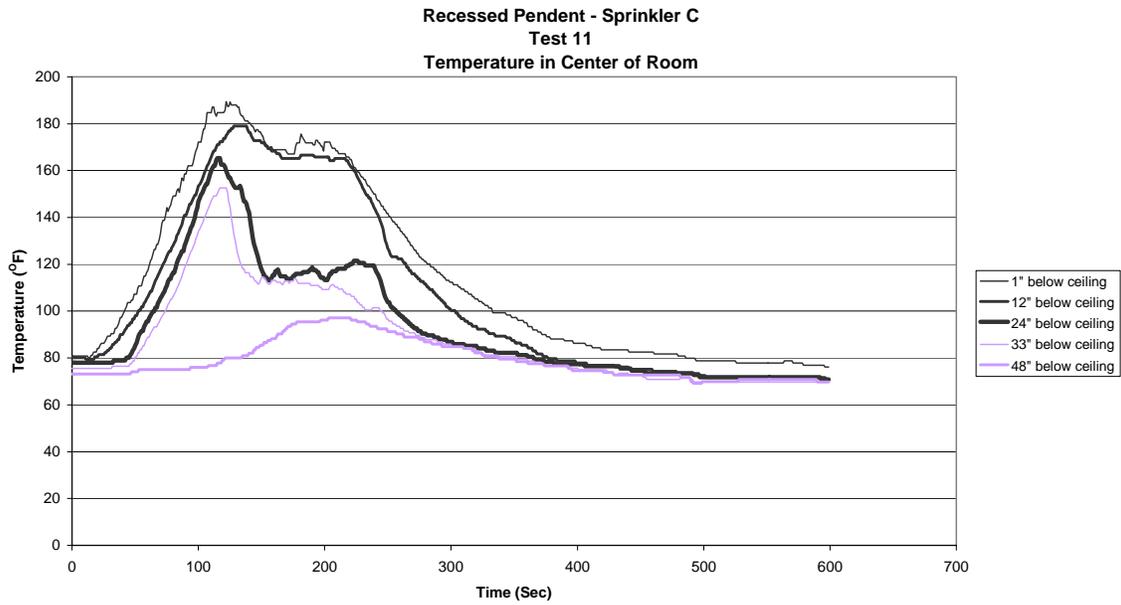


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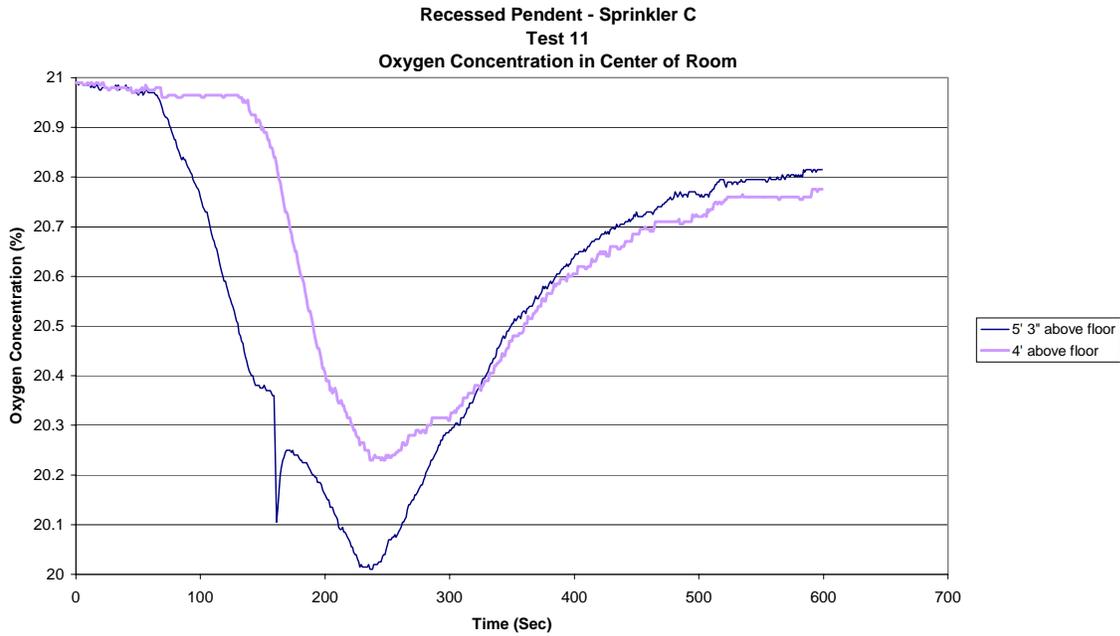


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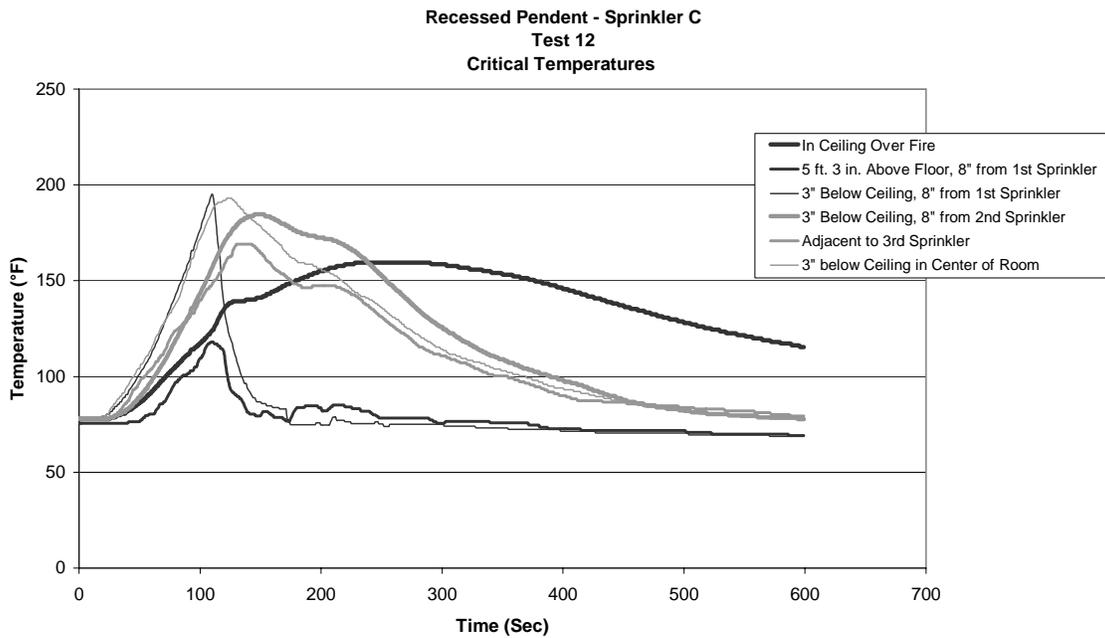


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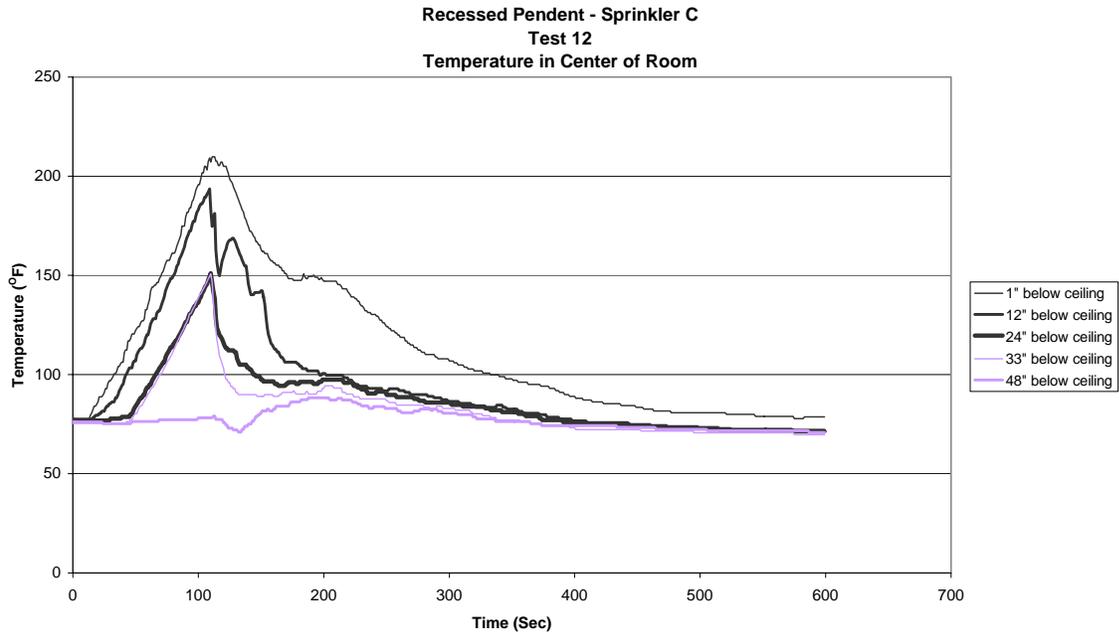


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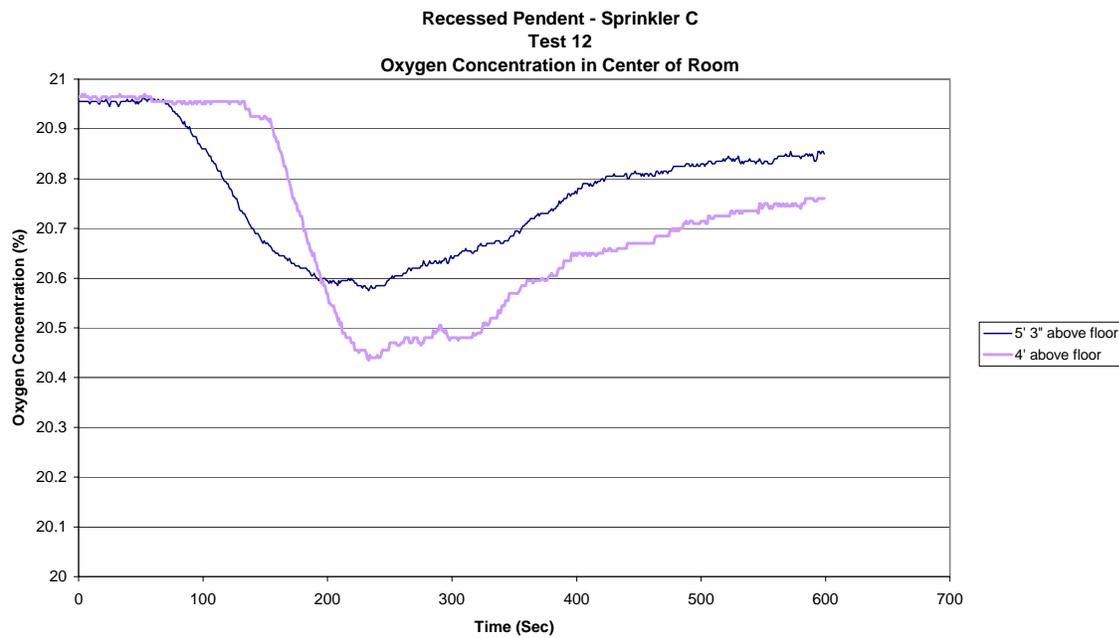


