SPECIAL SERVICES INVESTIGATION INVOLVING WATER ADDITIVES THROUGH SPRINKLERS TO EVALUATE THE PROTECTION OF RUBBER TIRES

Prepared by

Underwriters Laboratories Inc.

Project 02NK41689, NC4432

for

MICHELIN TIRE

April 30, 2003

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EXECUTIVE SUMMARY

Three fire tests were conducted to develop data relative to the fire protection of rubber tires on pallets using tread and sidewall stacking configurations and water additives. The work was conducted using a wet pipe ceiling sprinkler system arranged to deliver water, or water/additive mixtures to the sprinklers upon operation.

One hundred pendent sprinklers were positioned on a 10 by 10-ft spacing. The sprinklers had a flow coefficient (k) equal to 11.2 gpm/$(psi)^{1/2}$. The sprinkler temperature rating was 286°F with a standard response element. The deflector was positioned 13-in. below the ceiling.

For two of the tests, the sprinkler system was supplied with an aqueous solution consisting of a 3% UL Listed wetting agent identified as Coldfire manufactured by FireFreeze Worldwide.

The storage height of the commodity was a nominal 25-ft under a nominal 30-ft ceiling. The ignition was located under four sprinklers for each test.

Test 1 evaluated tread storage with water only and operated 18 sprinklers. Maximum one-minute average steel temperature above ignition exceeded 1000° F in test 1. Test 2 evaluated sidewall storage with the water additive and operated 13 sprinklers. Test 3 evaluated tread storage with water additive and operated 18 sprinklers.

A summary of the parameters and results is presented in Table E1. A complete description of the testing is presented in the following report.

Table E 1. Test Parameters and Results

FIRE TEST DATE	**10/17/02**	**10/23/02**	**10/29/02**
TEST NO.	**1**	**2**	**3**
TEST CODE	**10170202**	**10230202**	**10290202**
PARAMETERS			
Ambient Indoor Temp. °F	64	67	65
Storage & Commodity Type	Rubber tires on tread	Rubber tires on sidewall	Rubber tires on tread
Nominal Storage Height (ft)	20	24	20
Nominal Ceiling Height (ft)	27	28	27
Nominal Clearance (ft)	6	3	6
Ignition Location	Between four	Between four	Between four
Ceiling Sprinkler	Pendent	Pendent	Pendent
Temperature Rating °F	286	286	286
Deflector to Ceiling (in)	13	13	13
Sprinkler Spacing (ft x ft)	10 x 10	10 x 10	10 x 10
Agent	Water	3% Coldfire aqueous solution	3% Coldfire aqueous solution
Flowing Pressure (psig)	29	29	29
RESULTS			
Length of Test (M:S)	30:00	30:00	30:00
First Ceiling Sprinkler Operation (M:S)	03:12	03:31	02:56
Last Recorded Ceiling Sprinkler Operation During Test Period (M:S)	16:29	21:33	07:30
Number of Operated Ceiling Sprinklers	18	13	18
Peak Gas Temperature at Ceiling Above Ignition °F	1245	1768	1513
Maximum 1 Minute Average Gas Temperature at Ceiling Above Ignition °F	1423	1120	1142
Peak Steel Temperature at Ceiling Above Ignition °F	1274	599	655
Maximum 1 Minute Average Steel Temperature Above Ignition °F	1254	593	633
Fire Jump Across Aisle	No	NA	NA

NOTE

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1 INTRODUCTION

1.1 General

This Test Report describes the Special Service Investigation conducted for The Michelin Corporation to investigate fires occurring within the storage of rubber tires on pallets.

The information obtained by this investigation will be provided only to The Michelin Corporation for their use in evaluation of the fire protection issues concerning rubber tires and the use of wetting agents in the fire sprinkler water supply. No conclusions will be made from the data obtained.

1.2 Purpose

The sole purpose of this Special Service Investigation was to develop data relative to the protection of storage of rubber tires using a wet pipe ceiling sprinkler system. For two of the tests, the sprinkler system was supplied with an aqueous solution consisting of a 3% UL Listed wetting agent identified as Coldfire manufactured by FireFreeze Worldwide.

The information obtained from this investigation will be used only in assessing the degree of protection provided by ceiling sprinklers arranged as specified. The data developed may be used by The Michelin Corporation only.

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 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.

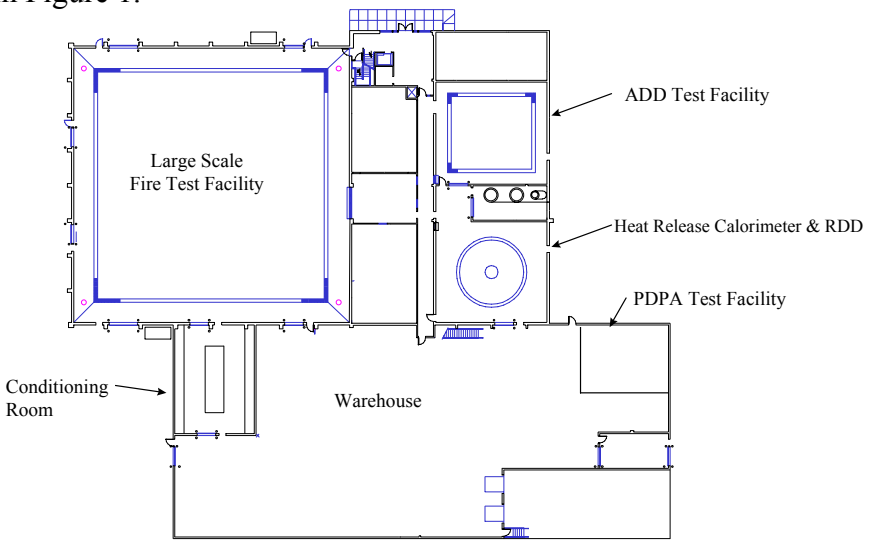


Figure 1. Test Facility

The fire tests were conducted in a 120 by 120 by 54-ft. high room fitted with a 100 by 100-ft. adjustable height ceiling set to a height of 30 feet.

The test room was equipped with an exhaust system through a regenerative, thermal-oxidizing smoke abatement system. Make-up air was provided through four inlet ducts positioned along the walls of the test facility.

The floor of the test facility was smooth, flat and surrounded with a grated drainage trench to insure adequate drainage from the test area. The water runoff from the suppression system drain was collected through an 180,000-gallon water treatment system.

3 EQUIPMENT AND INSTRUMENTATION

3.1 Ceiling Sprinkler Systems

A closed head, wet pipe, automatic sprinkler system was positioned below the movable smooth, flat, non-combustible ceiling and arranged to operate at the pressure required for the test.

For the first test, one hundred pendent sprinklers, with a discharge coefficient K=11.2, a 286°F temperature rating, and a standard response element were installed on a 10 by 10-ft. spacing with the deflector positioned 13-in. from the ceiling.

