Protection of Rack Stored Exposed Expanded Group A Plastics with ESFR Sprinklers and Vertical Barriers

Final Report

Prepared by:

UL LLC

THE FIRE PROTECTION RESEARCH FOUNDATION

Research in support of the NFPA mission

FIRE RESEARCH

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FOREWORD

Exposed expanded Group A plastics rack storage represents a growing challenge for sprinkler protection in warehouses. This report presents the results of seven full scale fire tests to explore the effectiveness of the combination of an innovative vertical barrier protection feature with ceiling only sprinkler protection.

The content, opinions and conclusions contained in this report are solely those of the authors.

THE
FIRE PROTECTION
RESEARCH FOUNDATION

Protection of Rack Stored Exposed Expanded Group A Plastics with ESFR Sprinklers and Vertical Barriers

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PROTECTION OF RACK STORED EXPOSED EXPANDED GROUP A PLASTICS WITH ESFR SPRINKLERS AND VERTICAL BARRIERS

Prepared by

UL LLC

for

The Fire Protection Research Foundation

Project 13CA25935, NC5756
Project 13CA2919, NC1838

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Executive Summary

This report describes a large scale fire test that was conducted to develop data relative to the level of protection provided by ESFR sprinklers installed to protect double-row rack arrangements of exposed, expanded Group A plastics stored 30 ft. high under a 40 ft. ceiling with vertical barriers installed within the primary rack storage array. The test described in this report was in addition to the test series conducted as a part of the Fire Protection Research Foundation's exposed expanded Group A plastics research project described in report entitled ***Protection of Rack Stored Exposed Expanded Group A Plastics with ESFR Sprinklers and Vertical Barriers*** dated November, 2012.

The commodity used in the investigation consisted of expanded polystyrene meat trays, stored in plastic bags and resting on two-way entry, hardwood pallets. The nominal external dimensions of the commodity was 37 inches wide by 45 inches deep by 40 inches tall resting on a nominal 4-1/2 inch tall, 42 by 42 inch hardwood pallet.

The vertical barriers installed within the primary rack storage array were intended to inhibit the horizontal fire travel and reduce the potential for the fire to travel to the extremities of the test array. The test was conducted with plywood vertical barriers installed 16 ft. on center. No transverse flue spaces were blocked during this test. The test was conducted with an 8 ft. aisle between the main array and the target commodity located on both sides of the main array.

For the test, nominal K=25.2 gpm/psig$^{1/2}$ pendent ESFR sprinklers were installed to protect the test commodity. The ignition was located at the base of the array under one sprinkler, offset in the transverse flue space. A constant flowing pressure of a nominal 60 psig was provided for the test.

During the test, a total of 7 sprinklers operated. The fire travelled beyond the vertical barriers both east and west of the ignition location, but did not spread to the ends of the main test array. Neither target array was ignited during the test.

Where breaching of the vertical barriers occurred during the tests, it was observed that the fire travelled around the barrier at the aisle face where the commodity extended approximately 4 inches beyond the face of the uprights or vertical barriers.

A summary of the test parameters and results for the test is provided in Table E 1.

Table E 1. Test Parameters and Results

Test Date	June 8, 2013
Test Parameters	
Storage Type	Double Row Rack
Commodity Type	Exposed Expanded Group A Plastic (Bagged Meat Trays on Hardwood Pallets)
Pallet Type	2 way entry, stringer, hardwood
Vertical Barriers	16 ft. on center - Main Array (3/8 in. plywood)
Horizontal Blocking of Transverse Flues in Main Array (non-combustible)	None
Length of Main Storage Array, ft.	40
Nominal Storage Height, ft.	30
Ceiling Height, ft.	40
Nominal Clearance, ft.	10
Aisle Width, ft.	8
Ignition Location	Under 1 Sprinkler (offset)
Sprinkler Systems	Ceiling Only (no in-rack sprinklers)
Sprinkler Orientation	Pendent
Deflector to Ceiling, in.	14
Sprinkler Spacing, sprinkler by branchline ft. by ft.	10 by 10
Temperature Rating, F	214
Sprinkler Type	ESFR
Nominal Sprinkler Discharge Coefficient K, gpm/psig $^{0.5}$	25.2
Nominal Discharge Density, gpm/ft^2	1.95
Nominal Discharge Pressure, psig	60
Test Results	
Length of Test, minutes	31
First Sprinkler Operation Time, min:sec	0:47
Last Sprinkler Operation Time, min:sec	1:28
Number of Operated Sprinklers	7
Peak Gas Temperature at Ceiling Above Ignition, °F	414
Maximum 1 minute Average Gas Temperature at Ceiling Above Ignition, °F	191
Peak Steel Temperature at Ceiling Above Ignition, °F	133
Maximum 1 minute Average Steel Temperature at Ceiling Above Ignition, °F	127
Fire Travel to Extremities of Test Array	No

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Abbreviations

°C	degrees Centigrade
°F	degrees Fahrenheit
psig	unit of pressure; pounds per square inch gauge
gpm	gallons per minute
ft.	foot
in.	inch
mm	millimeter
cm	centimeter
m	meter
RTI	Response time index
Lb_m	Pounds mass
dno	Did not operate

1. INTRODUCTION

This report describes a Special Services Investigation conducted for the Fire Protection Research Foundation in accordance with the test method described herein.

The sole purpose of this Special Services Investigation was to develop large scale fire test data on ceiling only, ESFR fire sprinkler systems protecting rack stored exposed expanded Group A plastic commodity. Vertical plywood barriers were employed strategically within the main test array to mitigate lateral fire spread.

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Investigations normally conducted by UL LLC involve Classification, Listing or Recognition and Follow-Up Services of proprietary products. However, UL LLC does conduct investigations without Classification, Listing or Recognition in Follow-Up Service when a need for test data in the interest of public safety has been indicated. Such investigations do not result in specific conclusions, nor any form of Recognition, Listing or Classification of the products involved. It is on this basis that UL LLC undertook the Special Services Investigation reported herein.

The issuance of this Report in no way implies Listing, Classification or Recognition by UL LLC for the storage configuration.

2. TEST FACILITY

The fire tests were conducted at UL's large-scale fire test facility located in Northbrook, Illinois.

2.1 Large-Scale Fire Test Building

The large-scale fire test building used for this investigation houses four fire test areas that 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. A schematic of the test facility is shown in Figure 1.

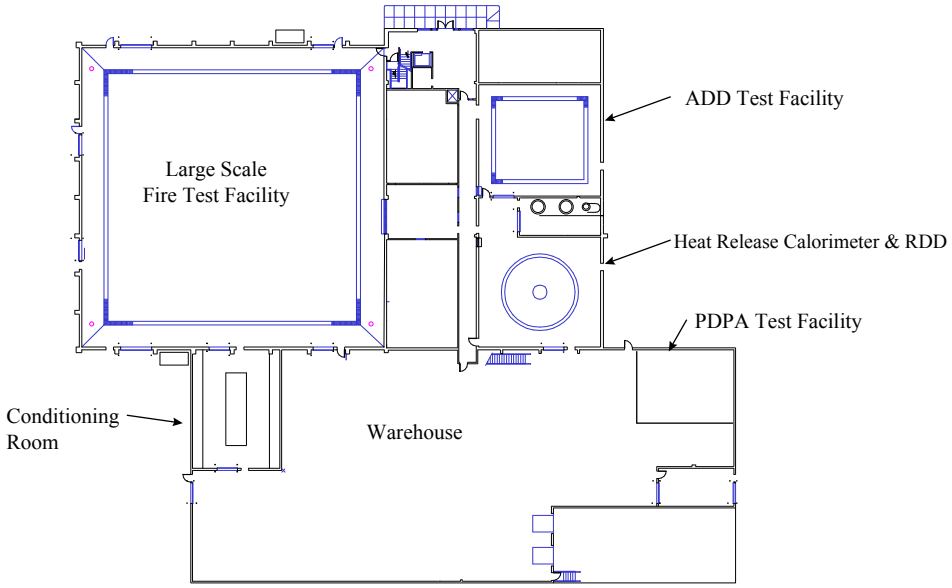


Figure 1 Test Facility

2.2 Large-Scale Fire Test Facility

The test was conducted in the 120 by 120-ft. main fire test cell that is equipped with a 100 by 100-ft adjustable height ceiling. The 10-ft perimeter between the moveable ceiling and the walls of the test room provides for the simulation of a larger warehouse by not allowing the smoke and heat layer from the test to be contained.

The center of the floor of the test facility is 100 by 100-ft., is smooth and flat and is surrounded with a grated drainage trench to insure adequate water drainage from the test area. The water from the suppression system is collected, contained and filtered through a nominal 180,000-gallon water treatment system.

The large-scale test cell used in this investigation is equipped with an exhaust system capable of a maximum flow of 60,000 cubic feet per minute through a smoke abatement system. Combustion air was provided through four inlet ducts positioned along the wall of the test facility. The combustion air was released into the room approximately 10-ft above the floor level through straightening screens. This ventilation arrangement provided adequate air so that the fire growth occurs naturally.

All products of combustion from the tests were contained within the test facility and processed through a regenerative thermal oxidizing system.

3. EQUIPMENT

3.1 Automatic Sprinkler System

A wet pipe automatic sprinkler system was positioned below the adjustable smooth, flat non-combustible ceiling and pressure controlled to provide a specific applied nominal flowing pressure as defined below.

The sprinklers were supplied through a looped piping system consisting of 2 ½-in. diameter, schedule 40 branch lines. The piping system was supplied by a variable speed pump capable of supplying an adequate pressure and flow to maintain the required applied flowing pressure throughout the course of the test.

3.1.1 Sprinkler

The automatic sprinkler system consisted of pendent ESFR sprinklers having a nominal K-Factor of 25.2 gpm/psig$^{0.5}$ in the 214°F temperature rating with a 1 inch NPT inlet thread. The sprinklers were installed on 10 ft. branch line by 10 ft. sprinkler spacing, with the sprinkler deflector located nominally 14 in. below the moveable ceiling. A photograph of the sprinkler used is shown in Figure 2. A schematic of the sprinkler numbering system is shown in Figure 3.