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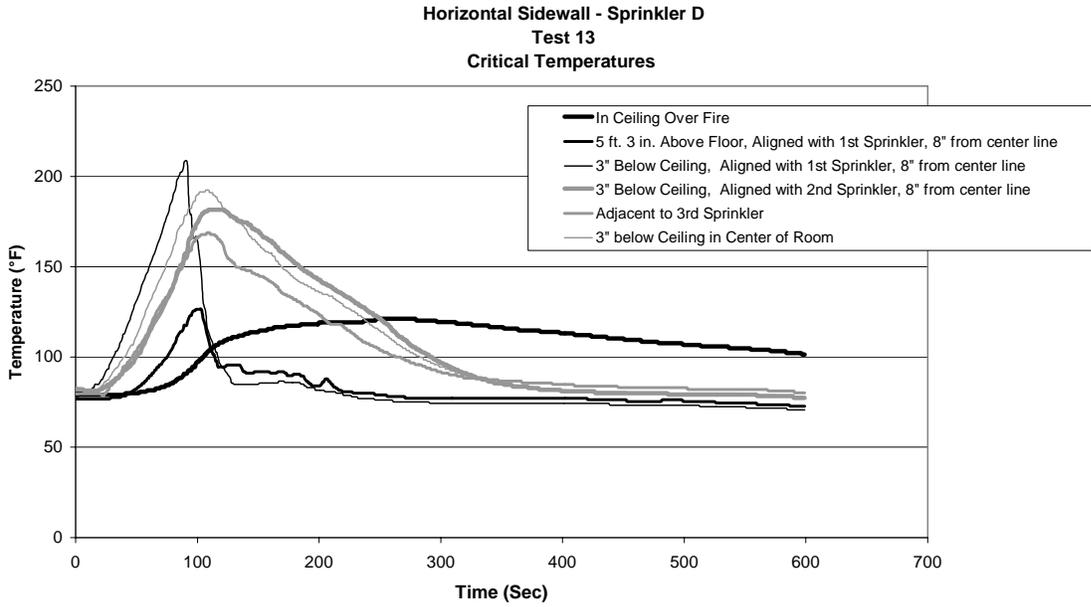


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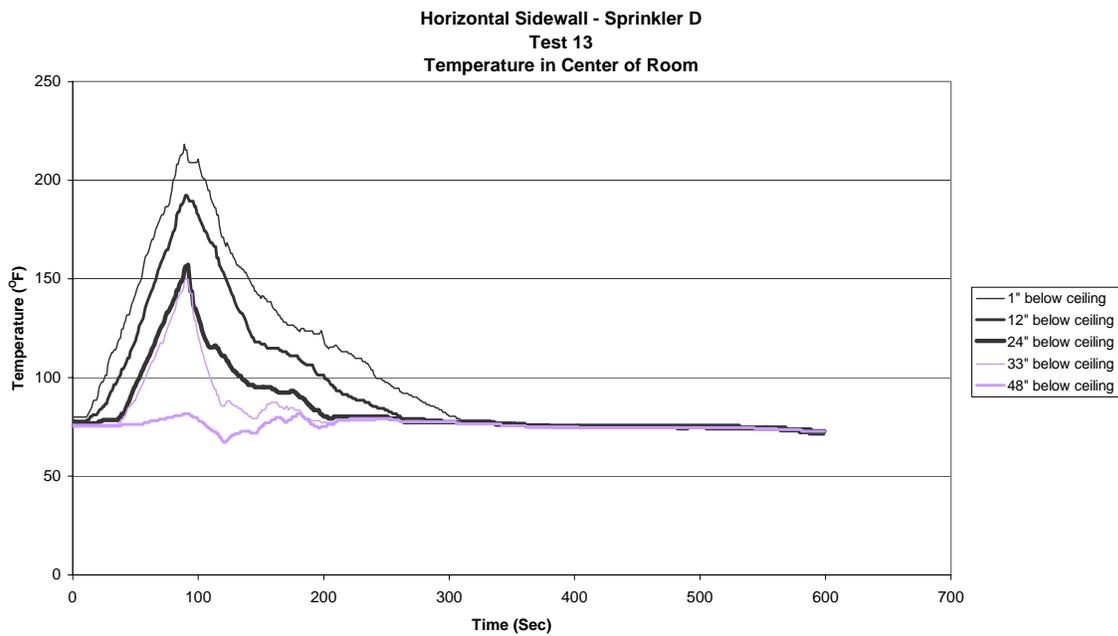


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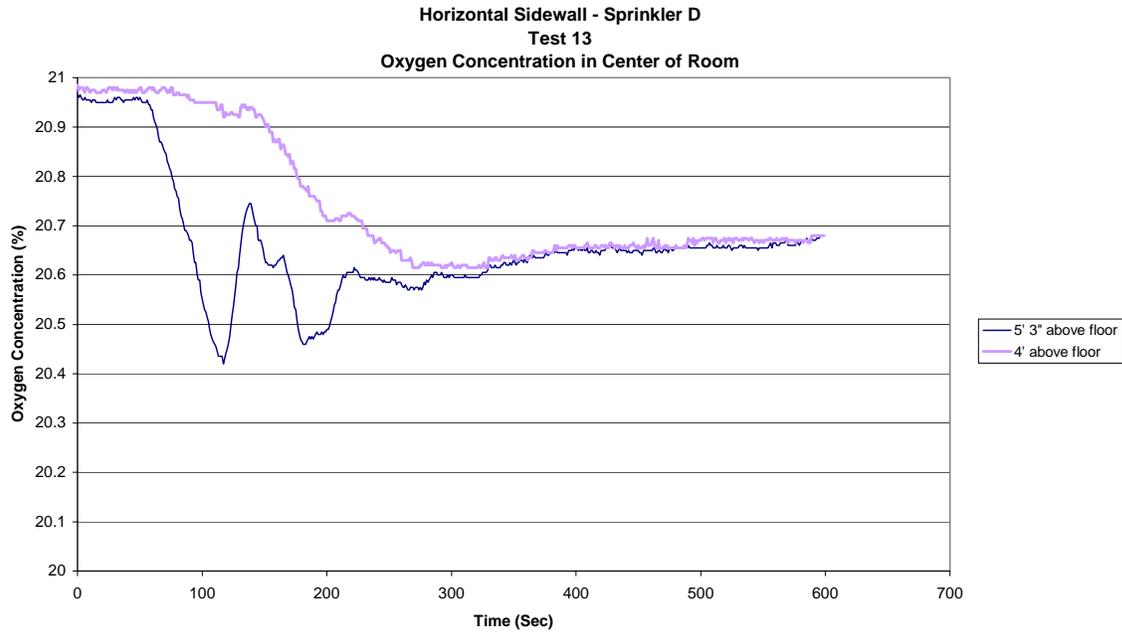


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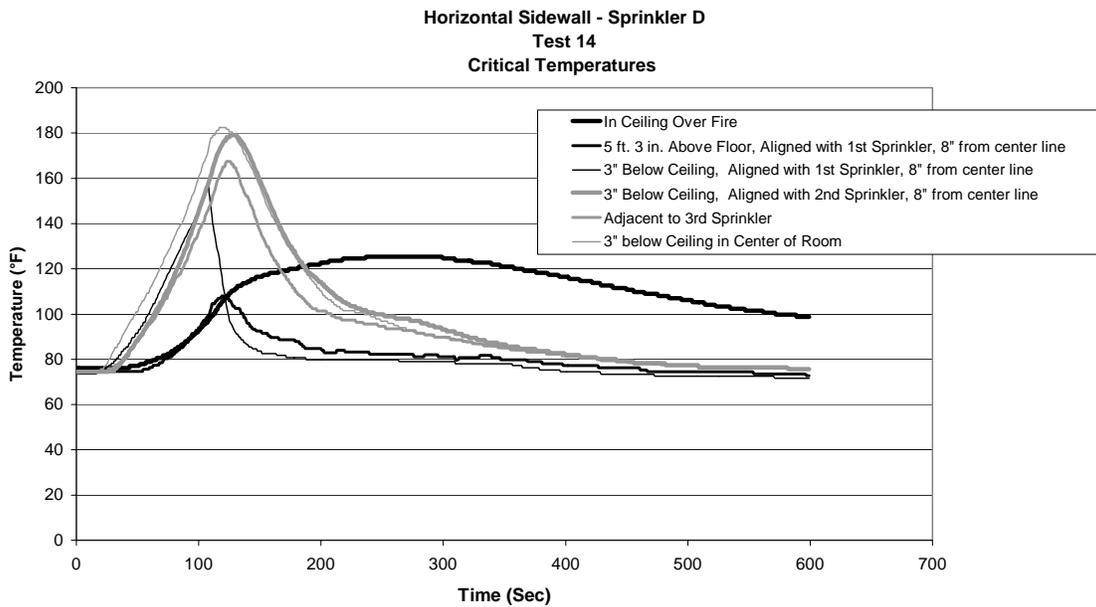


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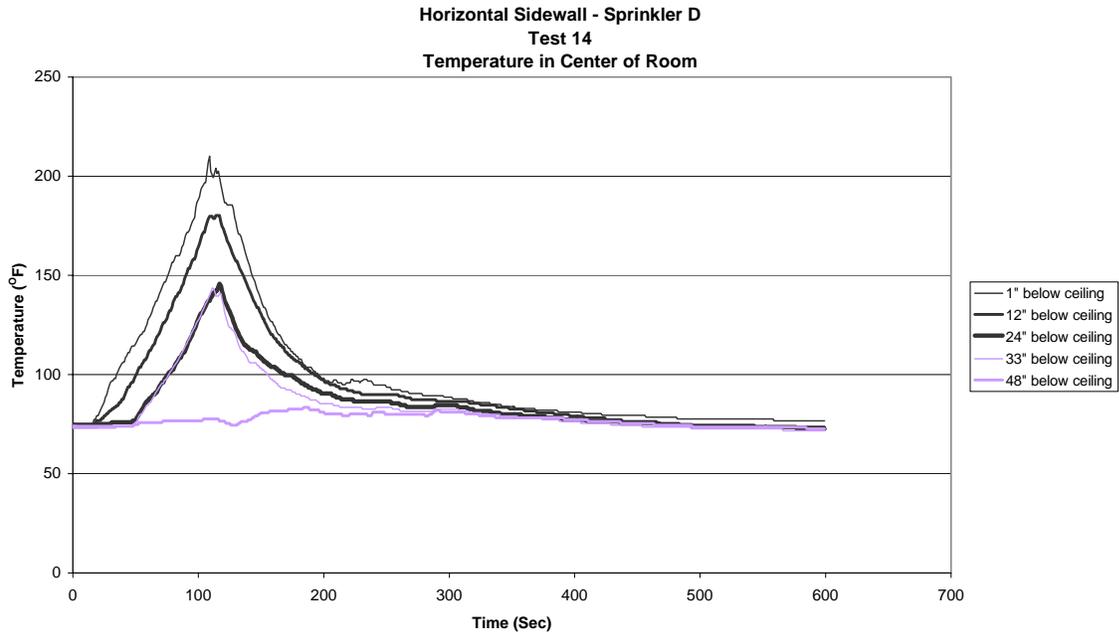


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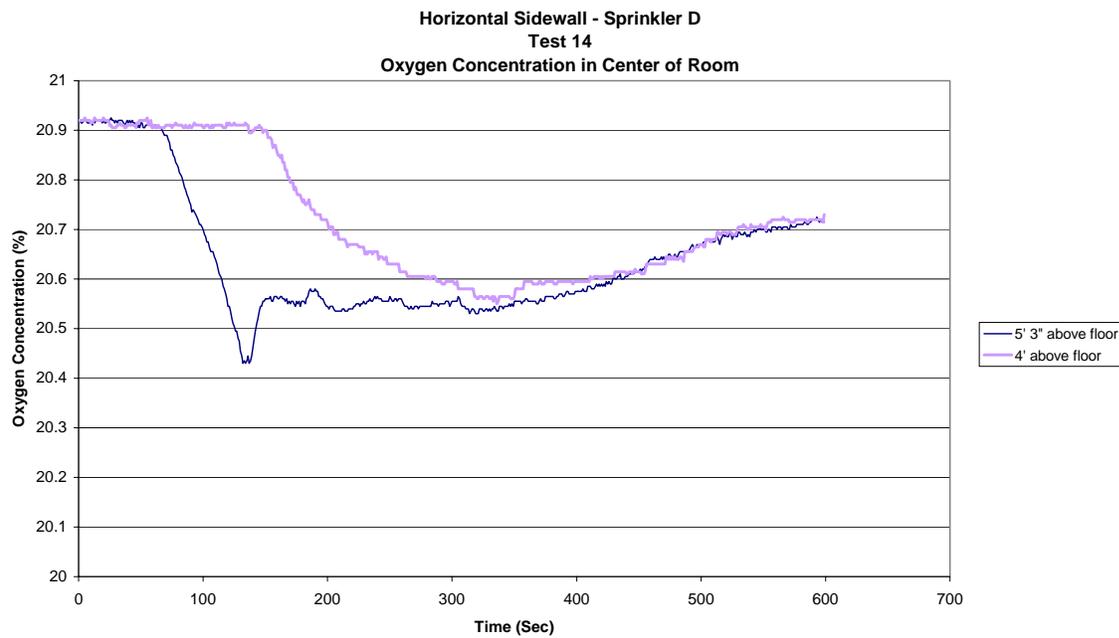