For the second test, one hundred pendent sprinklers, with a discharge coefficient K=11.2, a 286°F temperature rating, and a standard response element were installed on a 10 by 10-ft. spacing with the deflector positioned 13-in. from the ceiling. The sprinkler system was supplied with an aqueous solution consisting of a 3% UL Listed wetting agent identified as Coldfire manufactured by FireFreeze Worldwide.

For the third test, one hundred pendent sprinklers, with a discharge coefficient K=11.2, a 286°F temperature rating, and a standard response element were installed on a 10 by 10-ft. spacing with the deflector positioned 13-in. from the ceiling. The sprinkler system was supplied with an aqueous solution consisting of a 3% UL Listed wetting agent identified as Coldfire manufactured by FireFreeze Worldwide.

The sprinklers were supplied through a looped piping system consisting of 2 ½-in. diameter branch lines.

A plan view of the sprinkler and instrumentation layout is shown below in Figure 2.

A close-up photo of the sprinkler is shown in Figure 3.

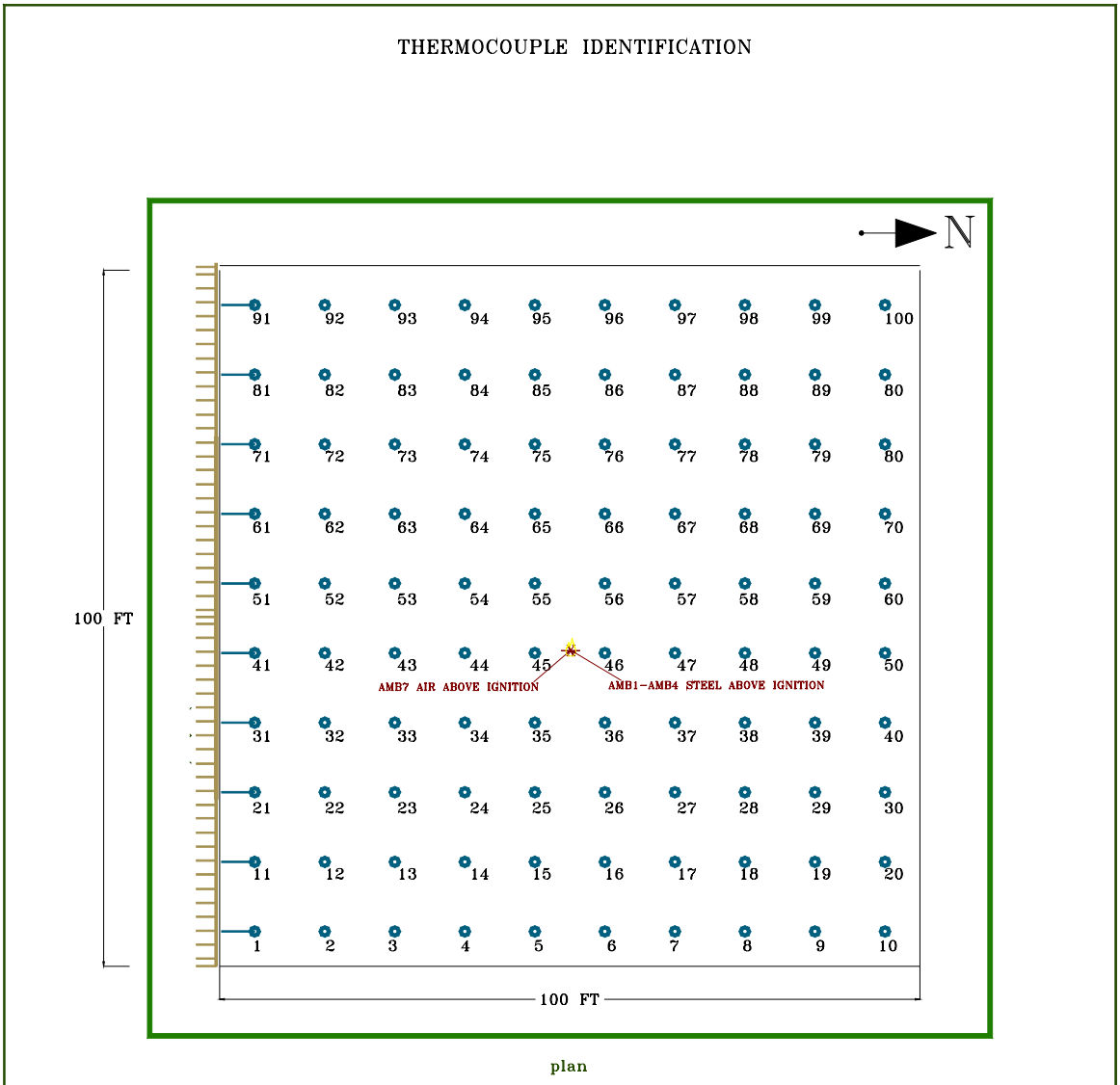


Figure 2. Thermocouple and Sprinkler Locations

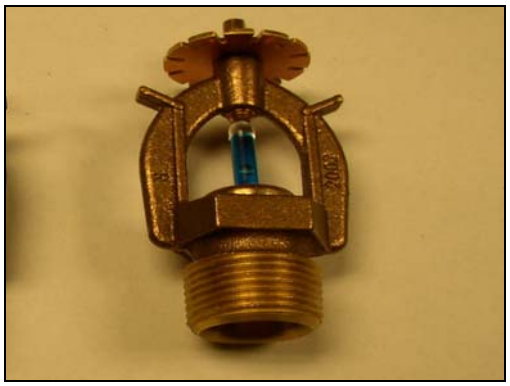


Figure 3. K=11.2 Pendent Sprinkler

3.2 Wetting Agent

A separate pump, utilizing motor speed control was used to deliver a stream of wetting agent concentrate into the water piping system. The flow of concentrate was controlled via a logic controller, which receives input from flow meters positioned on both the water line and the concentrate line, and outputs a corresponding signal to the concentrate motor speed controller. The system was arranged to provide a 3% mix ratio to the flowing sprinklers.
Photos of the pump set-up are shown in Figure 4.

3.3 Instrumentation

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

- 1/16 in. diameter, Type K inconel sheathed thermocouples located below the ceiling adjacent to each sprinkler to record ceiling temperatures for fire tests conducted in the 120 by 120-ft test cell.
- 1/16 in. diameter, Type K inconel sheathed thermocouple located 6-in. below the ceiling above the ignition location.
- Five 1/16 in. diameter, Type K inconel sheathed thermocouples embedded in a 50.5-in. long steel beam attached to the bottom of the ceiling directly above the fire.
- Bristol Babcock Model 250815B pressure transducers in a 0-300 psi range were used to measure the water pressure in the sprinkler system.
- Fischer Porter model X3311SFD20 – 12 inch magnetic flow meter in the 0-3200 gallons per minute (gpm) range were used to measure the water flow rate.
- Stopwatches and timing devices located within the data acquisition system were used to monitor and record significant events during the fire tests.
- Video and Infrared cameras were used to capture and record images of the fire test.