Figure 2 Test Sprinkler Photos

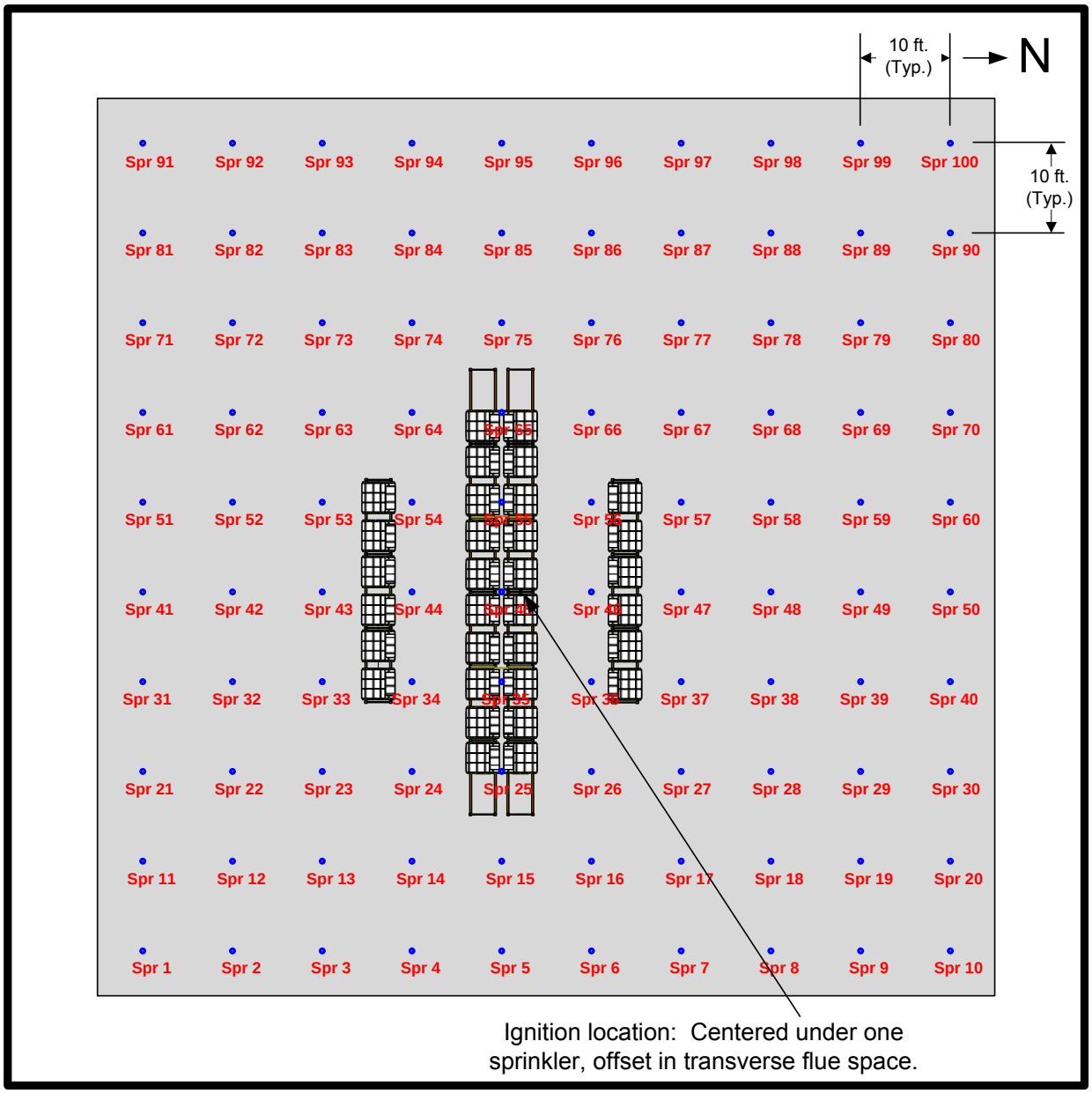


Figure 3 Test Arrangement and Sprinkler Numbering System

3.2 Air Temperature

3.2.1 Air Temperature Near Sprinklers

The air temperature adjacent to each sprinkler was measured with a 0.0625-in.diameter inconel sheathed Type K thermocouple.

3.2.2 Air Temperature Above Ignition

The ceiling gas temperature above ignition was measured using the same type of thermocouples as stated in 3.2.1. The gas temperature was measured adjacent to the steel beam described in 3.3, with the thermocouples, positioned 6, 12, and 18 inches below the ceiling. The three thermocouples were positioned near the ends and centered on the steel beam.

3.3 Steel Beam Temperature

A nominal 4 ft. long by 2 in. wide by 2 in. high steel angle was mounted below the ceiling above the ignition location of the test array. The temperature of the steel beam was measured with five Type K thermocouples embedded within the beam. The thermocouples were equally spaced within the beam.

3.4 Video

Six video cameras were used to record the test. Four cameras were centered on each wall of the test cell. One camera was positioned on the observation balcony in the North East corner of the laboratory, and one camera was positioned on the test room floor to capture critical events. In addition, an infrared camera was used to record the events from the South East corner of the test array.

3.5 Data Collection

All data was collected using an electronic data acquisition system at a one-second-scan rate.

4. EXPOSED EXPANDED GROUP A PLASTIC COMMODITY

4.1 Components

4.1.1 Pallets

The fire test series was conducted using two way pallets as a base for the commodity. The kiln dried 2-way entry white oak hard wood pallets had outside dimensions of 42 by 42 by 4-1/2 in. tall. Photographs of the pallets are shown in Figure 4.

Figure 4 2-Way Entry, Hard Wood Pallet

4.1.2 Meat Trays

The meat trays used in the exposed expanded Group A commodities were manufactured from expanded polystyrene. A grouping of meat trays were randomly selected and measured dimensionally and by weight to determine average values. The results are presented in Table 1. Photographs of a representative meat tray are shown in Figure 5.

Table 1 Meat Tray Details

Meat Tray Description	Average Length (in.)	Average Width (in.)	Average Height (in.)	Average Mass (grams)
Expanded Polystyrene	12-1/4	10-1/8	1-1/8	11.1

Figure 5 Front and Back View of Meat Tray

4.2 Commodity Description

4.2.1 Exposed Expanded Group A Plastic

The exposed expanded Group A plastic commodity consisted of eight, two sleeve bundles, each weighing an average of 6.2 lb. and containing approximately 250 expanded polystyrene meat trays. Each bundle was divided into two groups and contained in an outer plastic bag. The bundles were shrink wrapped around the sides to provide a more stable stored commodity arrangement. The nominal external dimensions of the commodity was 37 inches wide by 45 inches deep by 40 inches tall resting on a nominal 4-1/2 inch tall, 42 by 42 inch hardwood pallet.

The commodity is shown in Figure 6.

Figure 6 Exposed Expanded Group A Plastic Commodity

The test results apply only to the samples tested.

5. STRUCTURE

5.1 Racking

The racking configuration used in the investigation incorporated welded steel uprights and beams. The component uprights and beams are shown in Figure 7.

The welded uprights measured 36 inches wide, and the steel beams measured 8 ft. long.

Figure 7 Component Uprights and Beams with Plywood Vertical Barriers

5.2 Vertical Barriers

The rack storage arrangement incorporated vertical barriers to assist in the control of lateral fire spread.

The barriers terminated 4 inches from the test room floor as shown in Figure 9 and Figure 11. The uppermost termination of the barriers occurred at the maximum height of racking which was approximately 36 ft. tall.

The combustible barriers were constructed from nominal 3/8 inch thick plywood sheathing as shown in Figure 8. Both the gaps between the individual rack upright members as well as the gap between the two separate uprights of the double row rack array were covered as shown in Figure 9. The plywood was fastened to the steel uprights with metal, self-tapping screws.

Figure 8 Combustible Vertical Barriers Used in Test Series (Test 6 Construction)

Figure 9 Combustible Vertical Barrier Detail

5.3 Transverse Flue Blocking

No transverse flue space blocking was used in this test.

6. TEST ARRAY CONFIGURATION

6.1 Rack Array and Plan View

The racking system used is considered double row racking in accordance with NFPA 13.

Each bay of the racking system was filled with two pallet loads of the test commodity as defined in section 4.2.

Figure 10 and Figure 11 show the details of the rack array for the test.