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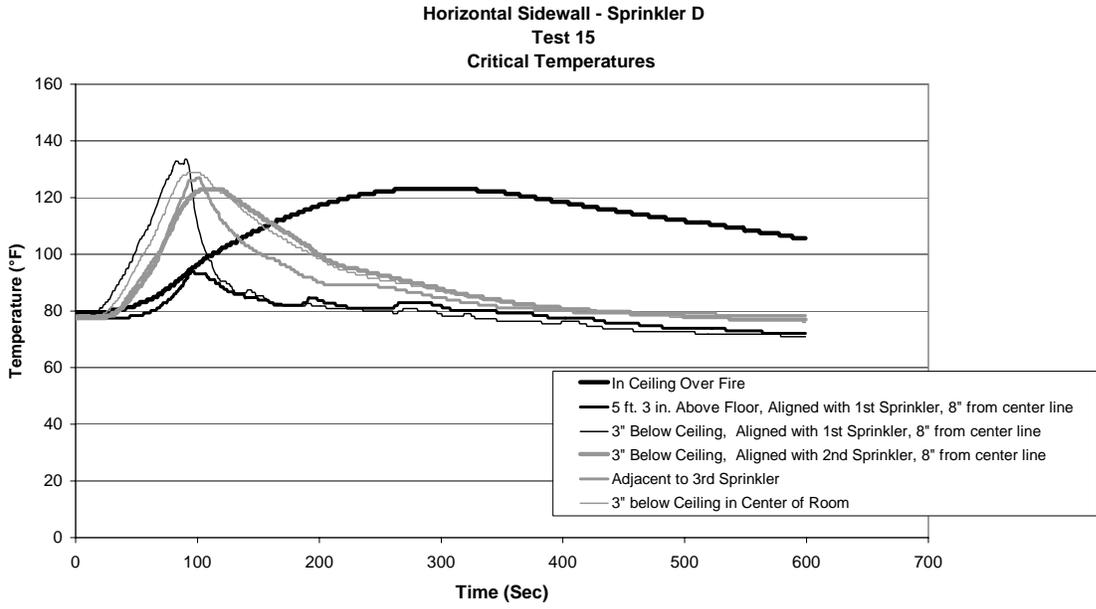


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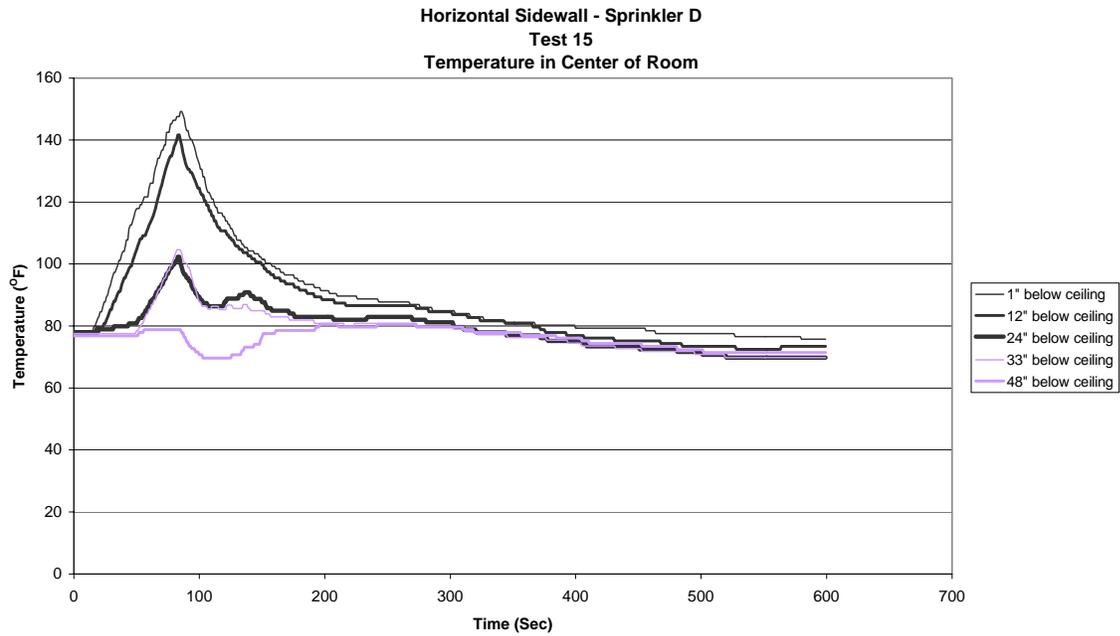


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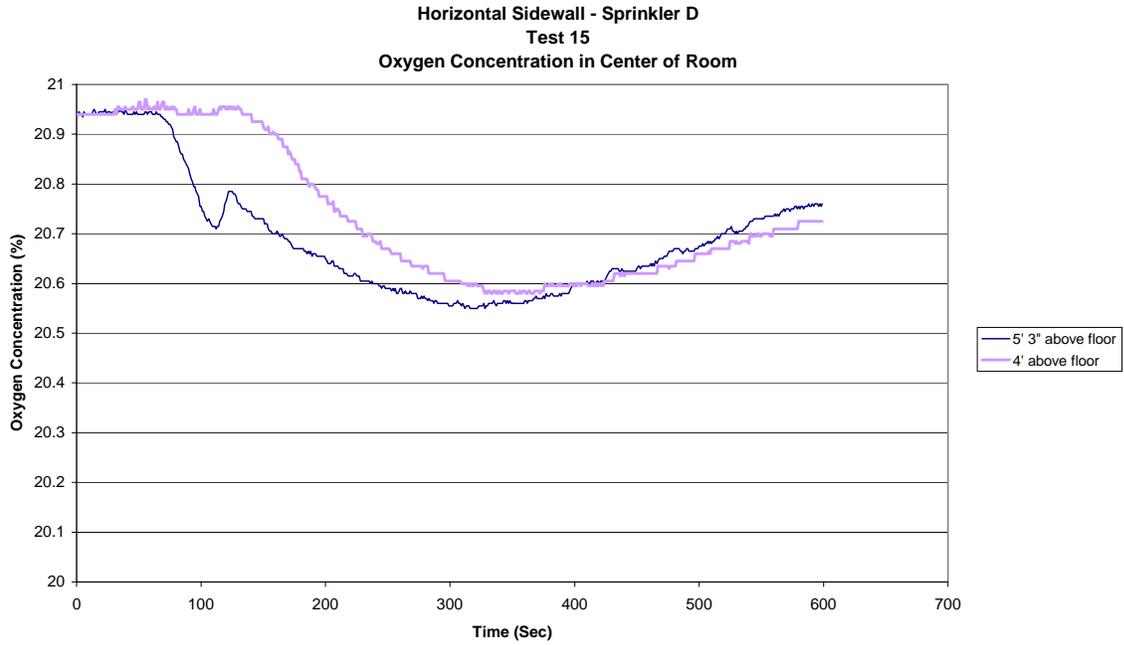


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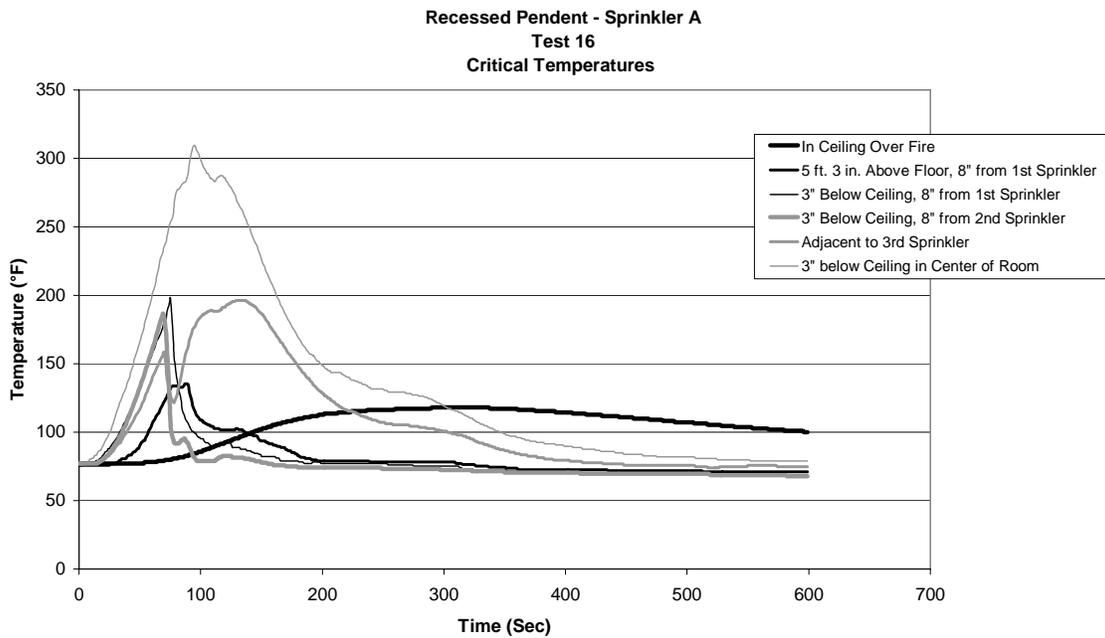


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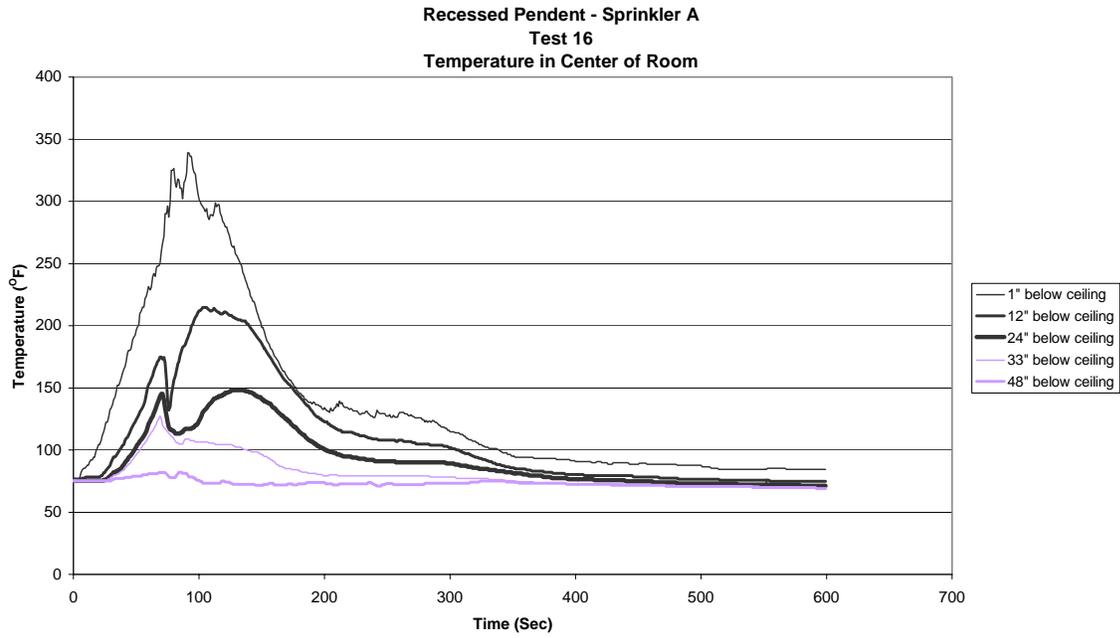