Figure 4. Pump Set-Up

4 TEST ARRANGEMENT

4.1 Stored Commodity

The commodity consisted of the following:

RUBBER TIRES – The sample consisted of rubber tires stored on tread or sidewall. Each pallet was a nominal 60-in. tall. Samples are shown in Figure 5.

On Tread On Sidewall

Figure 5. Rubber Tire Storage Arrangement

4.2 Target Commodity

The target commodity consisted of Class II commodity set across an 8-ft aisle space on the east side of the test array.

CLASS II – The Class 2 commodity was constructed from double tri-wall corrugated cardboard cartons with five sided steel stiffeners inserted for stability. Outer carton measurements were 42 by 42 by 42-in. tall on a single 42 by 42 by 5-in. tall hardwood two-way entry pallet. A sample is shown in Figure 6.

Figure 6. Standard Class II Commodity

5 FIRE TEST NO. 1

5.1 Storage Arrangement

The first fire test was conducted with 18 stacks of palletized rubber tires, with each stack containing 4 pallets. A six-in. flue space separated the stacks. The tires were stored on the tread with 36 tires per pallet. The test layout is presented inFigure 7. The storage arrangement will contain 2592 tires and 72 portable racks.

5.2 Test Parameters

Commodity storage height of a nominal 20-ft was positioned under a 27-ft ceiling. The distance from the top of the commodity to the sprinkler deflector was nominally 6 feet.

One hundred sprinklers were installed on a 10 by 10-ft spacing for this test. The center of the array was positioned under four sprinklers.

Ignition was accomplished using four standard igniters constructed from a 3-in. diameter by 6-in. long cellulosic bundle soaked with 8 oz. of gasoline and wrapped in a polyethylene bag.

Room exhaust conditions were set at 30,000 cfm until the operation of the first sprinkler, and then increased to 60,000 cfm for the remainder of the test.

Photos of the arrangement are shown in Figure 8. The fire test and posttest damage photos are presented in Figure 9 and Figure 10 respectively.

Table 1. Test 1 Parameters

FIRE TEST DATE	**10/17/02**
TEST CODE	**10170202**
PARAMETERS	
Storage & Commodity Type	Rubber tires on tread
Nominal Storage Height (ft)	20
Nominal Ceiling Height (ft)	27
Nominal Clearance (ft)	6
Ignition Location	Between four
Ceiling Sprinkler	Pendent
Temperature Rating °F	286
Deflector to Ceiling (in.)	13
Sprinkler Spacing (ft x ft)	10 x 10
Agent	Water
Flowing Pressure (psig)	29

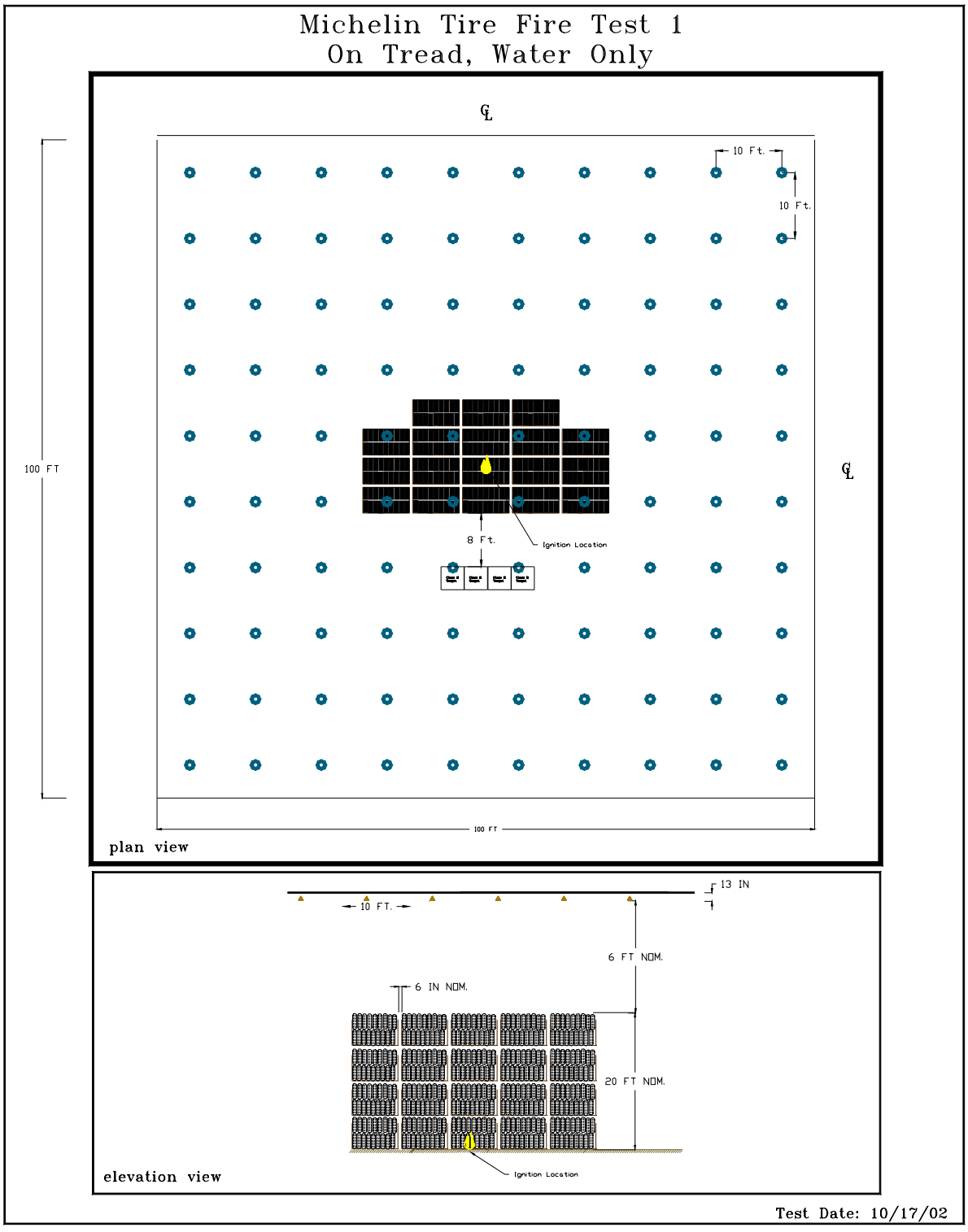
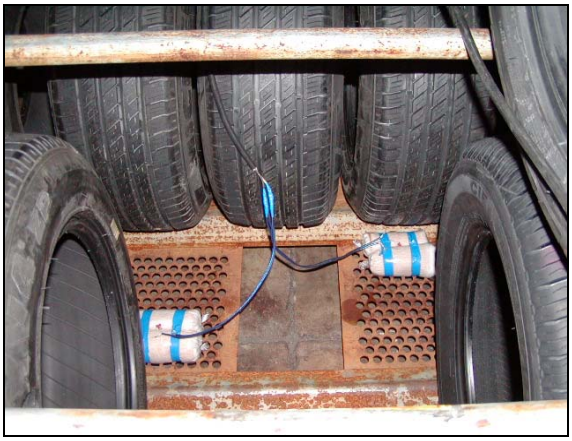


Figure 7. Test 1 Layout

North View

South East View

East View



Ignition Location

Figure 8. Test 1 Set-Up

Figure 9. Fire Test 1

Figure 10. Test 1 Posttest Damage

5.3 Test Results

Eighteen ceiling sprinklers operated. The first ceiling sprinkler operated at 03:12 after ignition and the last sprinkler operated at 16:29. There was no fire jump across the aisle to the target commodity.