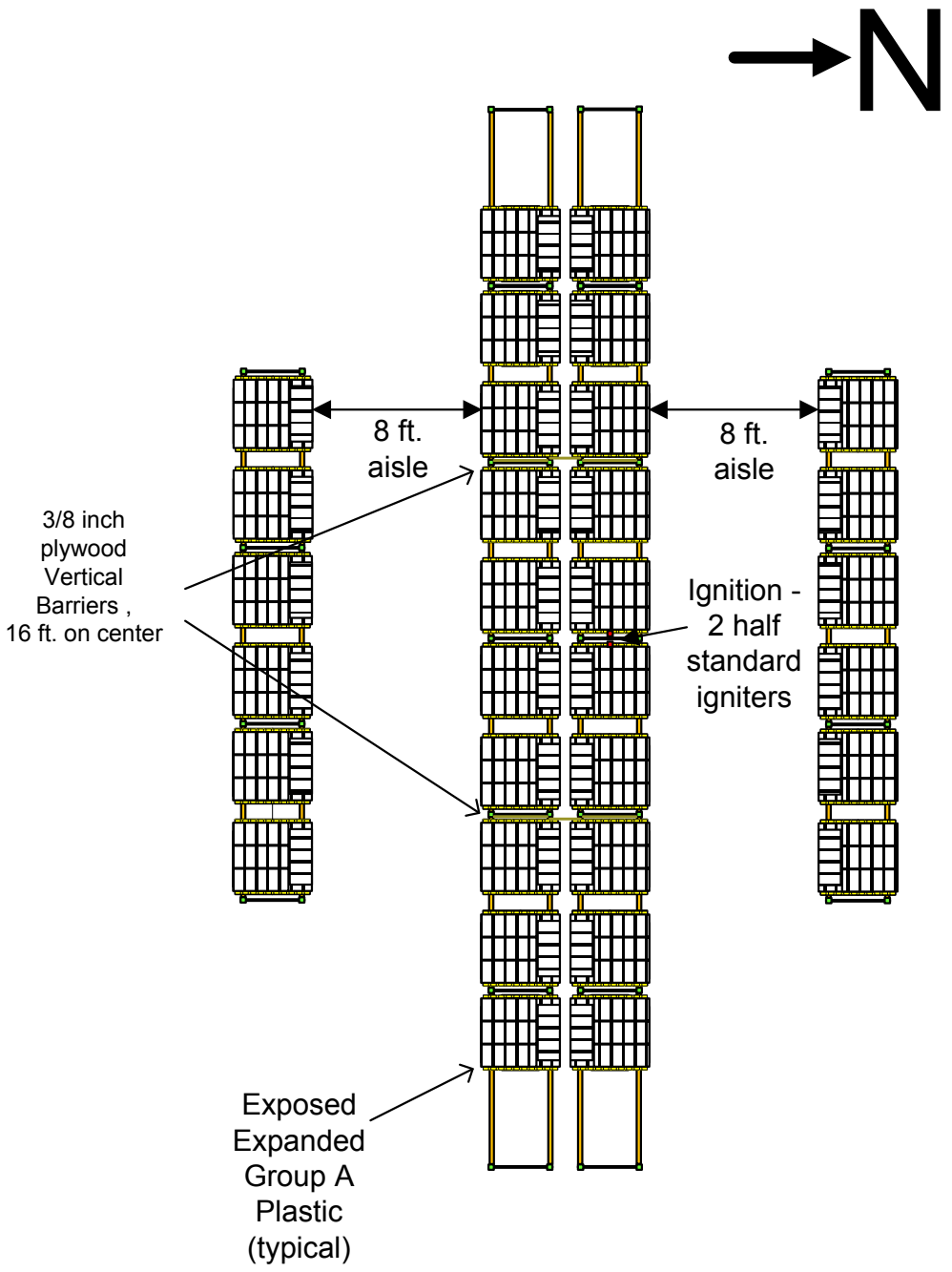


Figure 10 Test Array Plan View - General

6.2 Ceiling Height and Clearance

The test laboratory's moveable ceiling was positioned at 40 ft. from the test room floor as shown in Figure 11, which provided for a nominal 10 ft. clearance between the ceiling and the top of the commodity.

A 14 inch pendent sprinkler deflector to ceiling clearance was used for the test.

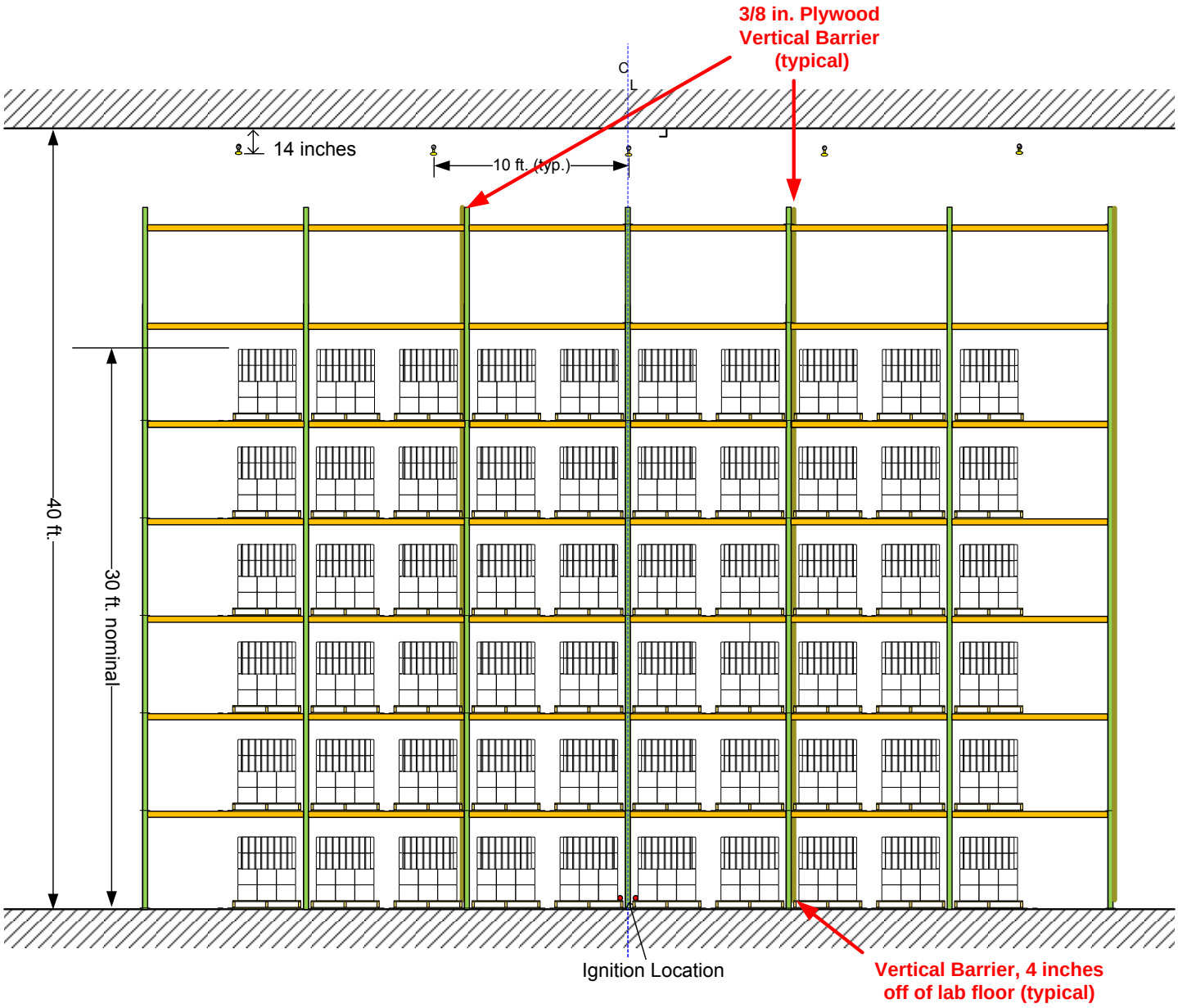


Figure 11 Elevation View of Main Test Array from the North

6.3 Test Arrangement

The steel racks were loaded with the commodity as defined in Section 4. The loading arrangement is as shown in Figure 10 and Figure 11.

Photographs of the test arrangements are shown in Figure 12 and Figure 13.

Limited length target arrays were established across a nominal 8 ft. aisle space as shown in Figure 10 and Figure 12.

Figure 12 Elevation View from the North East

Figure 13 Elevation View from the South (without the target array)

6.4 Ignition

Ignition was accomplished using two half igniters.

The igniters were constructed from a 3-in. diameter by 3-in. long cellulosic bundle soaked with 4 fluid ounces of gasoline and wrapped in a polyethylene bag. The igniters were positioned adjacent to the expanded plastic commodity, on top of the pallet in the transverse flue space, at the center of the North main rack array as shown in Figure 10, Figure 11 and Figure 14.

The main rack array was positioned such the geometric center was directly under one sprinkler for the test.

The location of ignition relative to the sprinklers for the test is illustrated in Figure 3.

A photograph illustrating the ignition source is provided in Figure 14.

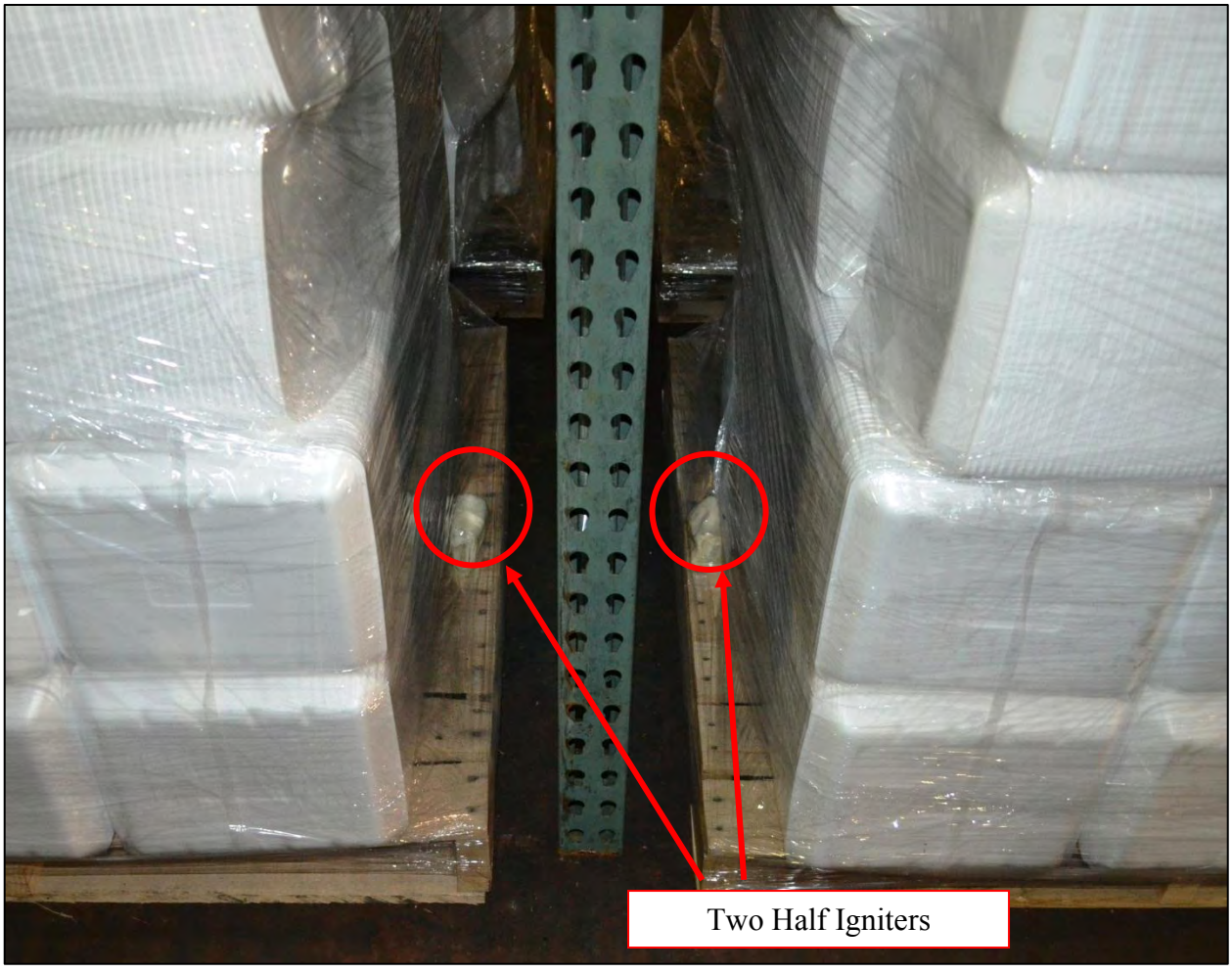


Figure 14 View Showing Igniters in North Main Transverse Flue Space at Base of Array