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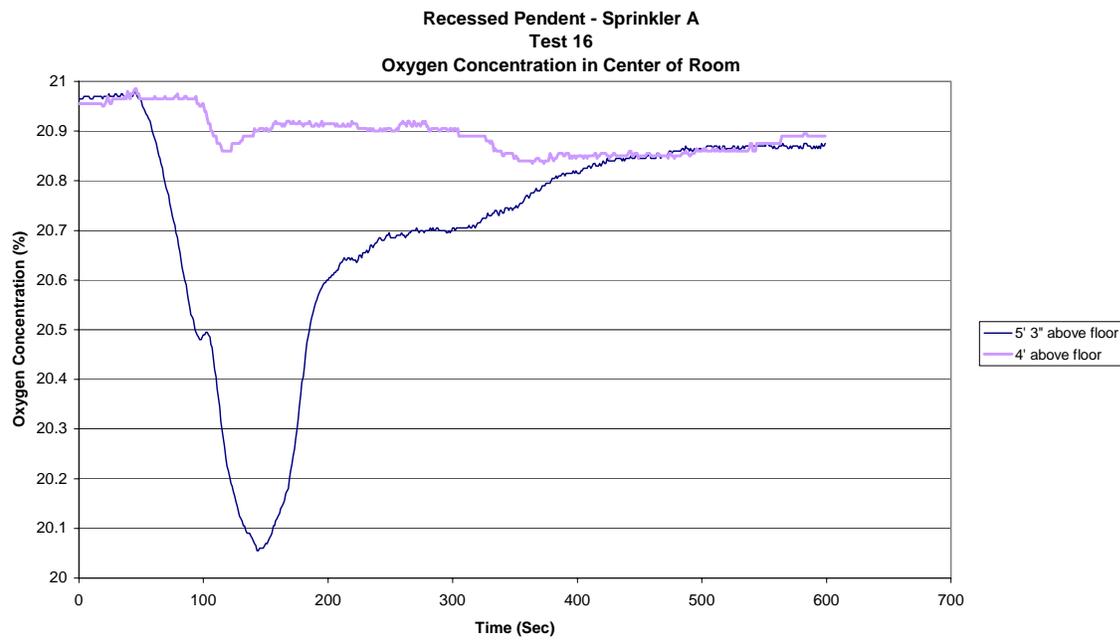


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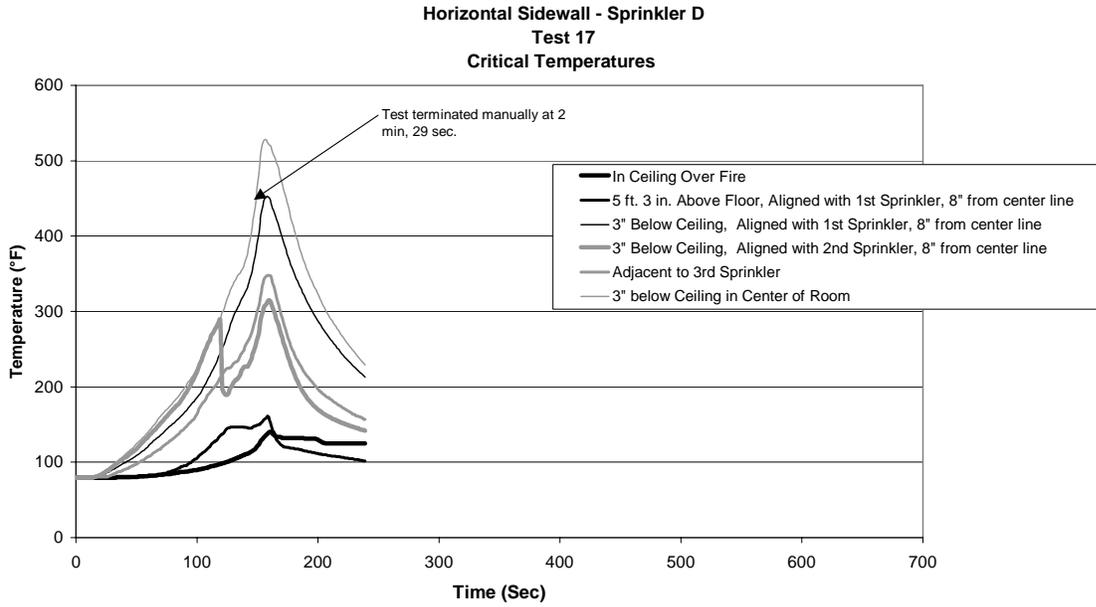


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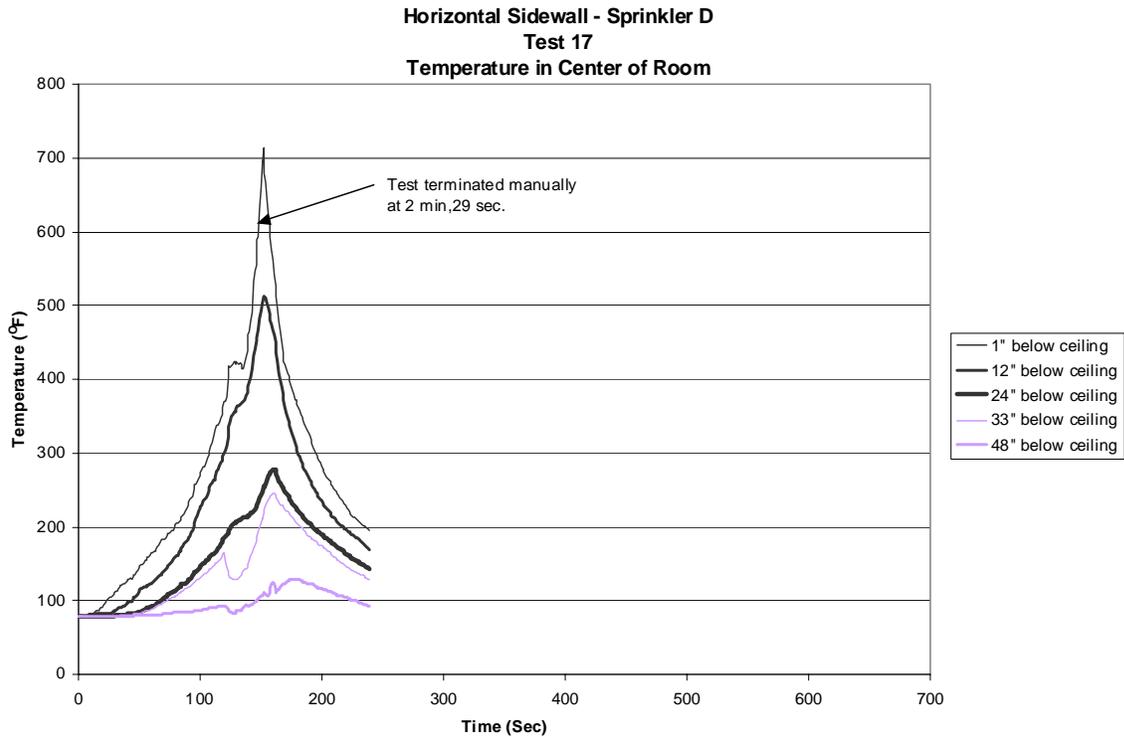


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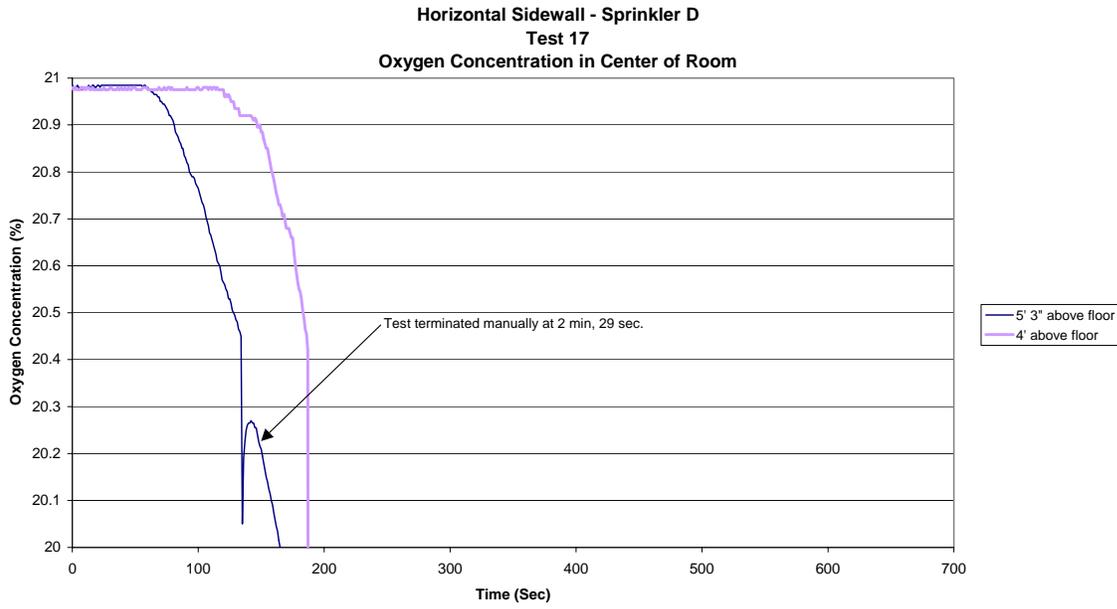


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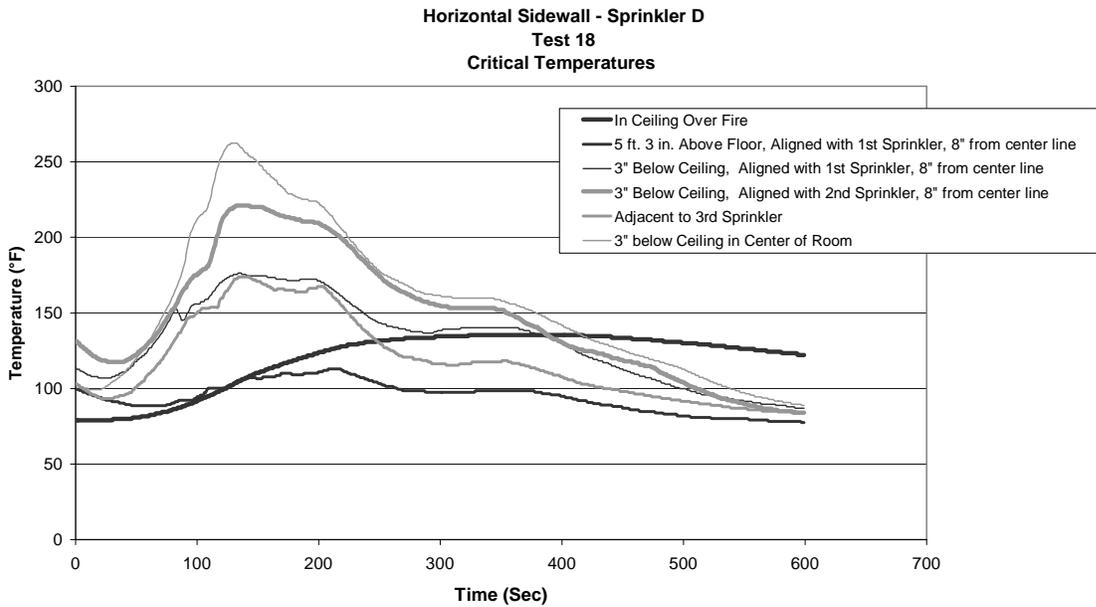