Tabulated test results are presented in Table 2. A plan view of the sprinkler operation is presented in Figure 11.

Temperature data vs. time charts are presented in Appendix A.

Table 2. Test 1 Results

FIRE TEST DATE	**10/17/02**
TEST CODE	**10170202**
RESULTS	
Length of Test (M:S)	30:00
First Ceiling Sprinkler Operation (M:S)	03:12
Last Recorded Ceiling Sprinkler Operation During Test Period (M:S)	16:29
Number of Operated Ceiling Sprinklers	18
Peak Gas Temperature at Ceiling Above Ignition °F	1245
Maximum 1 Minute Average Gas Temperature at Ceiling Above Ignition °F	1423
Peak Steel Temperature at Ceiling Above Ignition °F	1274
Maximum 1 Minute Average Steel Temperature Above Ignition °F	1254
Fire Jump Across Aisle	No

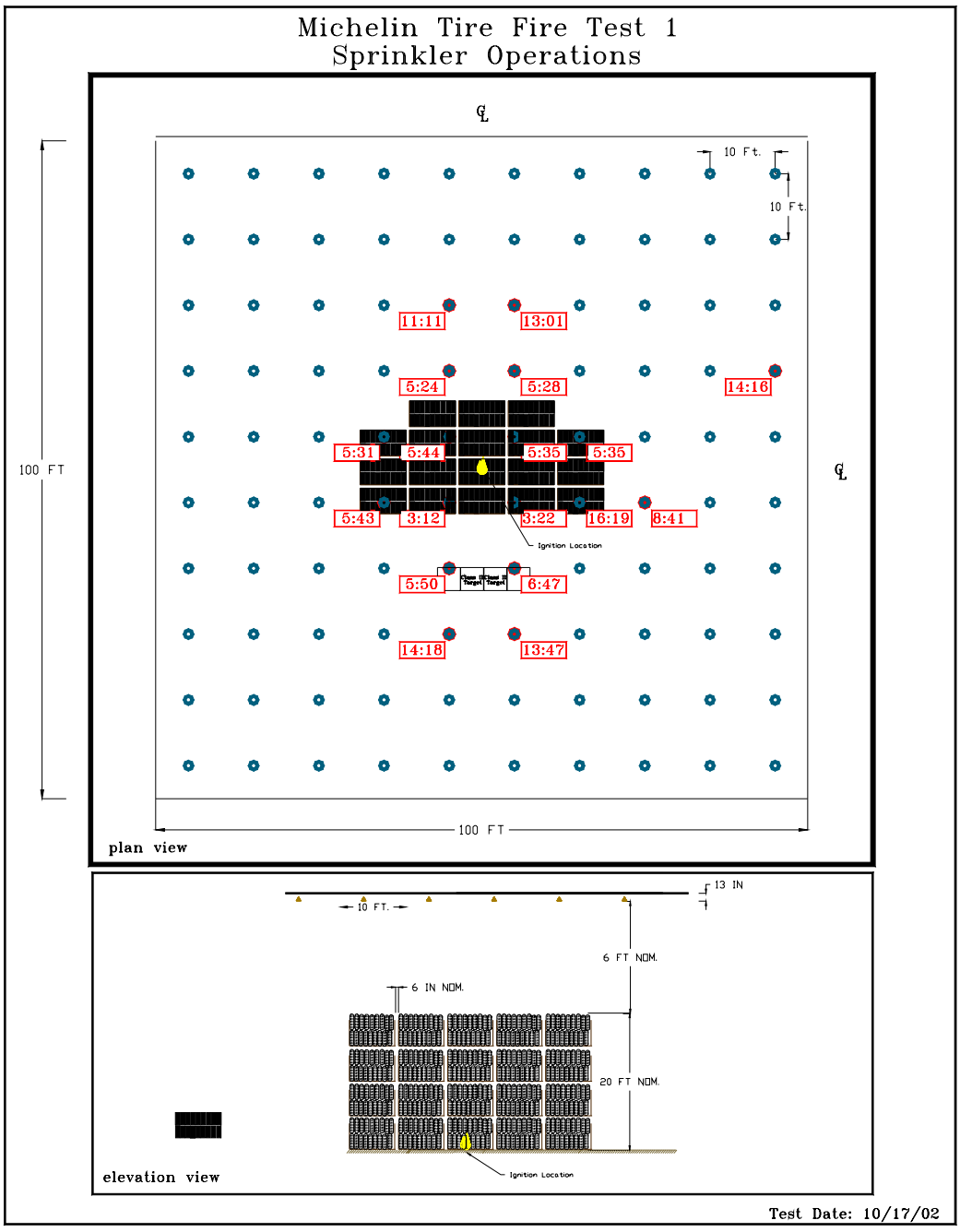


Figure 11. Test 1 Sprinkler Operation Times

6 FIRE TEST NO. 2

6.1 Storage Arrangement

The second fire test was conducted with 13 stacks of palletized rubber tires, with each stack containing 4 pallets. A six-in. flue space separated the stacks. The tires were stored on the tread with 63 tires per pallet. The test layout is presented in Figure 12. The storage arrangement contained 3276 tires and 52 portable racks.

6.2 Test Parameters

Commodity storage height of a nominal 24-ft was positioned under a 28-ft ceiling. The distance from the top of the commodity to the sprinkler deflector was nominally 3 feet.

One hundred sprinklers were installed on a 10 by 10-ft spacing for this test. The center of the array was positioned under four sprinklers.

Ignition was accomplished using four standard igniters constructed from a 3-in. diameter by 6-in. long cellulosic bundle soaked with 8 oz. of gasoline and wrapped in a polyethylene bag.

Room exhaust conditions were set at 30,000 cfm until the operation of the first sprinkler, and then increased to 60,000 cfm for the remainder of the test.

Photos of the arrangement are shown in Figure 13. The fire test photos and posttest damage photos are presented in Figure 14 and Figure 15 respectively.