7. TEST METHOD

7.1 Test Procedure

The test procedure consisted of the following steps:

1. A detailed camera assessment of the commodity and vertical barrier positions within the racking array was documented prior to test.
2. The igniters were placed as discussed previously in the "Ignition" section above.
3. The data acquisition system was started upon ignition of the igniters.
4. The test pressures for the sprinkler system was established by adjusting the system's fire pump speed.
5. The test proceeded for 30 minutes after the operation of the first sprinkler, rounded up to the nearest whole minute.
6. After test termination, fire fighters manually fought the fire until it was extinguished.
7. A detailed hand held video and photographs of the commodity damage within the racking array were made after the test had been completed. See Appendix B for photographs of the damage assessment.

7.2 Fire Test Photographs

The initial stage of the fire test is shown in Figure 15.

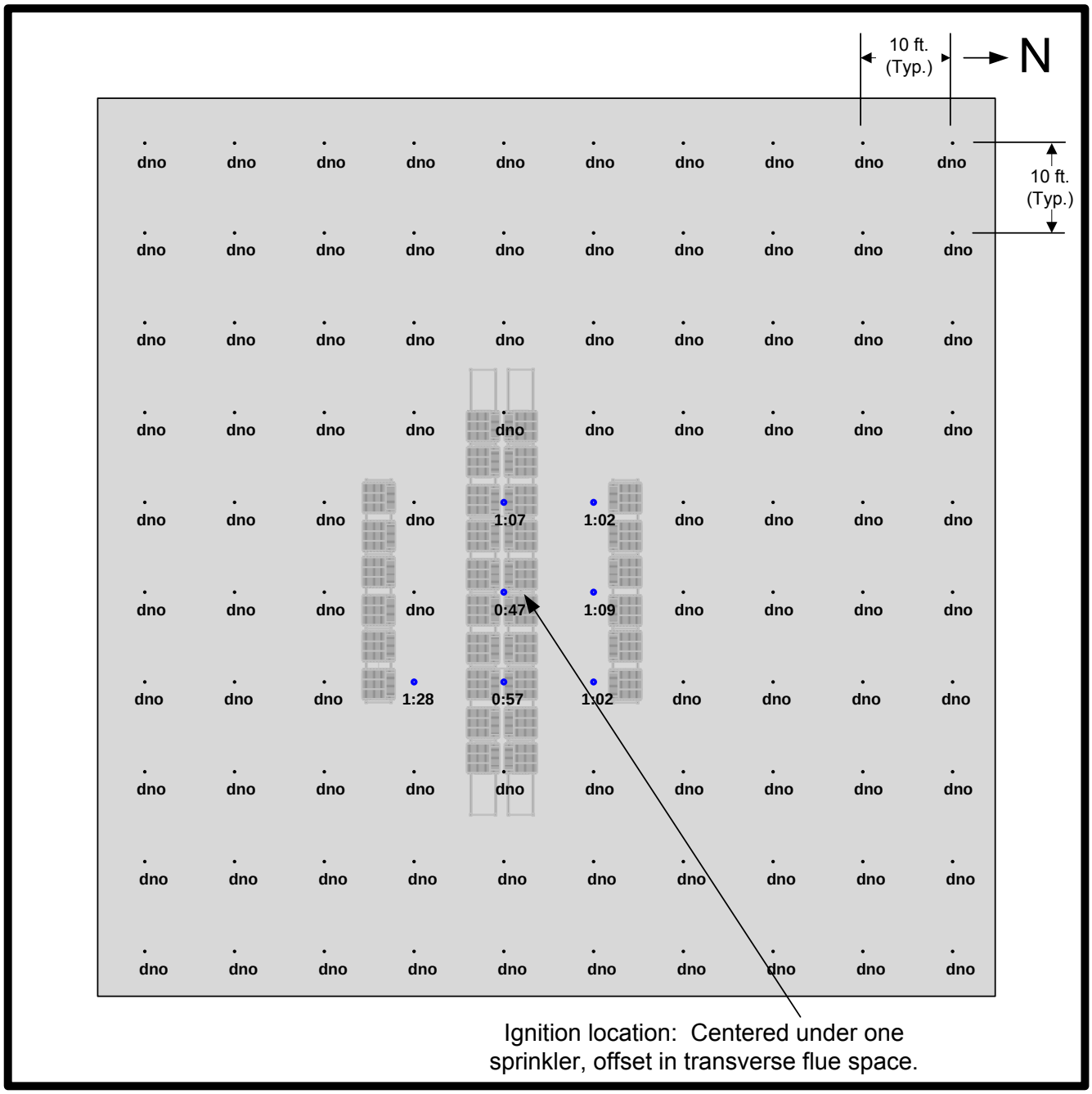
Figure 15 Fire Test Photo During Early Stage of Test

8. RESULTS AND DISCUSSION

The fire test incorporating rack storage of exposed expanded Group A plastic was conducted at UL LLC in Northbrook, IL on Saturday, June 8, 2013. The following is a summary of the resulting data.

8.1 Number of Operating Sprinklers:

Figure 16 illustrates the sprinkler operation times for the test.



dno – did not operate

Figure 16 Operation Sequence of Sprinklers (minutes:seconds)

8.2 Temperature Results:

Appendix A provides the data for the test.

The individual sprinkler temperature profiles are presented in Figures 1 - 10.

Steel beam and gas temperatures above ignition are presented in Figures 11 and 12.

Sprinkler system flowing pressures and system flow rates are presented in Figure 13.

8.3 Commodity Damage Results:

The test arrangement was reviewed for fire test damage to the stored commodity.

In the test, the fire damage extended to a single pallet load beyond the 16 ft. spaced vertical barriers. No target array ignition occurred, however there was partial melting of the exposed surface of the target array across the 8 ft. aisle space.

Detailed photographs of the damage assessment are presented in Appendix B.

Drawings illustrating the damage to the commodity are depicted in Figure 17 and Figure 18.