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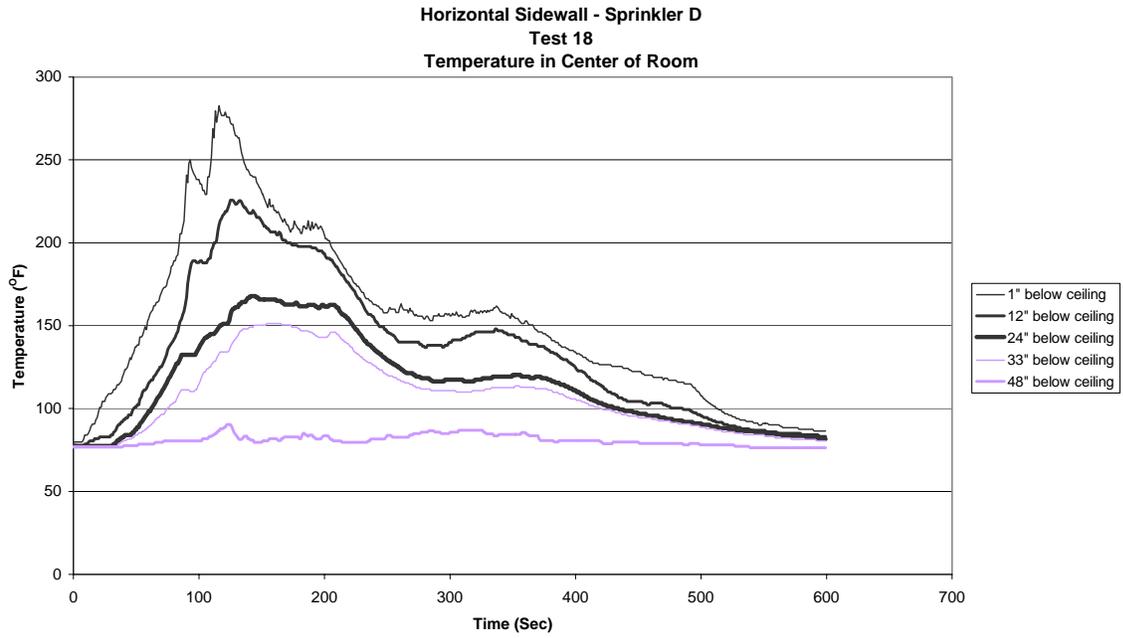


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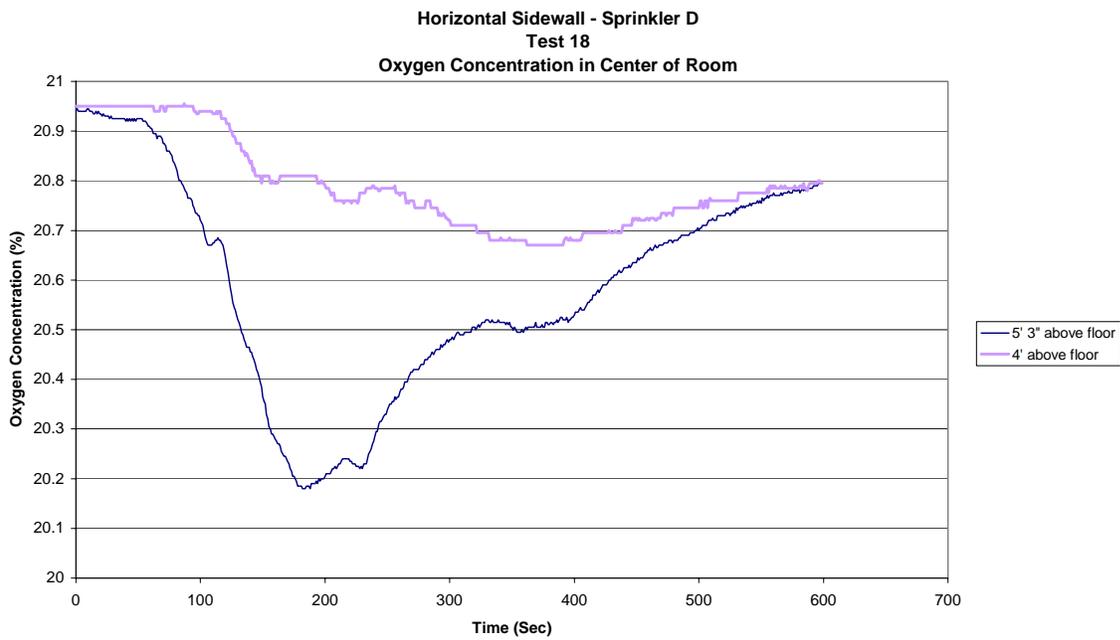
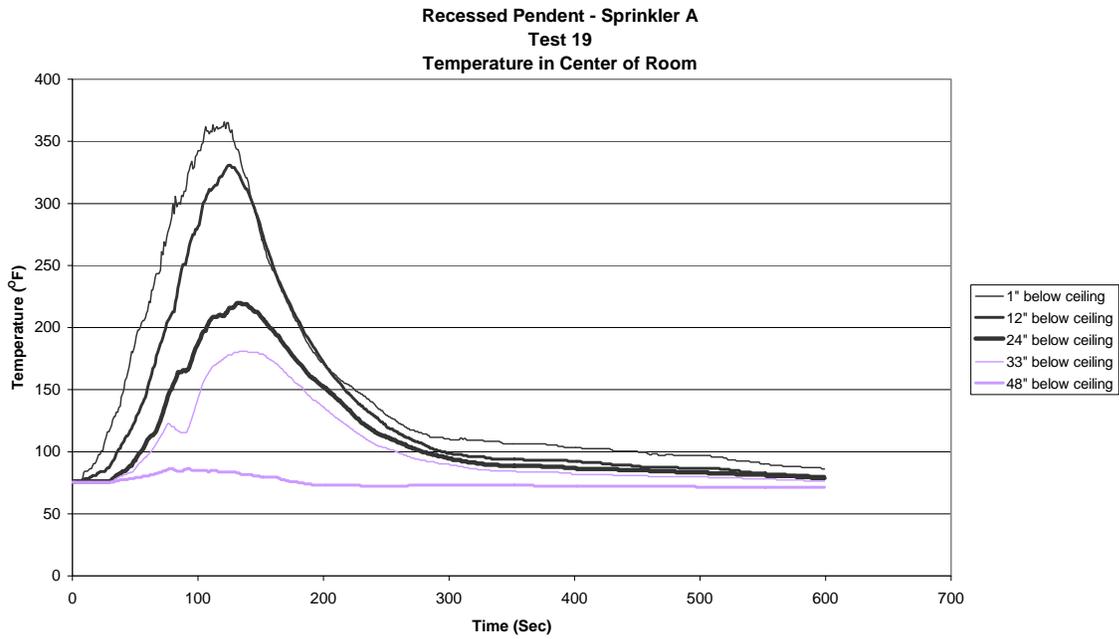
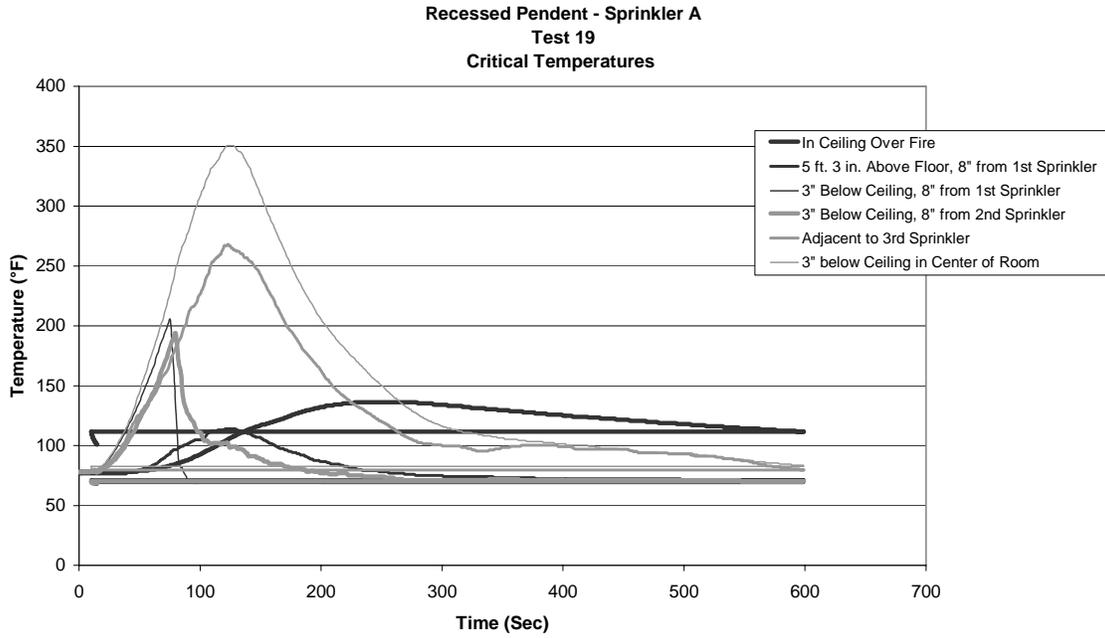