Table 3. Test 2 Parameters

FIRE TEST DATE	**10/23/02**
TEST CODE	**10230202**
PARAMETERS	
Storage & Commodity Type	Rubber tires on sidewall
Nominal Storage Height (ft)	24
Nominal Ceiling Height (ft)	28
Nominal Clearance (ft)	3
Ignition Location	Between four
Ceiling Sprinkler	Pendent
Temperature Rating °F	286
Deflector to Ceiling (in.)	13
Sprinkler Spacing (ft x ft)	10 x 10
Agent	3% Coldfire aqueous solution
Flowing Pressure (psig)	29

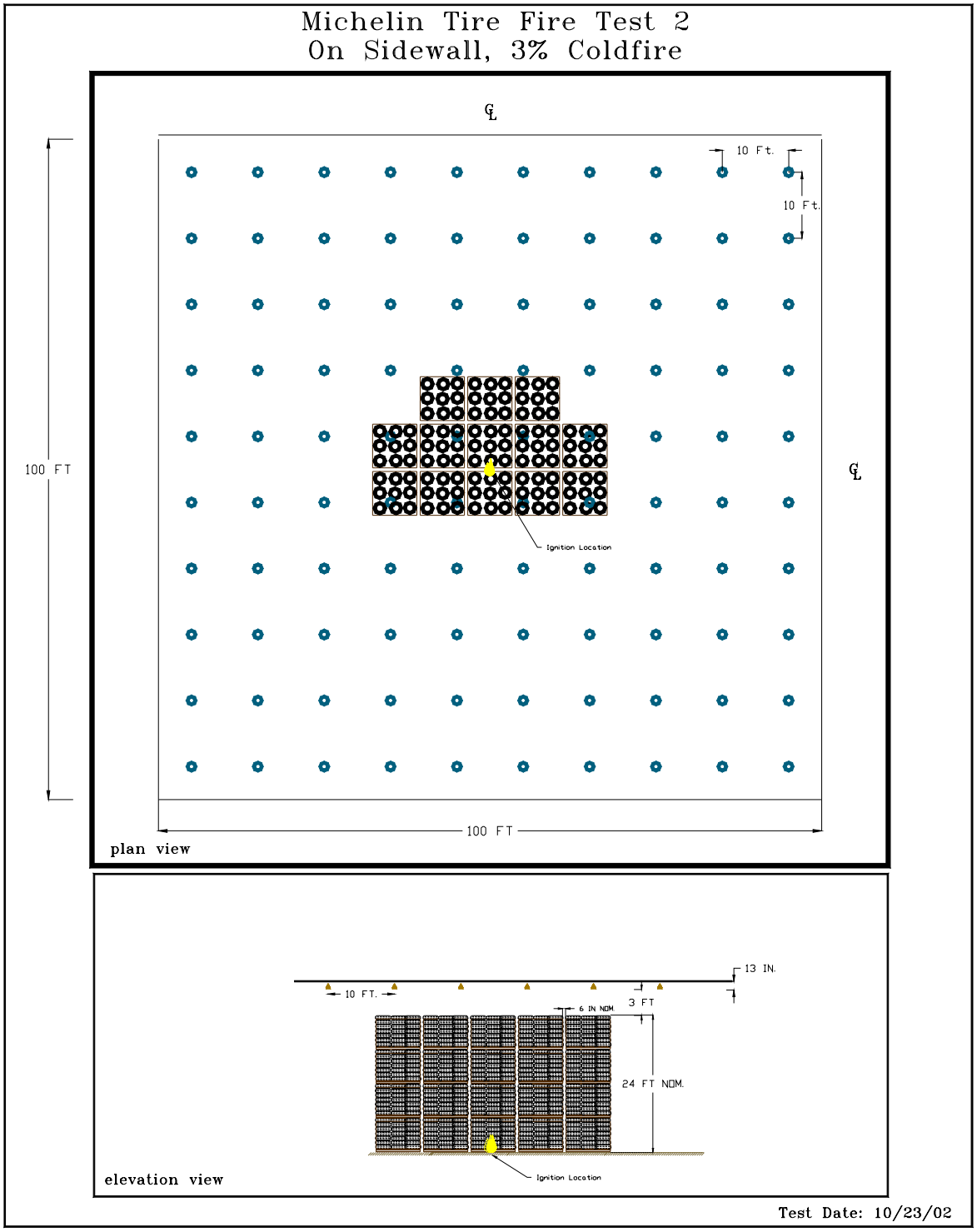


Figure 12. Test 2 Layout

North West View

South East View

Ignition Location

West View

East View

Figure 13. Test 2 Set-Up

Figure 14. Fire Test 2

Figure 15. Test 2 Posttest Damage

6.3 Test Results

Thirteen ceiling sprinklers operated. The first ceiling sprinkler operated at 03:31 after ignition and the last sprinkler operated at 21:33.

Tabulated test results are presented in Table 4. A plan view of the sprinkler operation is presented in Figure 16

Temperature data vs. time charts are presented in Appendix B.

Table 4. Test 2 Results

FIRE TEST DATE	**10/23/02**
TEST CODE	**10230202**
RESULTS	
Length of Test (M:S)	30:00
First Ceiling Sprinkler Operation (M:S)	03:31
Last Recorded Ceiling Sprinkler Operation During Test Period (M:S)	21:33
Number of Operated Ceiling Sprinklers	13
Peak Gas Temperature at Ceiling Above Ignition °F	1768
Maximum 1 Minute Average Gas Temperature at Ceiling Above Ignition °F	1120
Peak Steel Temperature at Ceiling Above Ignition °F	599
Maximum 1 Minute Average Steel Temperature Above Ignition °F	593