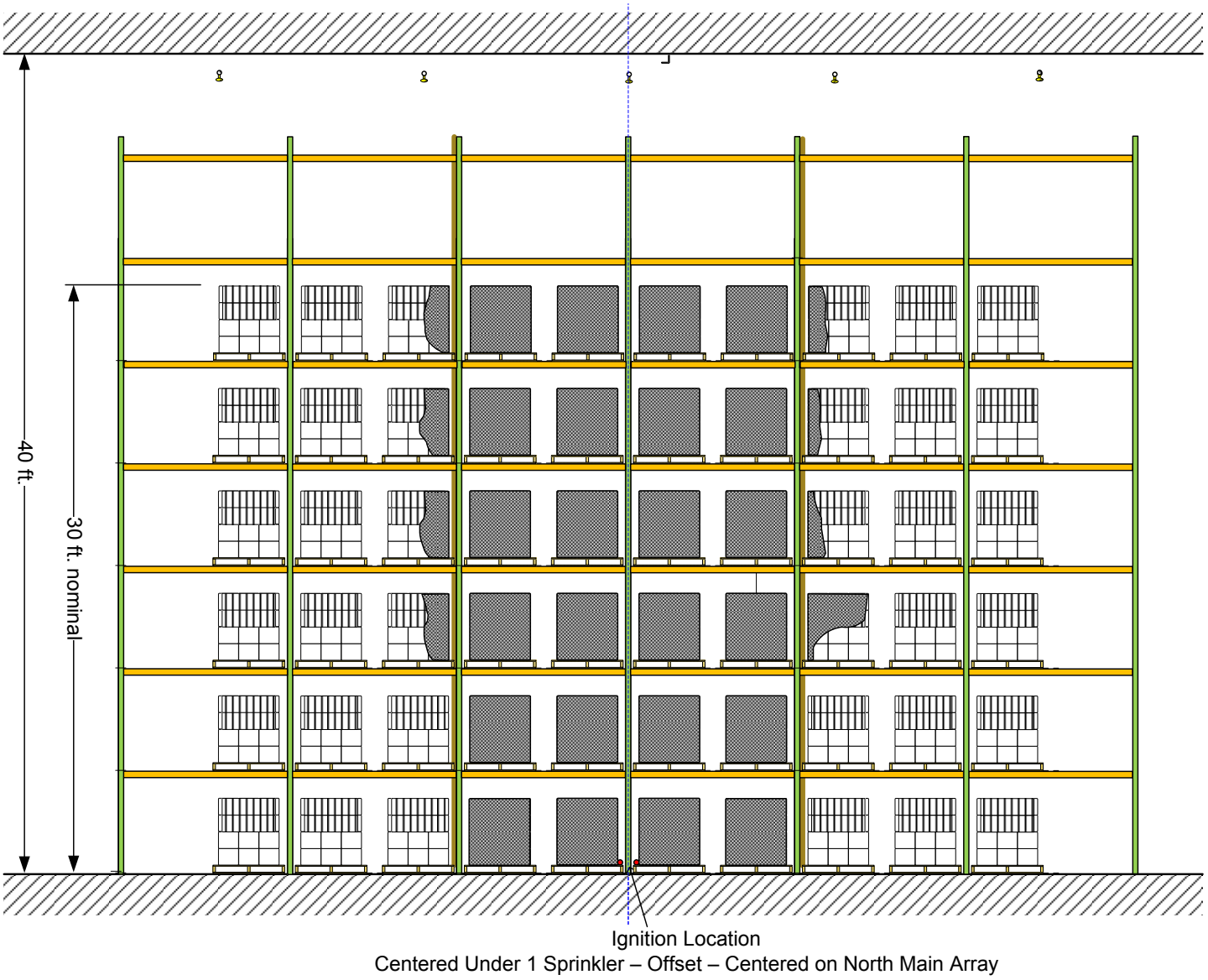


Figure 17 Damage Assessment - Elevation View of North Main Array

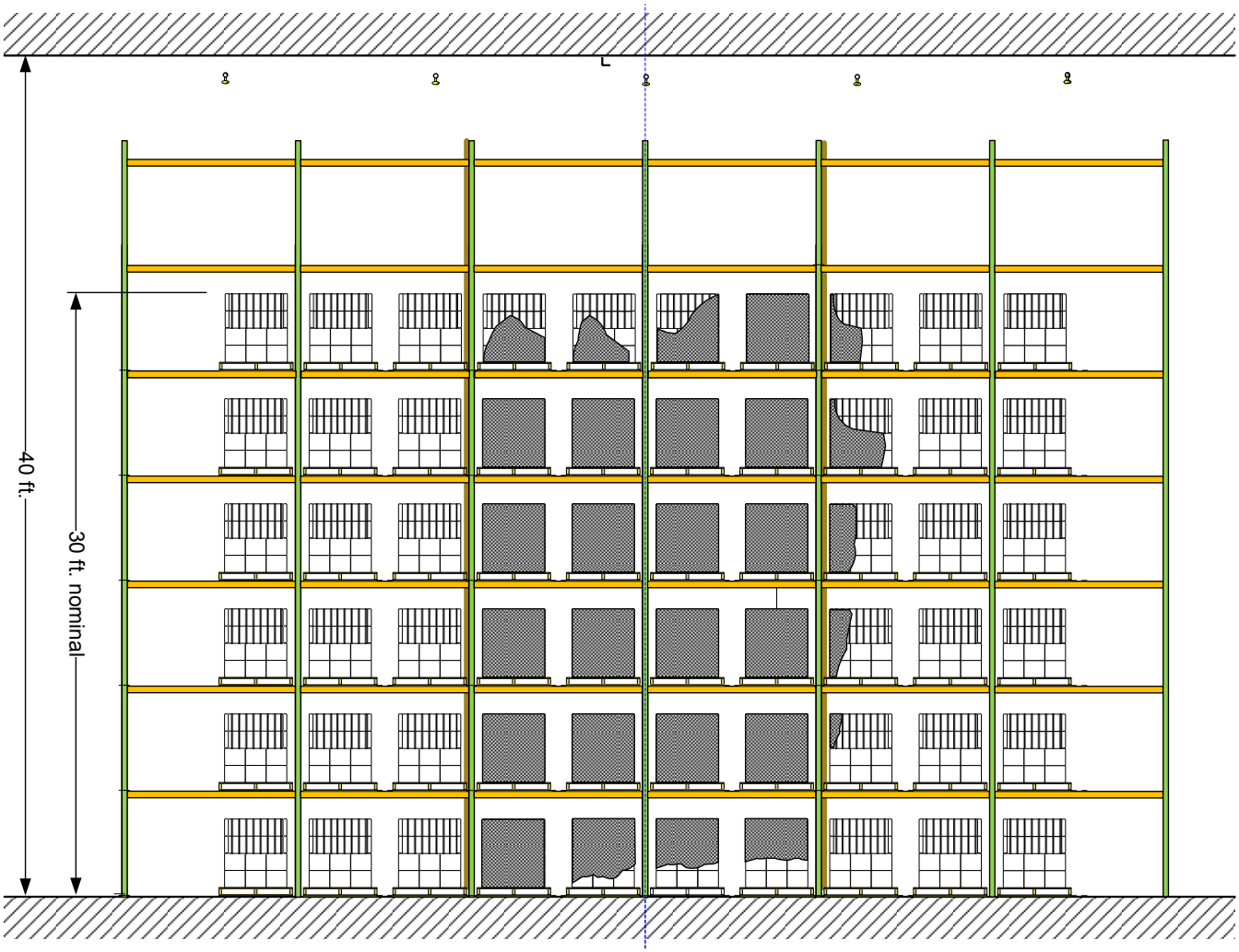


Figure 18 Damage Assessment - Elevation View of South Main Array

9. SUMMARY

9.1 General

A large scale fire test was conducted to develop data regarding the level of protection provided by ESFR sprinklers installed to protect a double- row rack arrangement of exposed, expanded Group A plastics stored 30 ft. high under a 40 ft. ceiling with vertical barriers installed within the rack array. No transverse flue space blocking was used in the test.

The ignition of the test commodity created a fire that grew very rapidly both vertically and horizontally. In the test, the operation of the first sprinkler occurred at less than 1 minute after ignition. A total of 7 sprinklers operated with the last sprinkler operating at 1 minute 28 seconds after ignition. The fire breached both of the vertical barriers located immediately to the east or west of the ignition; however, the barriers were observed to inhibit horizontal fire travel to the extremities of the main test array. Where breaching of the vertical barriers occurred during the test, it was observed that the fire travelled around the barrier at the aisle face where the commodity extended approximately 4 inches beyond the face of the uprights or vertical barriers.

There was no ignition of the target commodity across the 8 ft. aisle, although partial melting of the commodity was witnessed due to the intensity of the radiation from the main rack array.

The maximum 1-minute average steel temperature at the ceiling above the ignition was 127 °F.

Test parameters and results are summarized in Table 2.

Table 2 Test Parameters and Results

Test Date	June 8, 2013
Test Parameters	
Storage Type	Double Row Rack
Commodity Type	Exposed Expanded Group A Plastic (Bagged Meat Trays on Hardwood Pallets)
Pallet Type	2 way entry, stringer, hardwood
Vertical Barriers	16 ft. on center - Main Array (3/8 in. plywood)
Horizontal Blocking of Transverse Flues in Main Array (non-combustible)	None
Length of Main Storage Array, ft.	40
Nominal Storage Height, ft.	30
Ceiling Height, ft.	40
Nominal Clearance, ft.	10
Aisle Width, ft.	8
Ignition Location	Under 1 Sprinkler (offset)
Sprinkler Systems	Ceiling Only (no in-rack sprinklers)
Sprinkler Orientation	Pendent
Deflector to Ceiling, in.	14
Sprinkler Spacing, sprinkler by branchline ft. by ft.	10 by 10
Temperature Rating, F	214
Sprinkler Type	ESFR
Nominal Sprinkler Discharge Coefficient K, gpm/psig $^{0.5}$	25.2
Nominal Discharge Density, gpm/ft^2	1.95
Nominal Discharge Pressure, psig	60
Test Results	
Length of Test, minutes	31
First Sprinkler Operation Time, min:sec	0:47
Last Sprinkler Operation Time, min:sec	1:28
Number of Operated Sprinklers	7
Peak Gas Temperature at Ceiling Above Ignition, °F	414
Maximum 1 minute Average Gas Temperature at Ceiling Above Ignition, °F	191
Peak Steel Temperature at Ceiling Above Ignition, °F	133
Maximum 1 minute Average Steel Temperature at Ceiling Above Ignition, °F	127
Fire Travel to Extremities of Test Array	No

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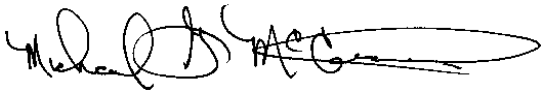