Figure A- 54



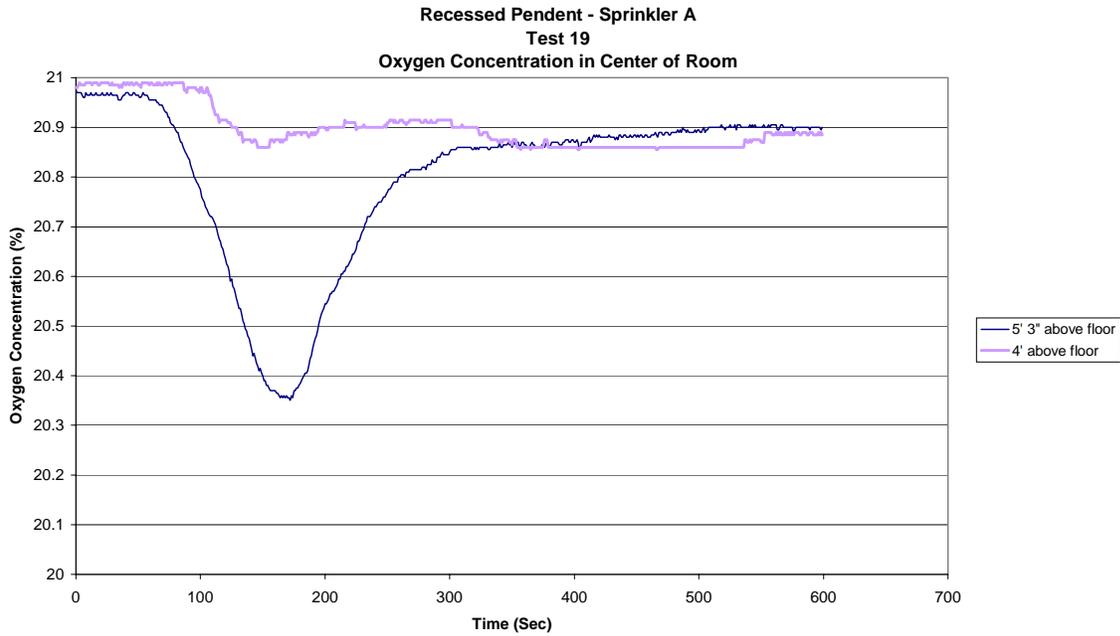


Figure A- 57

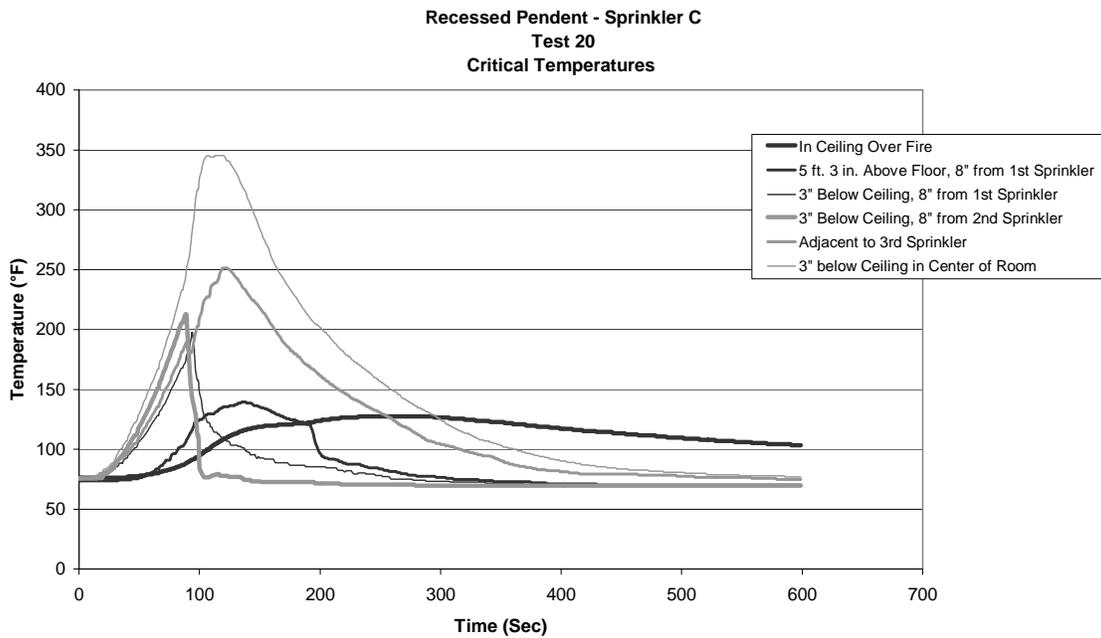


Figure A- 58

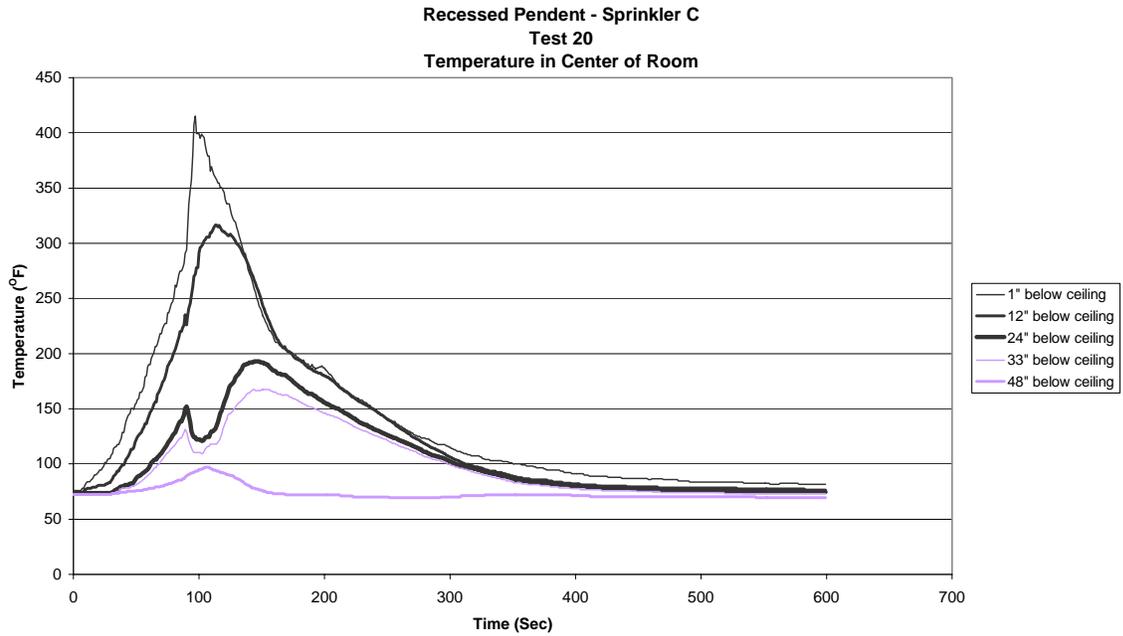


Figure A- 59

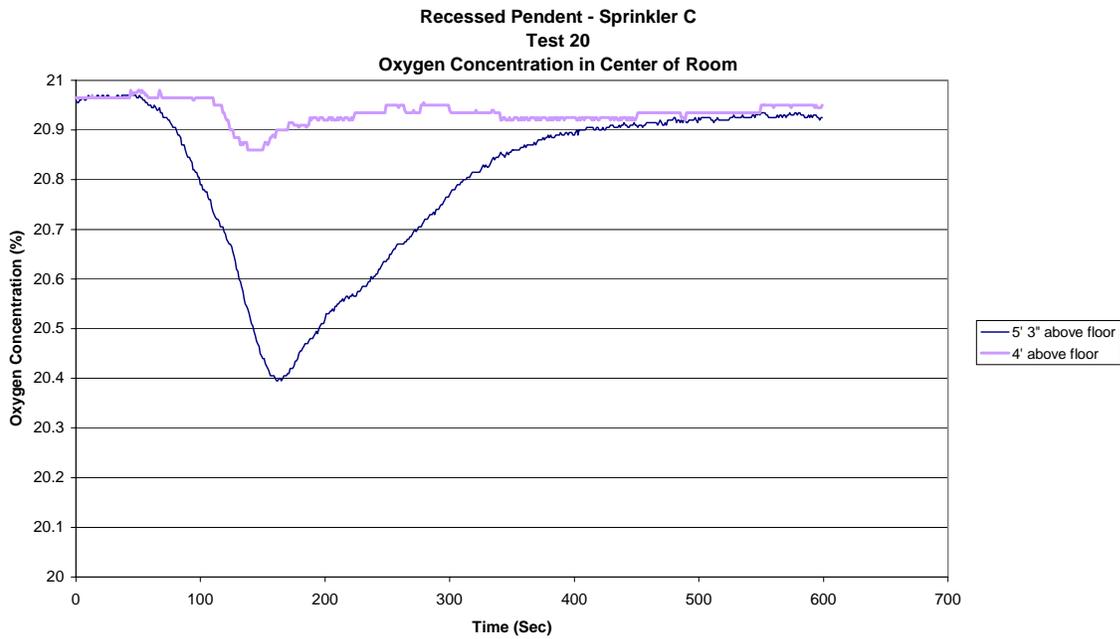


Figure A- 60

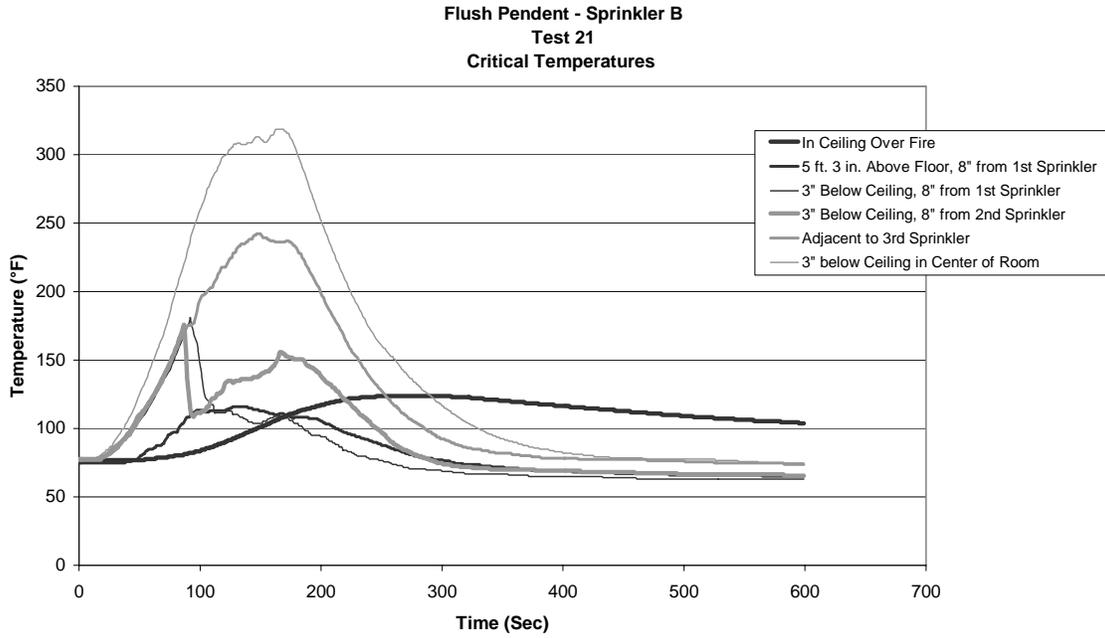


Figure A- 61

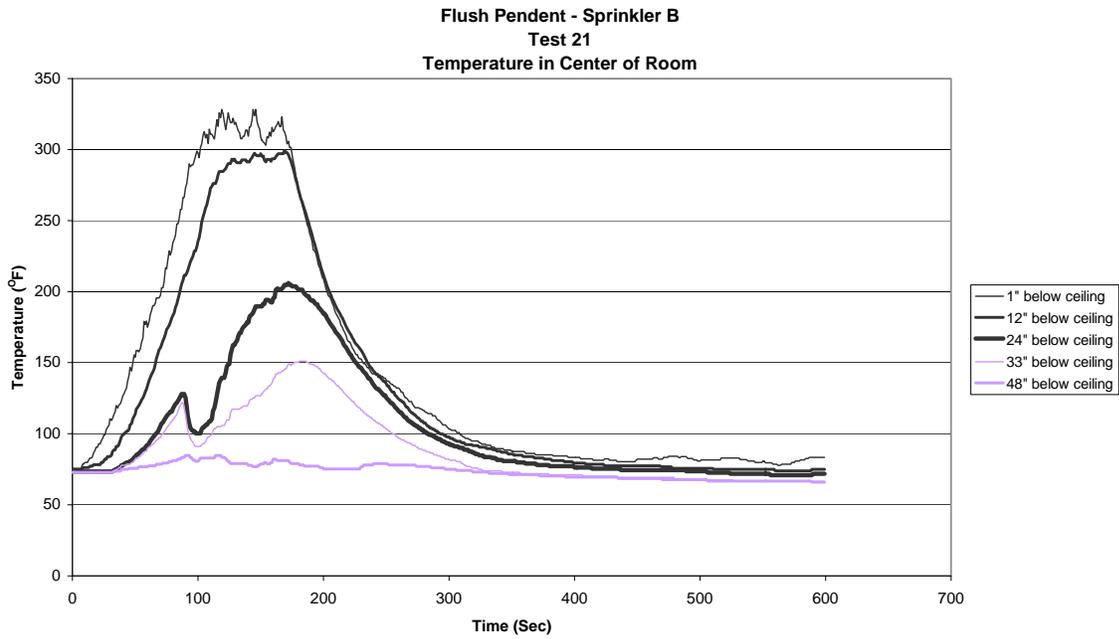


Figure A- 62

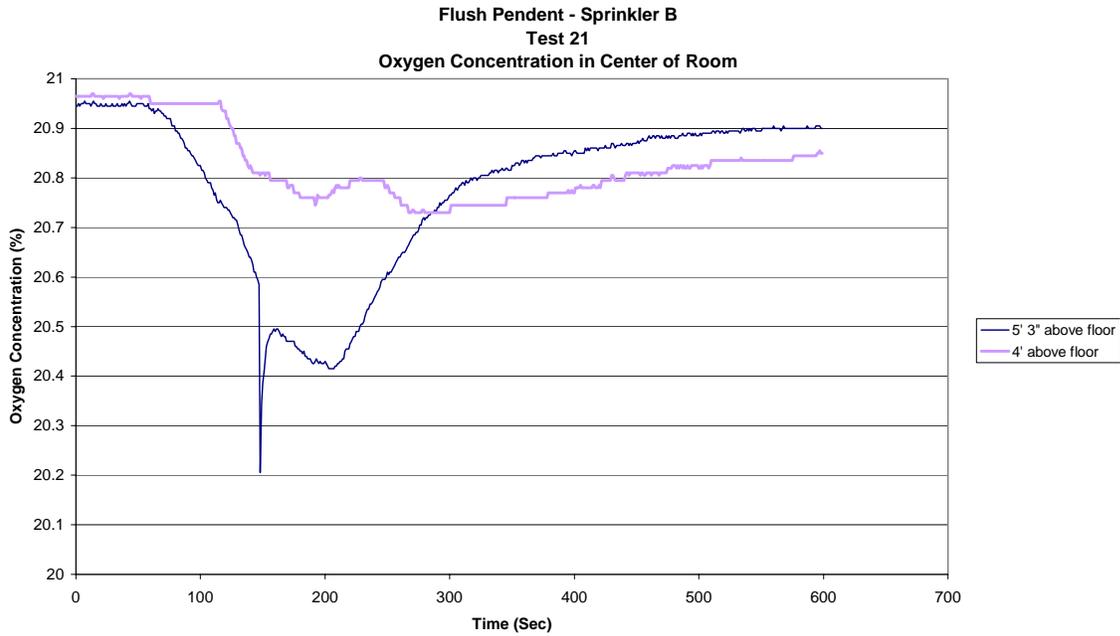


Figure A- 63

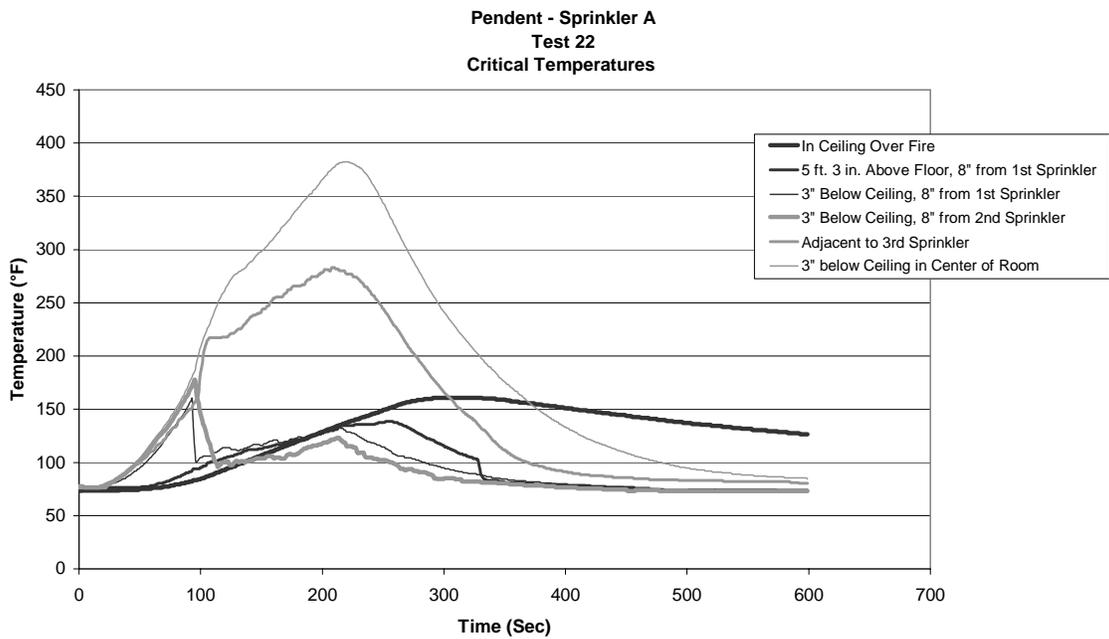


Figure A- 64

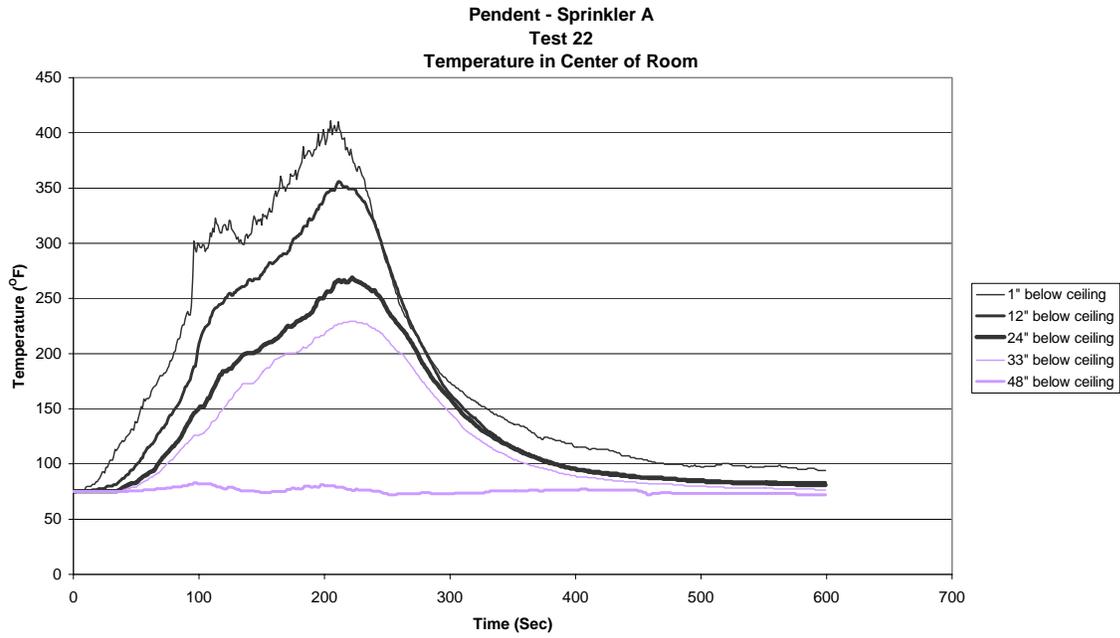


Figure A- 65

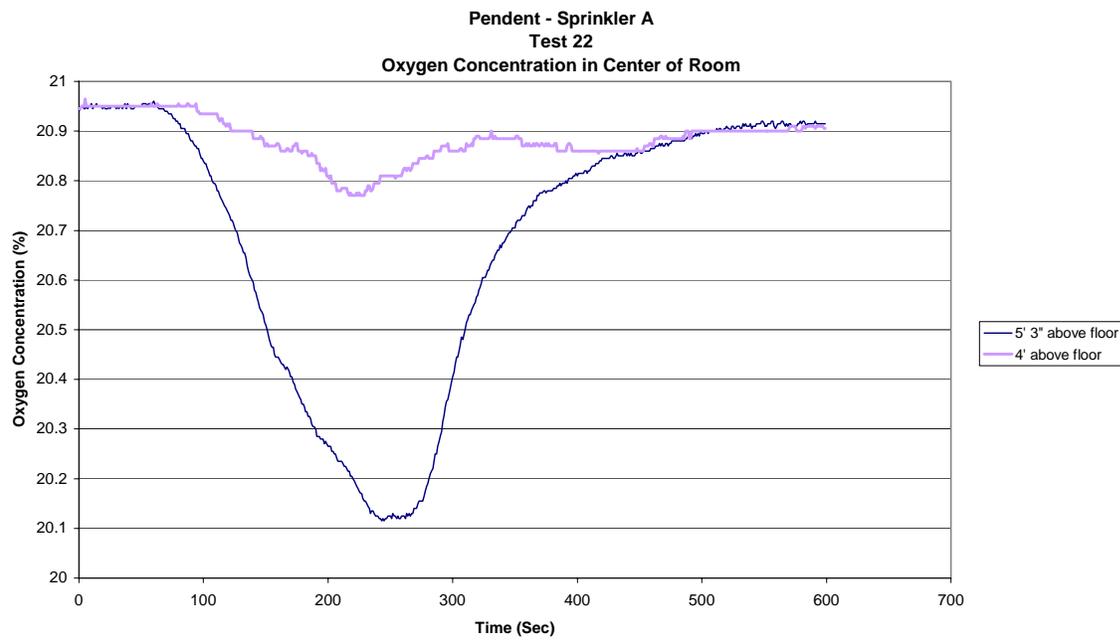


Figure A- 66

**APPENDIX B**  
**Fire Tests with Lodgement of Operating Parts**

**GENERAL**

Two tests were re-conducted due to a lodgement of water seal components in Sprinkler #1 as described in Table 4. The results presented in the main report are from the re-conducted tests where no lodgement occurred. The lodgment tests, Test 14L and Test 19L, are presented in this appendix.

**TEST PARAMETERS**

The tests were conducted as described in Section 0 of this report.

The general test parameters are presented in Table B- 1.

Table B- 1. Test Parameters

Test No	Sprinkler Code	Sprinkler Type	Deflector to Ceiling (in.)	Orientation to Short Wall	Coverage Area, W 3 L (ft.3ft.)	Flow Rate (gpm)	Fire Source Location
14L	D	HSW	4	Far Wall	16 by 16	21.0	Corner
19L	A	Recessed Pendent	*	Parallel	16 by 16	18.2	Between two

\* Recessed to the maximum permitted by the escutcheon, which was approximately ¾ in.

**RESULTS**

Test 14L was terminated at 2 minutes, 45 seconds due to high ceiling temperatures and operation of all three sprinklers in the test room.

Test 19L was continued for the full 10 minutes.

The results of each test are summarized in Table B- 2 and Table B- 3. Graphs of the results are presented in Figure B- 1 to Figure B- 6.