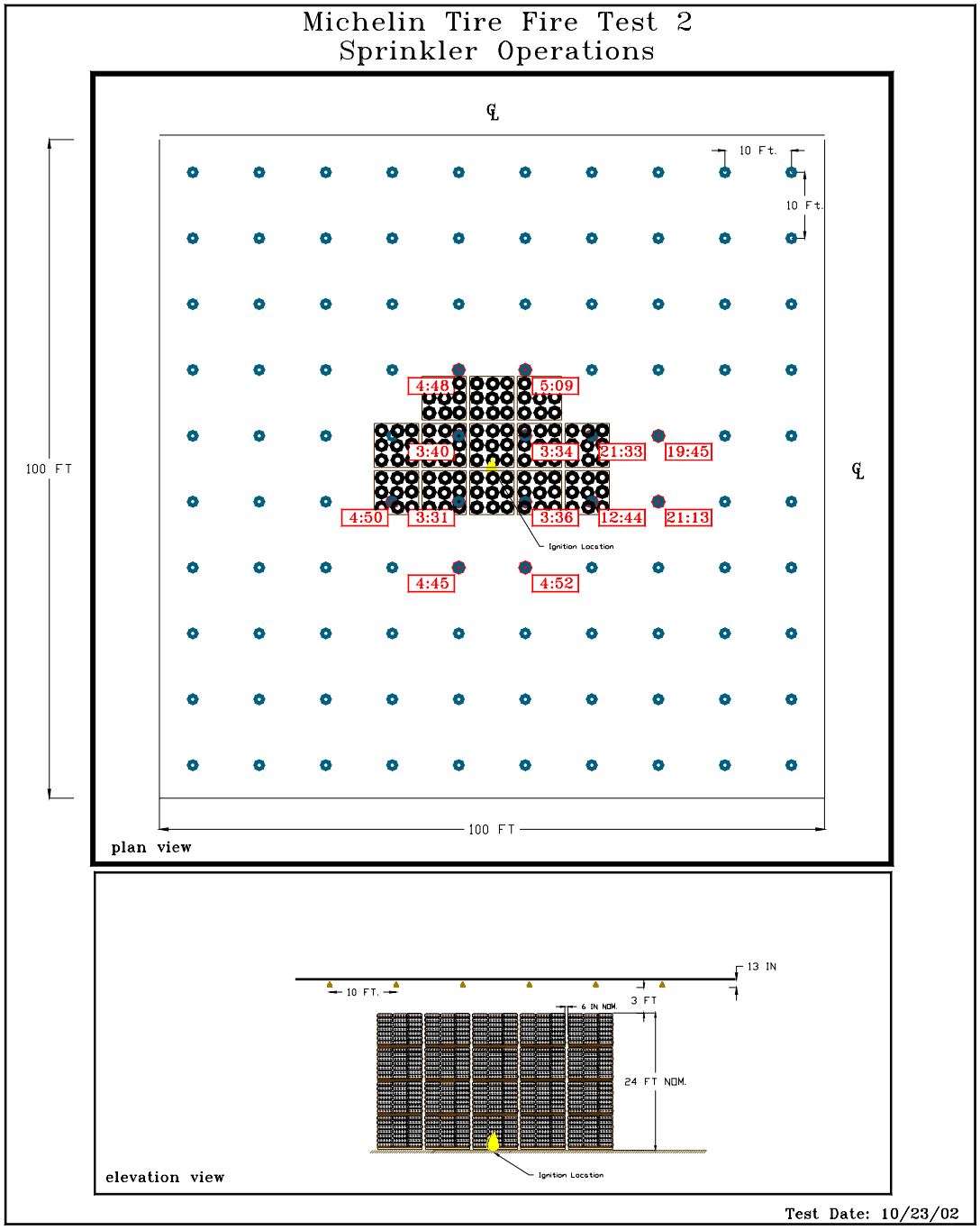


Figure 16. Test 2 Sprinkler Operation Times

7 FIRE TEST NO. 3

7.1 Storage Arrangement

The third fire test was conducted with 18 stacks of palletized rubber tires, with each stack containing 4 pallets. A six-in. flue space separated the stacks. The tires were stored on the tread with 36 tires per pallet. The test layout is presented in Figure 17 and is identical to that of Test 1. The storage arrangement will contain 2592 tires and 72 portable racks.

7.2 Test Parameters

Commodity storage height of a nominal 25-ft was positioned under a 30-ft ceiling. The distance from the top of the commodity to the sprinkler deflector was nominally 5 feet.

One hundred sprinklers were installed on a 10 by 10-ft spacing for this test. The center of the array was positioned under four sprinklers.

Ignition was accomplished using four standard igniters constructed from a 3-in. diameter by 6-in. long cellulosic bundle soaked with 8 oz. of gasoline and wrapped in a polyethylene bag.

Room exhaust conditions were set at 30,000 cfm until the operation of the first sprinkler, and then increased to 60,000 cfm for the remainder of the test.

Photos of the arrangement are shown in Figure 18. The fire test and posttest damage photos are presented in Figure 19 and Figure 20 respectively.

Table 5. Test 3 Parameters

FIRE TEST DATE	**10/29/02**
TEST CODE	**10290202**
PARAMETERS	
Storage & Commodity Type	Rubber tires on tread
Nominal Storage Height (ft)	20
Nominal Ceiling Height (ft)	27
Nominal Clearance (ft)	6
Ignition Location	Between four
Ceiling Sprinkler	Pendent
Temperature Rating °F	286
Deflector to Ceiling (in)	13
Sprinkler Spacing (ft x ft)	10 x 10
Agent	3% Coldfire aqueous solution
Flowing Pressure (psig)	29

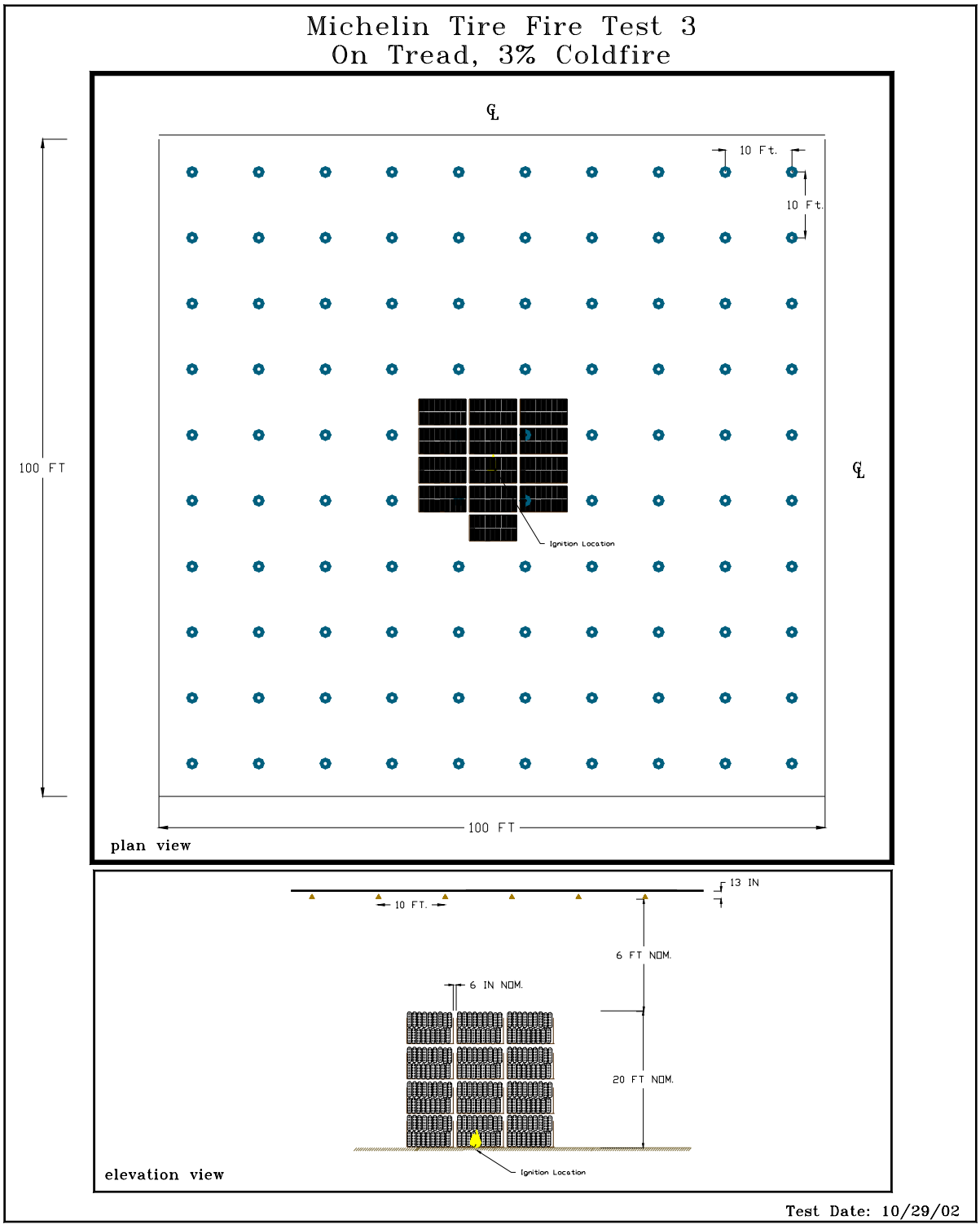
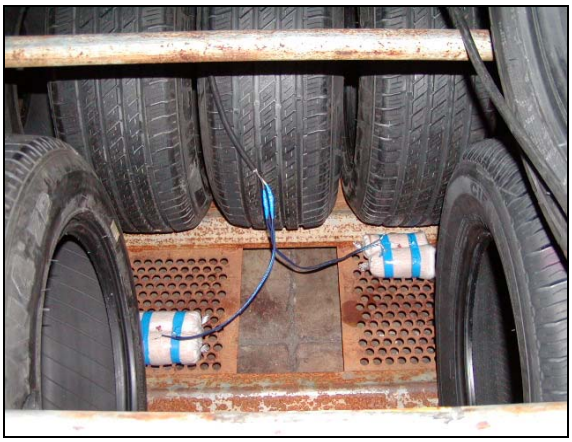