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APPENDIX A

Temperature, Flow and Pressure Graphs

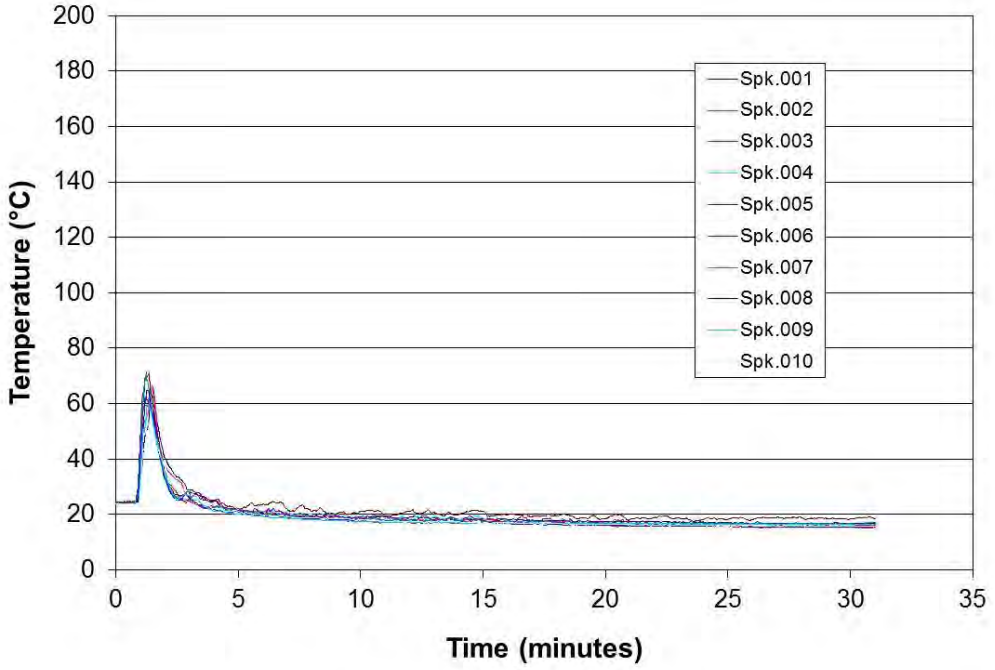

Figure A- 1 Ceiling Sprinklers 1 through 10

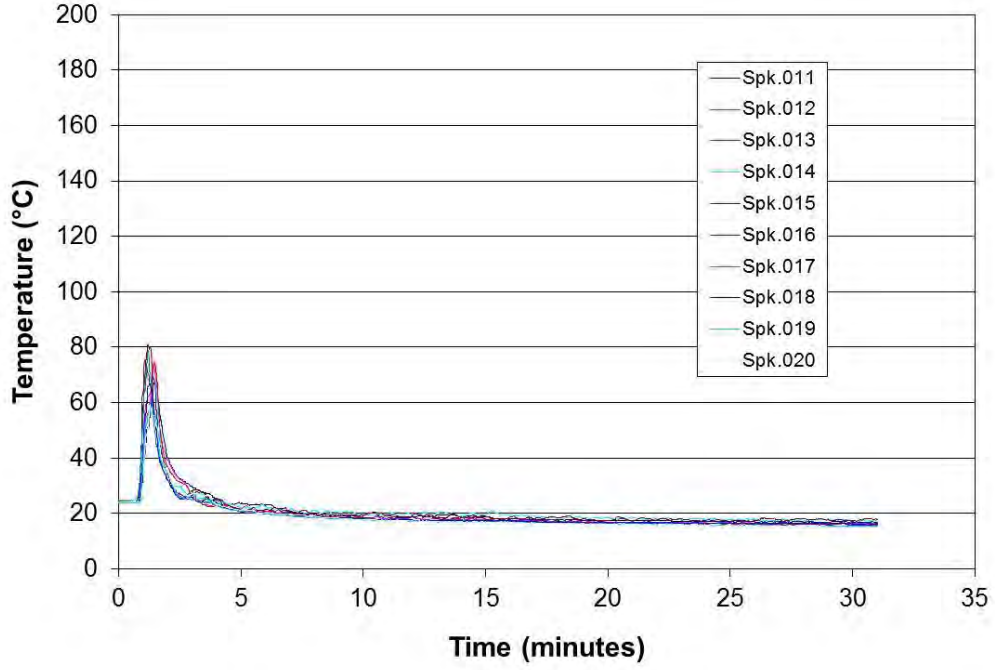

Figure A- 2 Ceiling Sprinklers 11 through 20

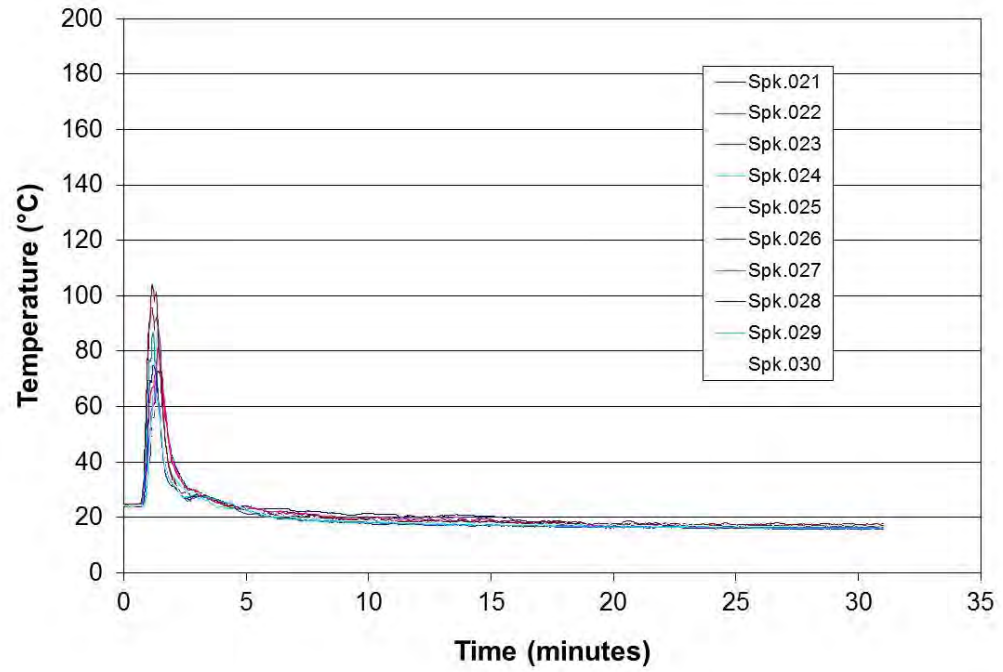

Figure A- 3 Ceiling Sprinklers 21 through 30

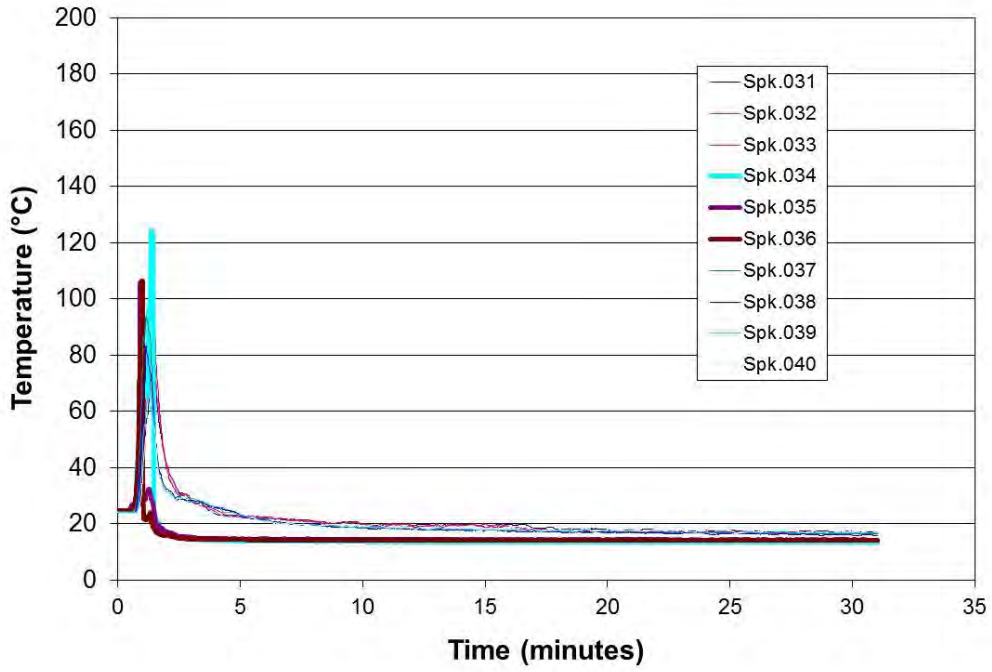

Figure A- 4 Ceiling Sprinklers 31 through 40

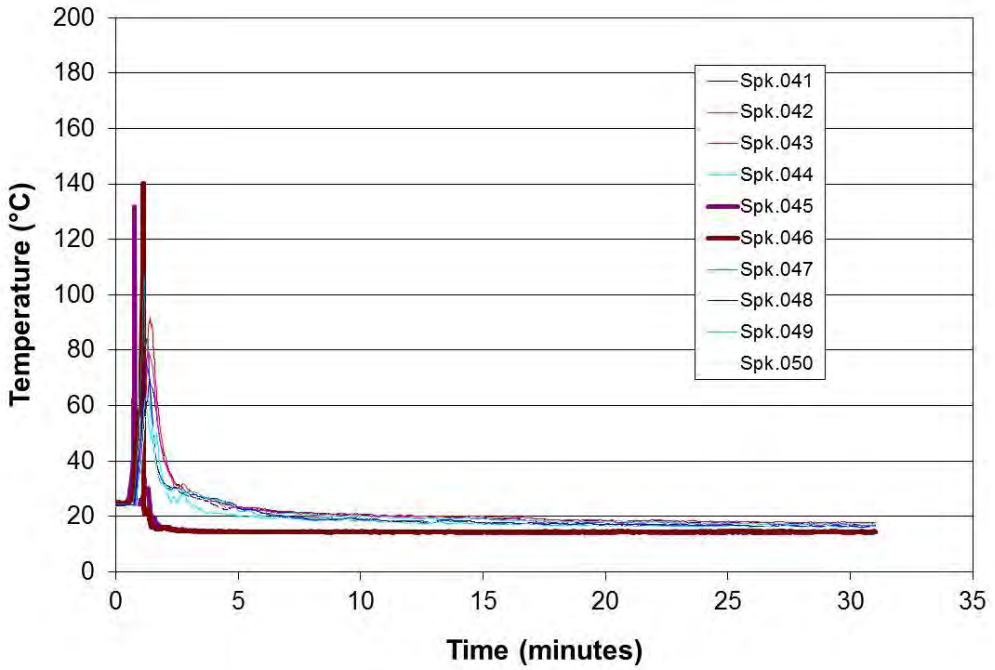

Figure A- 5 Ceiling Sprinklers 41 through 50

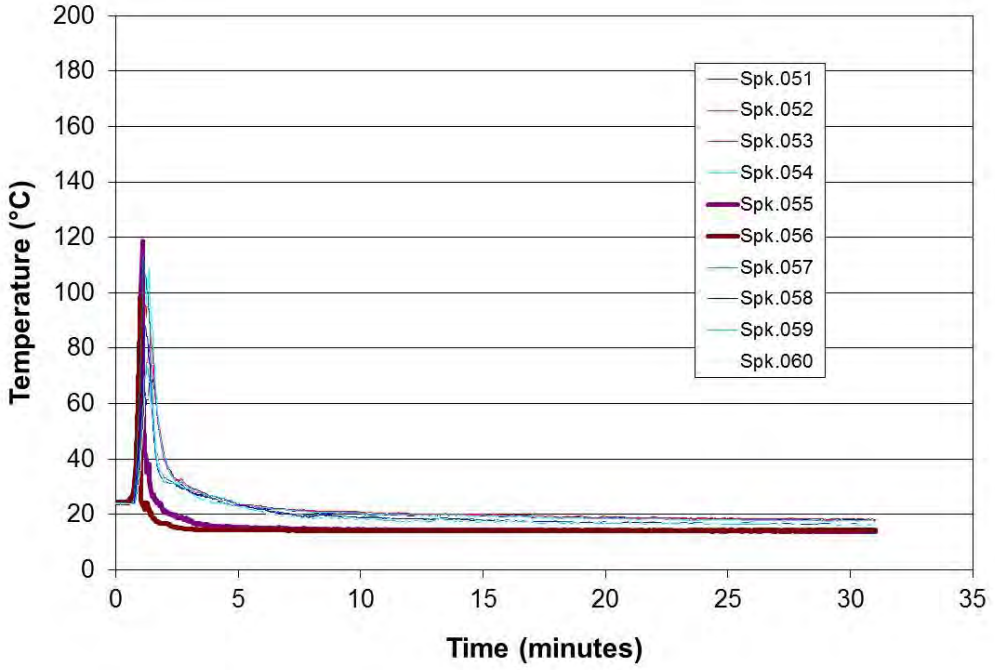