Table B- 2. Summary of Results

PARAMETERS							RESULTS									
Test No.	Test Code	Spklr Code	Spklr Type	Orient. to Short Wall	Fire Source Location	Coverage Area, W 3 L (ft.3ft.)	Operation Time (min:sec) Sprinkler No.			Max Temperature (°F) Thermocouple Locations						Duration TC #2 over 130°F (sec)
							1	2	3	1	2	3	4	5	6	
14L	10170301	D	HSW	F. Wall	Corner	16 by 16	2:00	2:18	2:39	283	136	612	582	398	575	8
19L	10210303	A	R. Pend	Parallel	Between 2	16 by 16	1:35	1:39	2:33	113	127	258	206	247	334	0

TC location: 1 = Embedded in the ceiling tile directly above the wood crib.

2 = Aligned with sprinkler #1, 8 inches from center line, 5 feet 3 inches above floor.

3 = Aligned with sprinkler #1, 8 inches from center line, 3 inches below ceiling

4 = Aligned with sprinkler #2, 8 inches from center line, 3 inches below ceiling.

5 = Adjacent to Sprinkler #3.

6 = In center of room, 3 inches below ceiling.

DNO = Did Not Operate

Table B- 3. Summary of Results (Metric Units)

PARAMETERS							RESULTS									
Test No.	Test Code	Spklr Code	Spklr Type	Orient. to Short Wall	Fire Source Location	Coverage Area, W 3 L (m3m)	Operation Time (min:sec) Sprinkler No.			Max Temperature (°C) Thermocouple Locations						Duration TC #2 over 54°C (sec)
							1	2	3	1	2	3	4	5	6	
14L	10170301	D	HSW	F. Wall	Corner	4.9 by 4.9	2:00	2:18	2:39	139	58	322	306	203	302	8
19L	10210303	A	R. Pend	Parallel	Between 2	4.9 by 4.9	1:35	1:39	2:33	45	53	126	97	119	168	0

TC location: 1 = Embedded in the ceiling tile directly above the wood crib.

2 = Aligned with sprinkler #1, 0.20 m from center line, 1.60 m above floor.

3 = Aligned with sprinkler #1, 0.20 m from center line, 76 mm below ceiling

4 = Aligned with sprinkler #2, 0.20 m from center line, 76 mm below ceiling.

5 = Adjacent to Sprinkler #3.