Figure 17. Test 3 Layout

Northwest View

West View



Ignition Location

Figure 18. Test 3 Set-Up

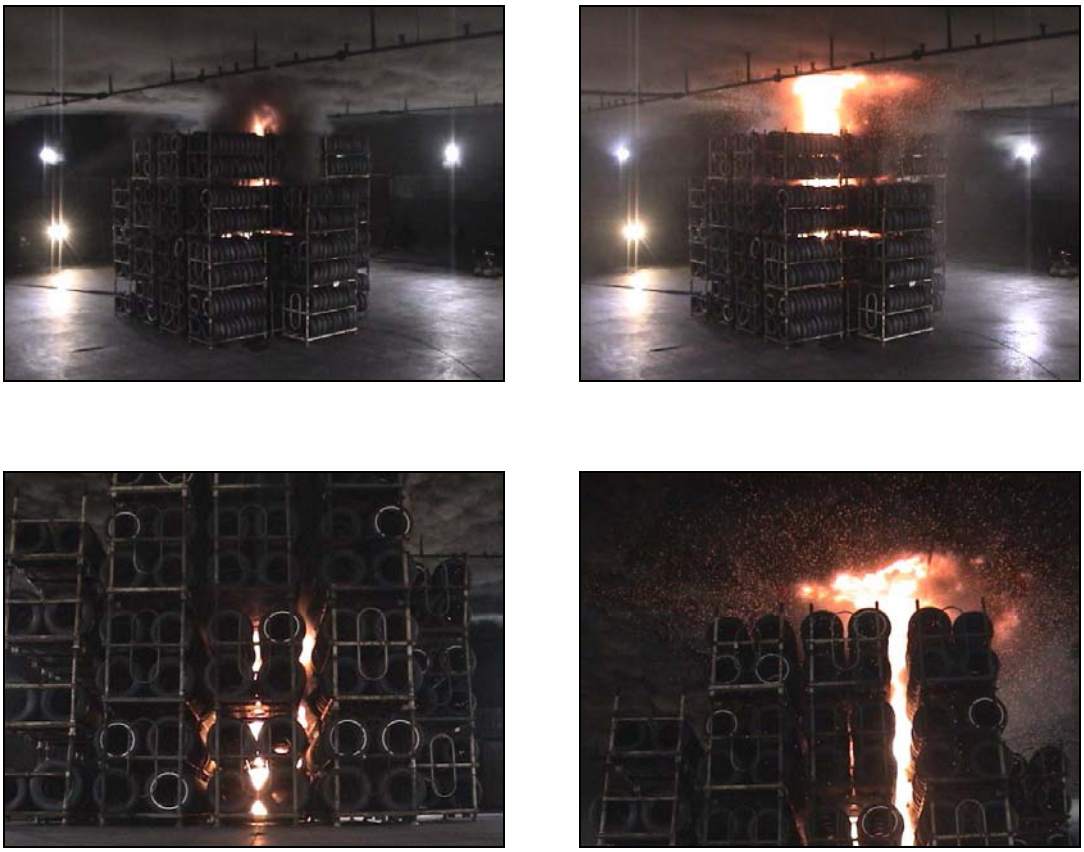


Figure 19. Fire Test 3

Figure 20. Test 3 Posttest Damage Results

7.3 Test Results

Eighteen ceiling sprinklers operated. The first ceiling sprinkler operated at 02:56 after ignition and the last sprinkler operated at 07:30. There was no fire jump across the aisle to the target commodity.

Tabulated test results are presented in Table 6. A plan view of the sprinkler operation is presented in Figure 21.

Temperature data vs. time charts are presented in Appendix C.