Figure A- 6 Ceiling Sprinklers 51 through 60

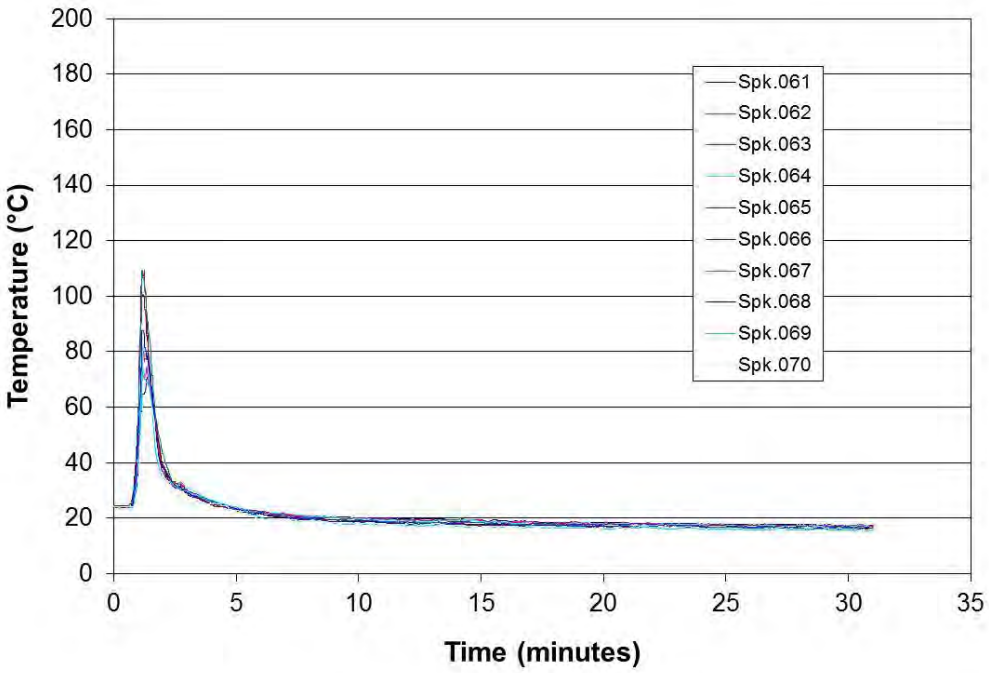

Figure A- 7 Ceiling Sprinklers 61 through 70

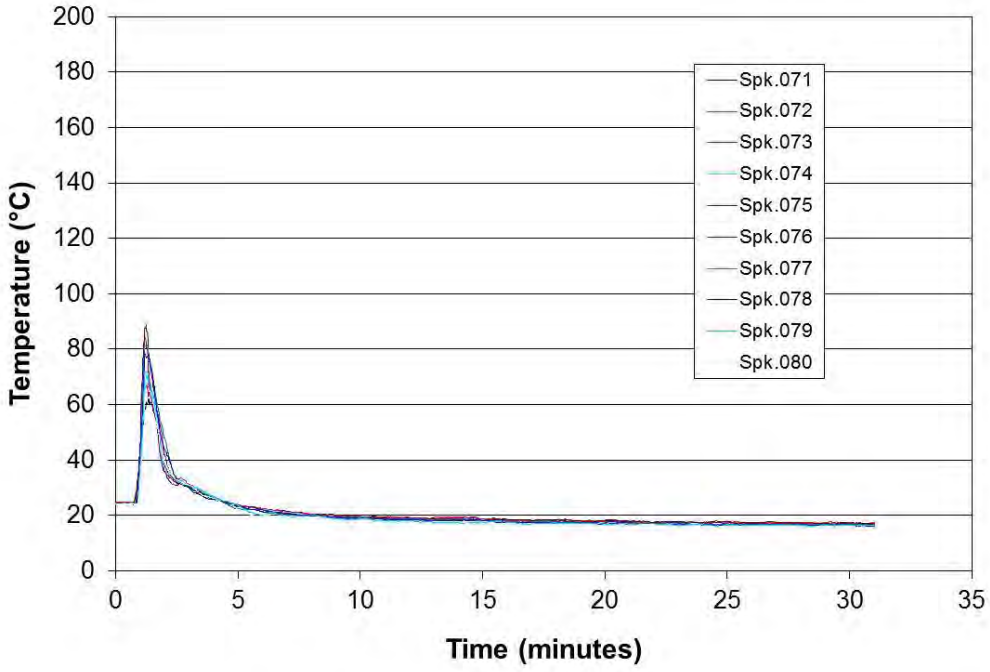

Figure A- 8 Ceiling Sprinklers 71 through 80

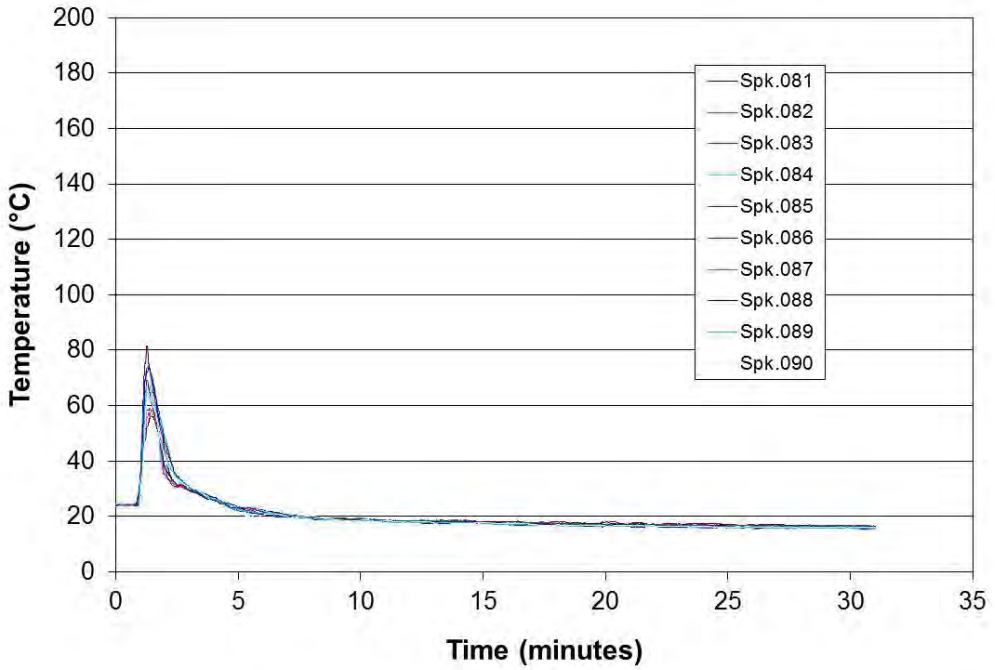

Figure A- 9 Ceiling Sprinklers 81 through 90

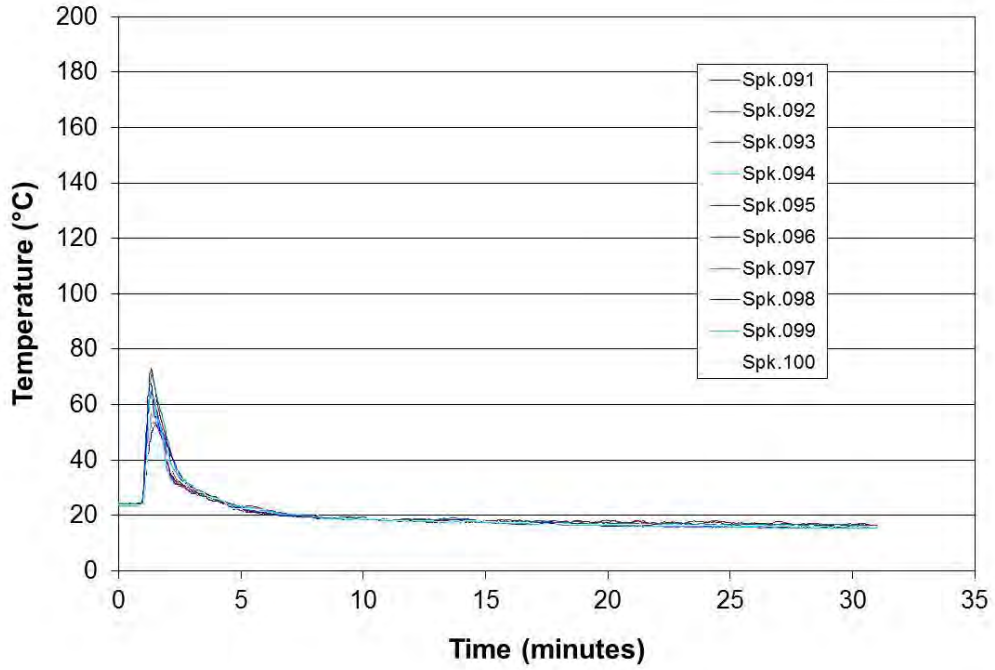

Figure A- 10 Ceiling Sprinklers 91 through 100

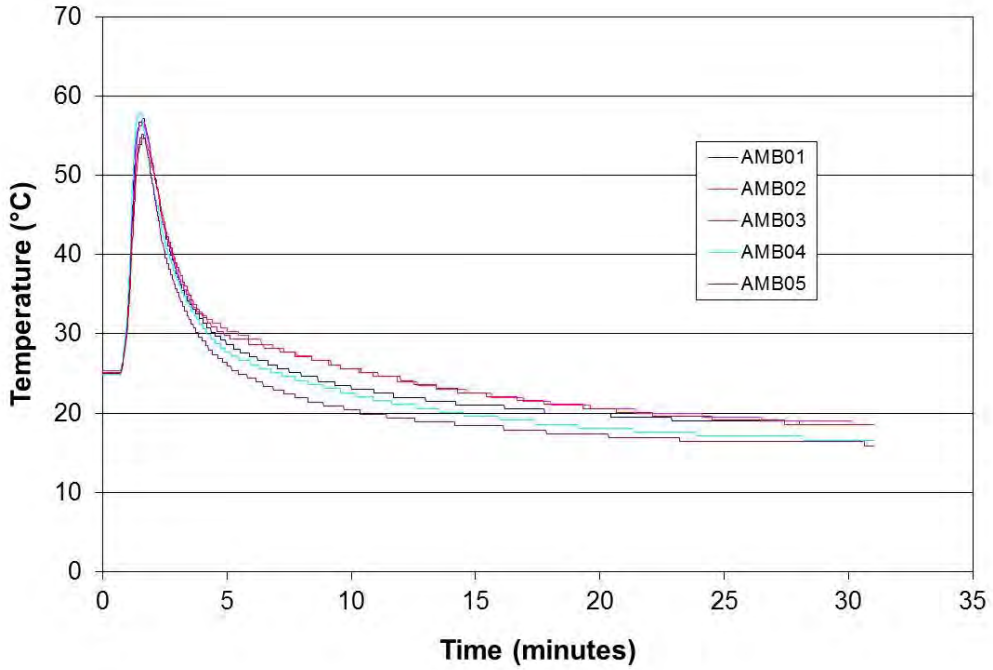

Figure A- 11 Ceiling Steel Beam Temperature Above Ignition

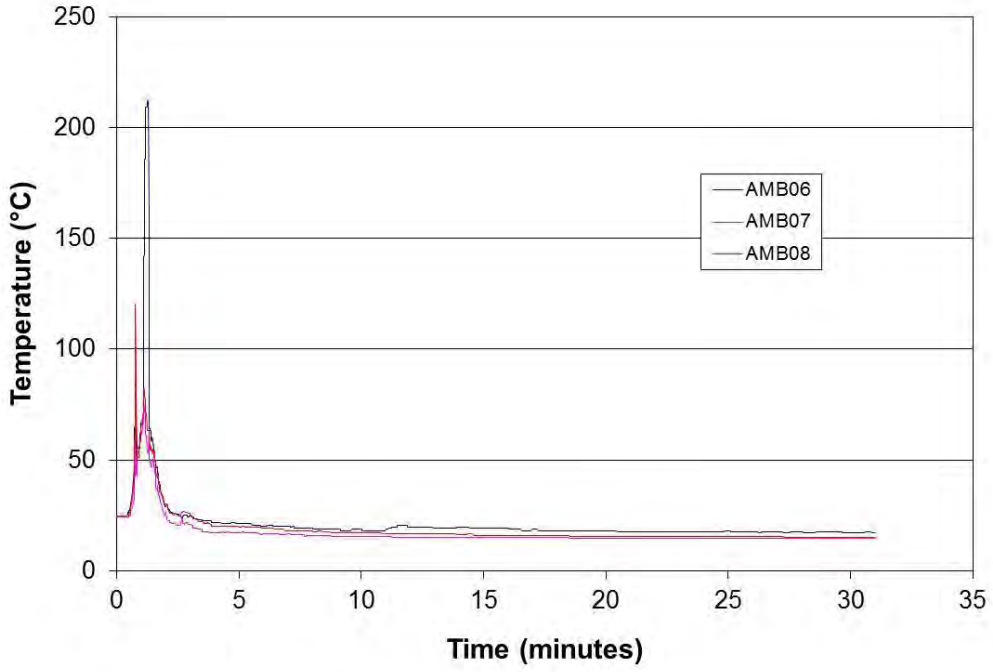

Figure A- 12 Ceiling Gas Temperature Above Ignition