6 = In center of room, 76 mm below ceiling

DNO = Did Not Operate

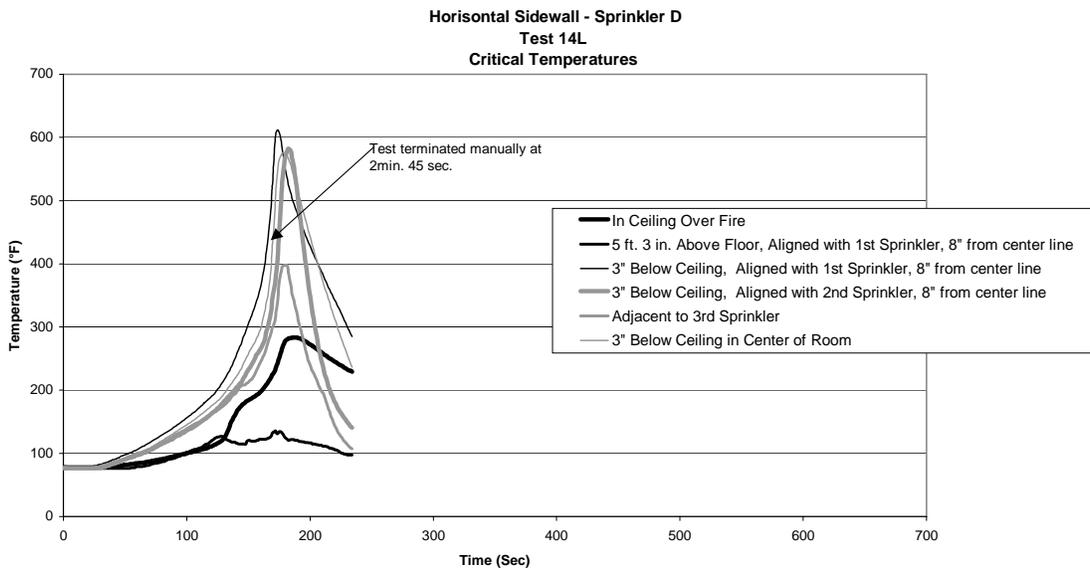


Figure B- 1

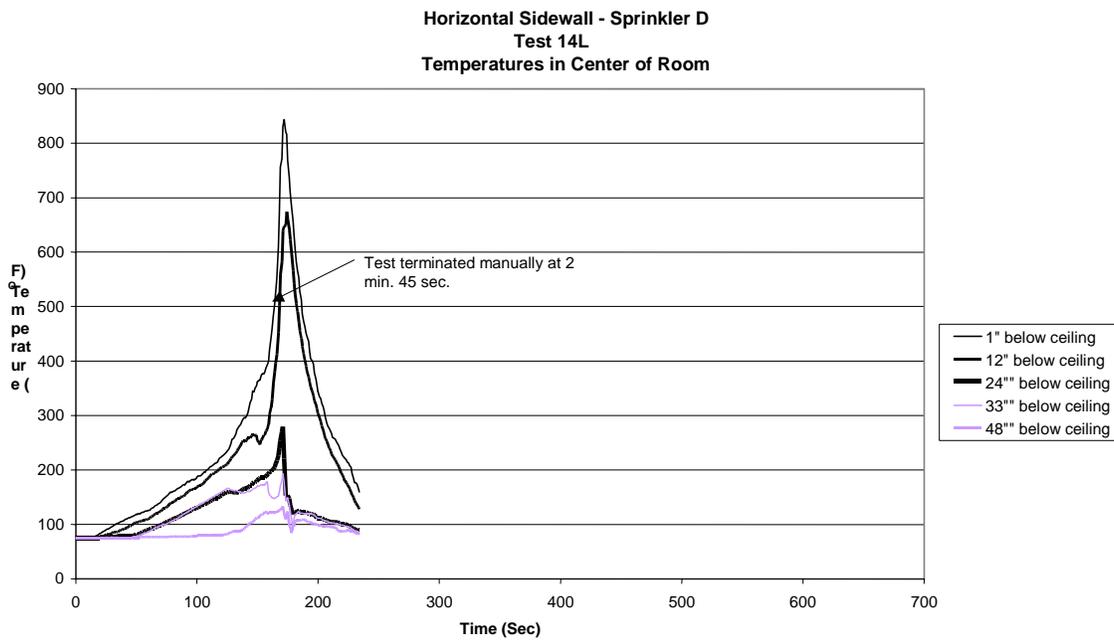


Figure B- 2

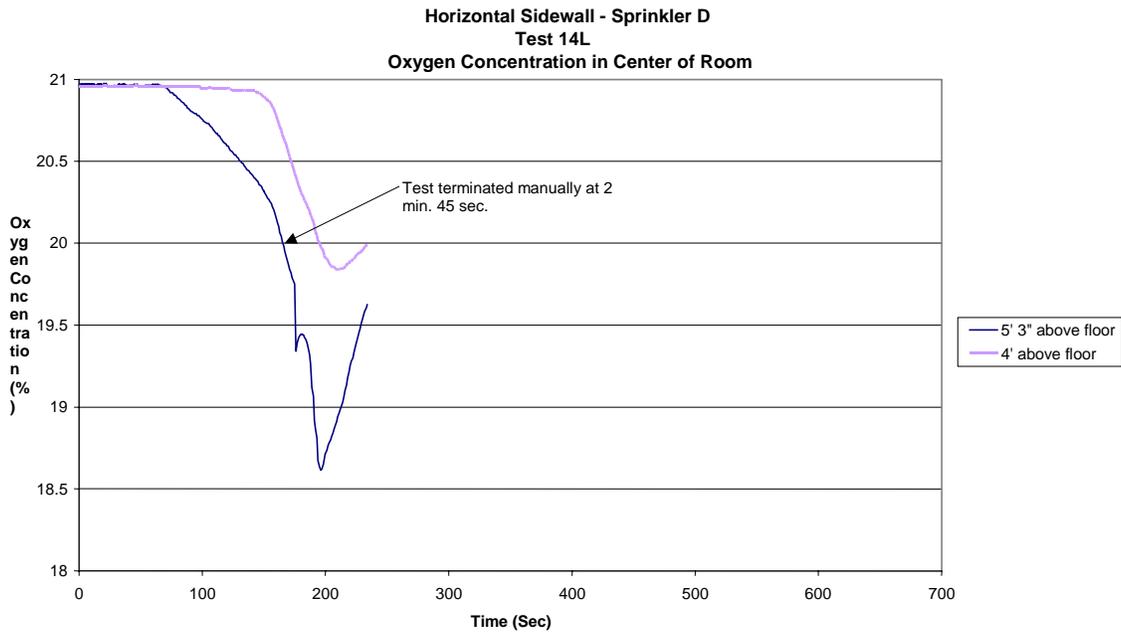


Figure B- 3

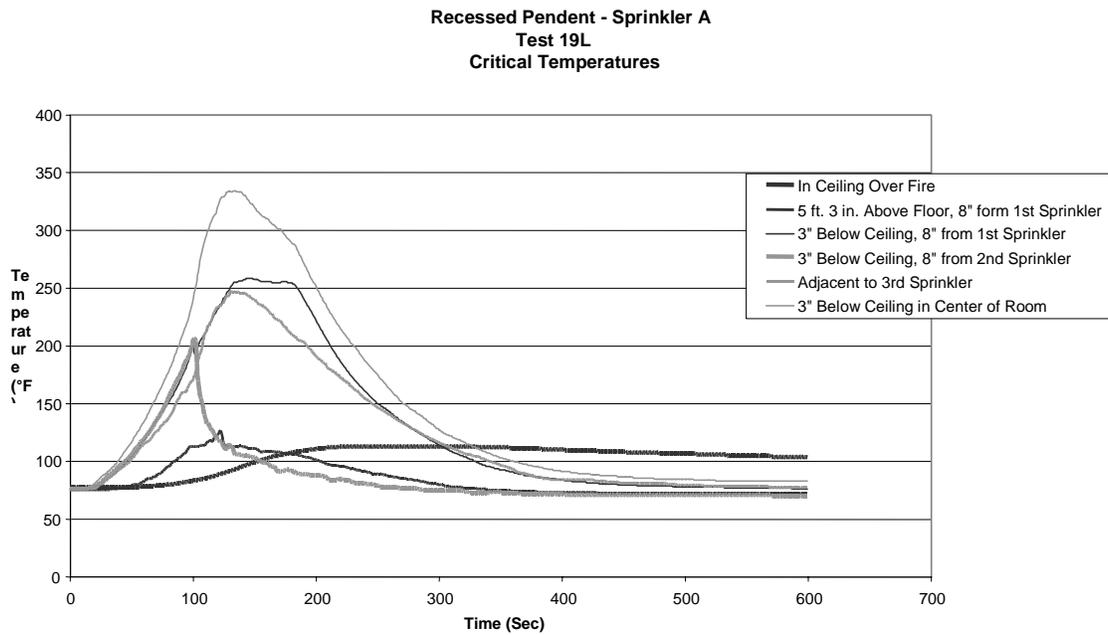


Figure B- 4

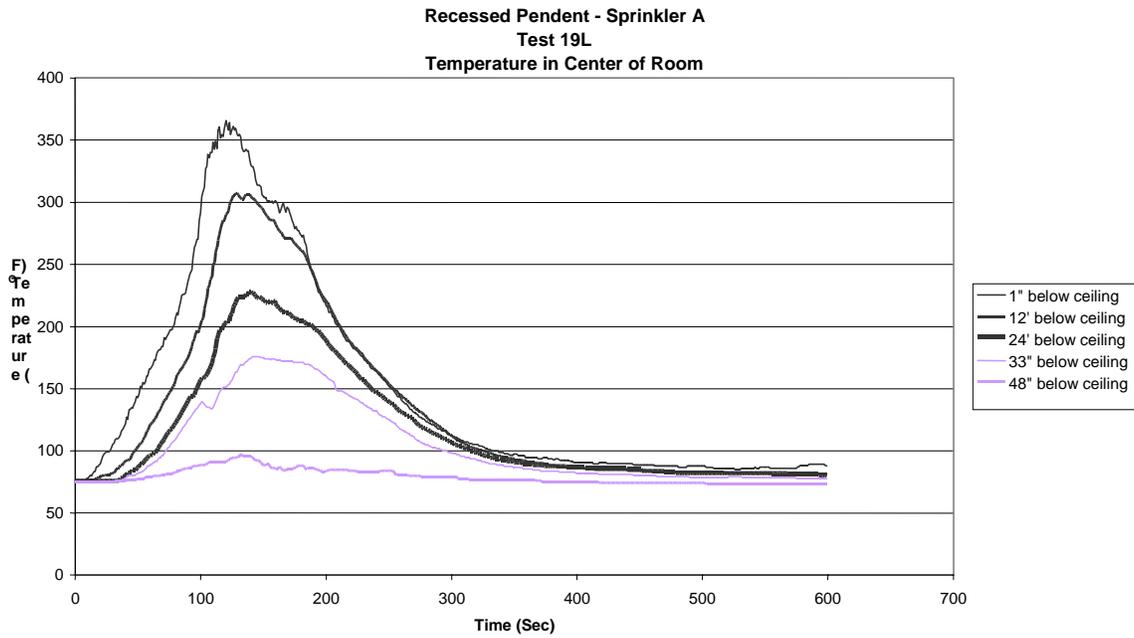


Figure B- 5

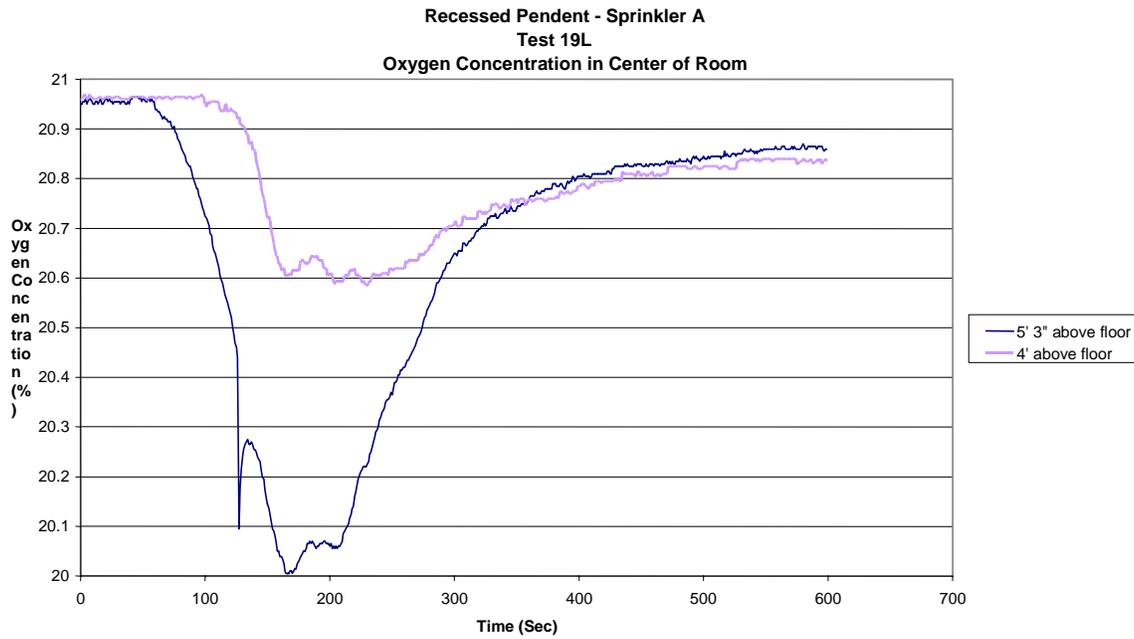


Figure B- 6