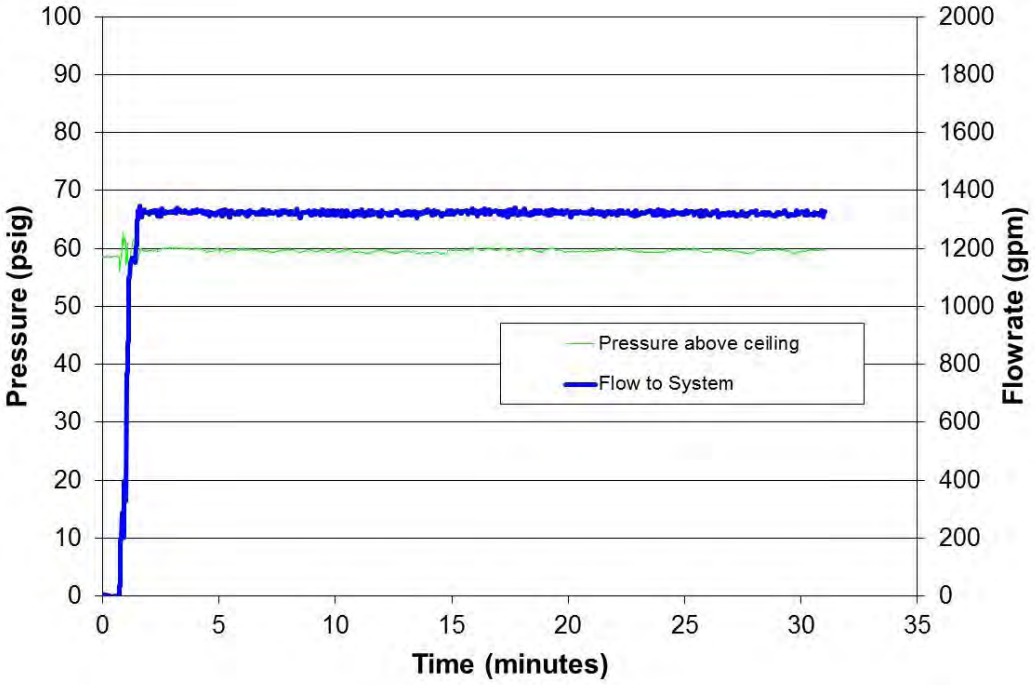

Figure A- 13 Ceiling Sprinkler System Flow rate and Pressure

APPENDIX B

Damage Assessment Photographs

Figure B- 1 Overall View - From Southeast

Figure B- 2 Overall View - From Northwest

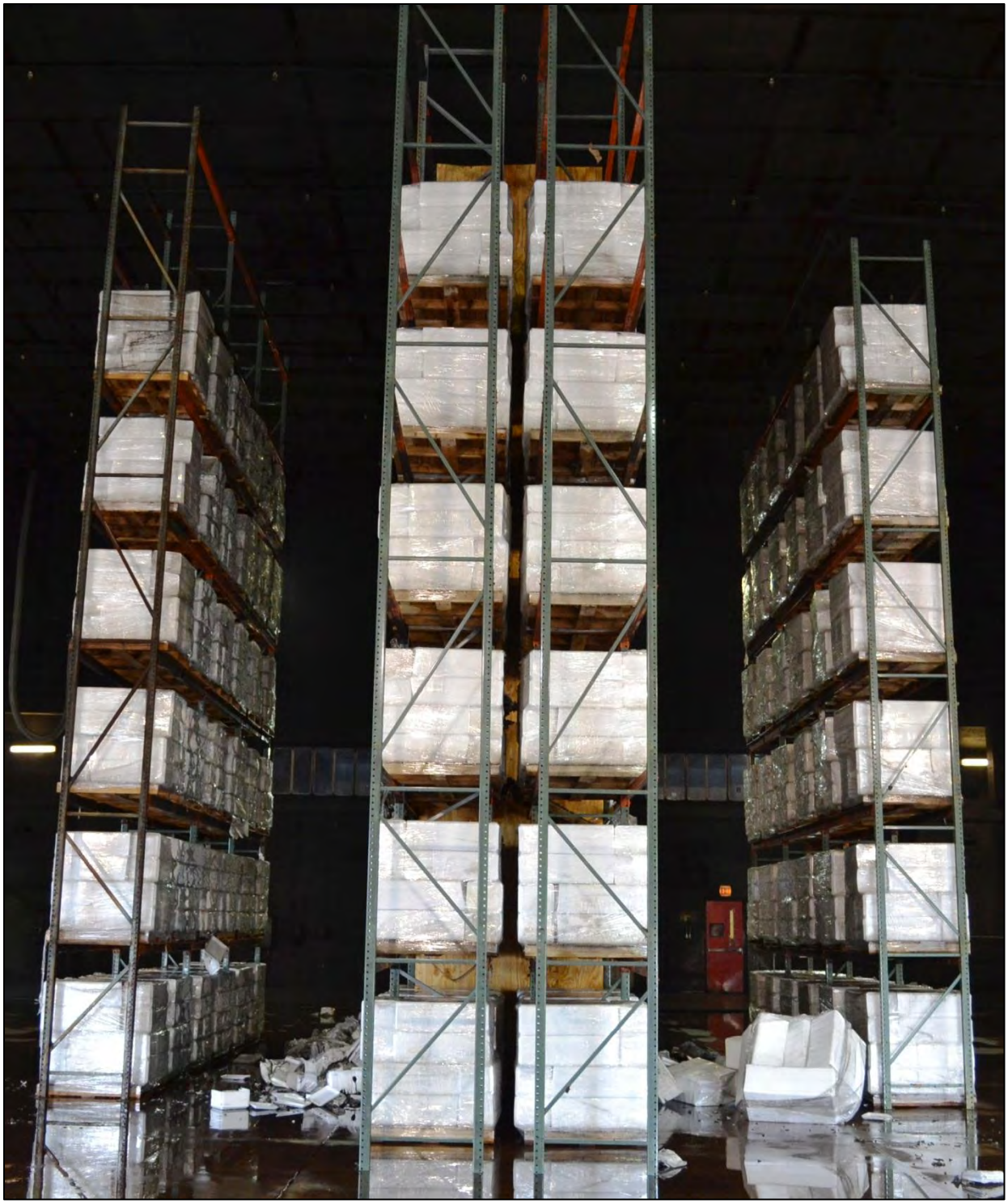

Figure B- 3 Overall View - From West

Figure B- 4 Overall View - From East

Figure B- 5 View of North Main Array

Figure B- 6 View of South Main Array

Figure B- 7 View of Combustible Barriers from the Southeast with Commodity Removed

Figure B- 8 View of Combustible Barriers from the Southeast with Commodity Removed