Table 6. Test 3 Results

FIRE TEST DATE	**10/29/02**
TEST CODE	**10290202**
RESULTS	
Length of Test (M:S)	30:00
First Ceiling Sprinkler Operation (M:S)	02:56
Last Recorded Ceiling Sprinkler Operation During Test Period (M:S)	07:30
Number of Operated Ceiling Sprinklers	18
Peak Gas Temperature at Ceiling Above Ignition °F	1513
Maximum 1 Minute Average Gas Temperature at Ceiling Above Ignition °F	1142
Peak Steel Temperature at Ceiling Above Ignition °F	655
Maximum 1 Minute Average Steel Temperature Above Ignition °F	633

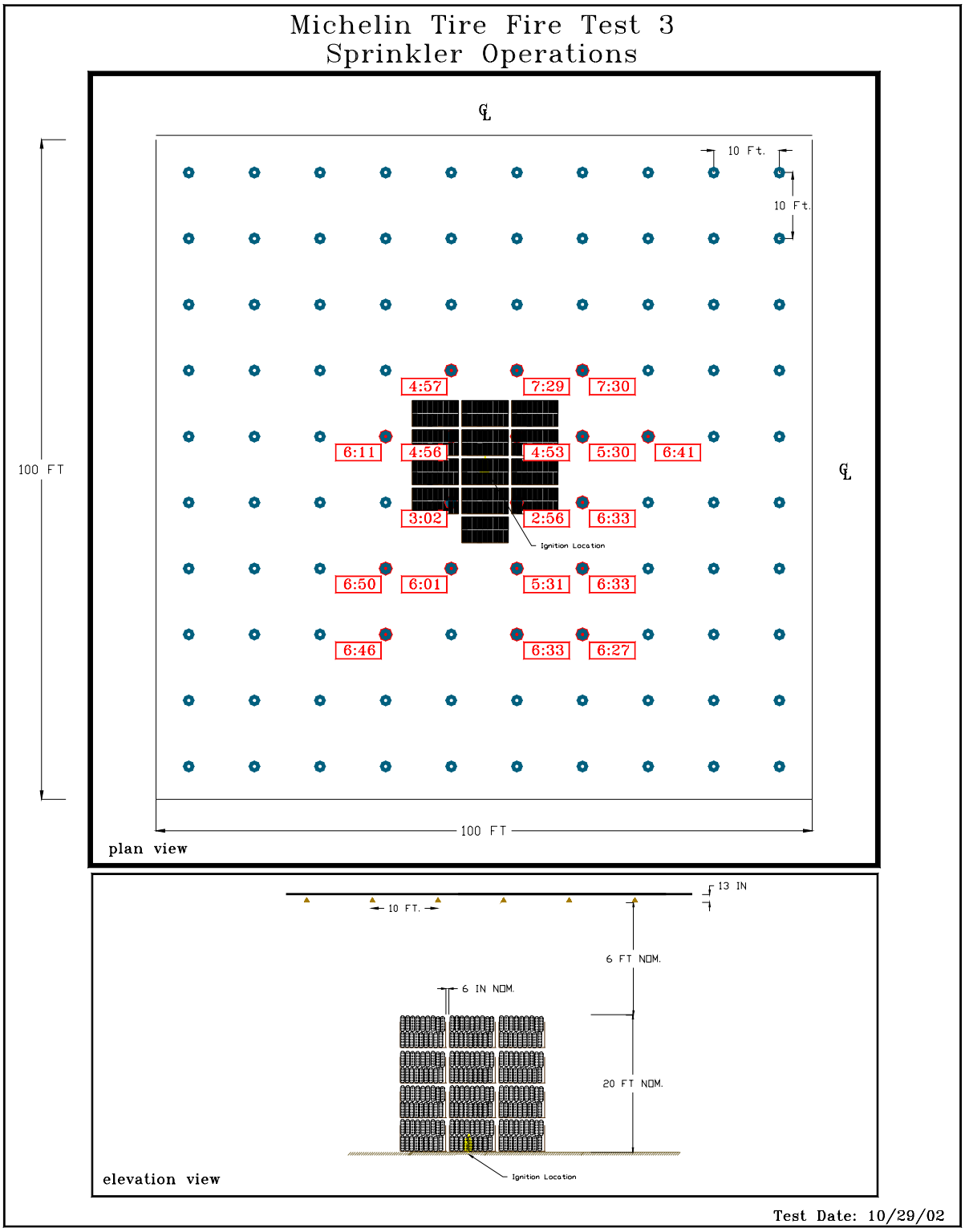


Figure 21. Test 3 Sprinkler Operation Times

8 SUMMARY

Three fire tests were conducted to develop data relative to the protection of rubber tires stored on pallets. Test 1 evaluated tread storage with water only and operated 18 sprinklers. Maximum one-minute average steel temperature above ignition exceeded 1000° F in test 1. Test 2 evaluated sidewall storage with the water additive and operated 13 sprinklers. Test 3 evaluated tread storage with water additive and operated 18 sprinklers.

If the maximum one-minute average air temperatures exceed 1600° F, or the maximum one-minute average steel temperatures exceed 1000° F there is an increased potential for changes to physical properties of steel. Damage to steel structural components could occur due to the heat. During test 1, with water only, the maximum one-minute average steel beam temperature above ignition exceeded 1000° F and was 621° F higher than that observed with test 3 which utilized the same storage configuration and resulted in the same number of operating sprinklers.

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APPENDIX A

Test 1 Graphs

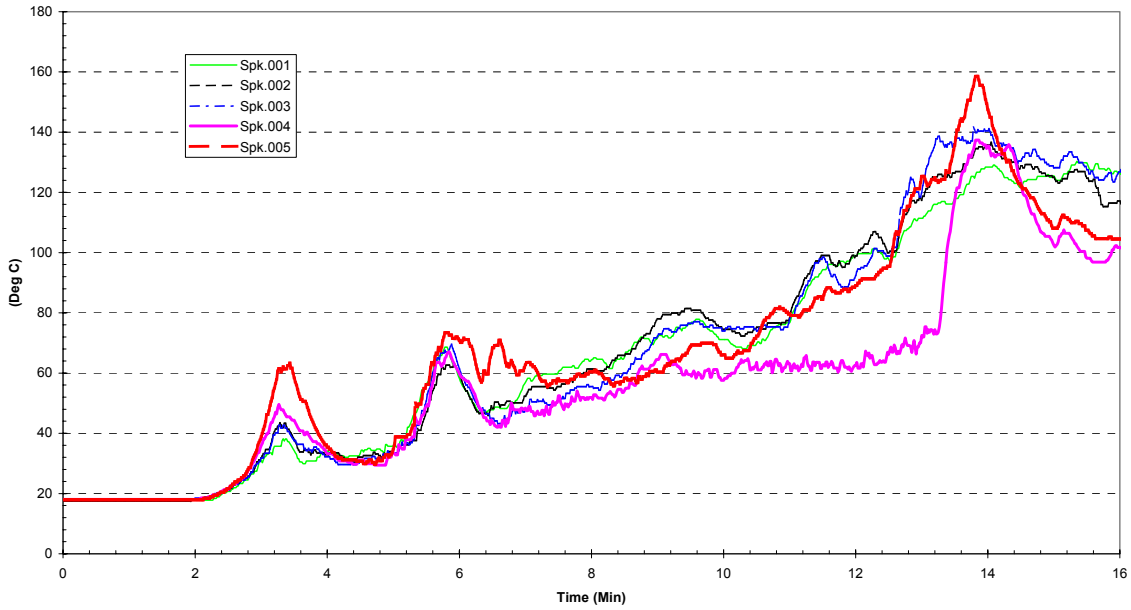

Figure A-1. Sprinklers 1, 2, 3, 4, and 5

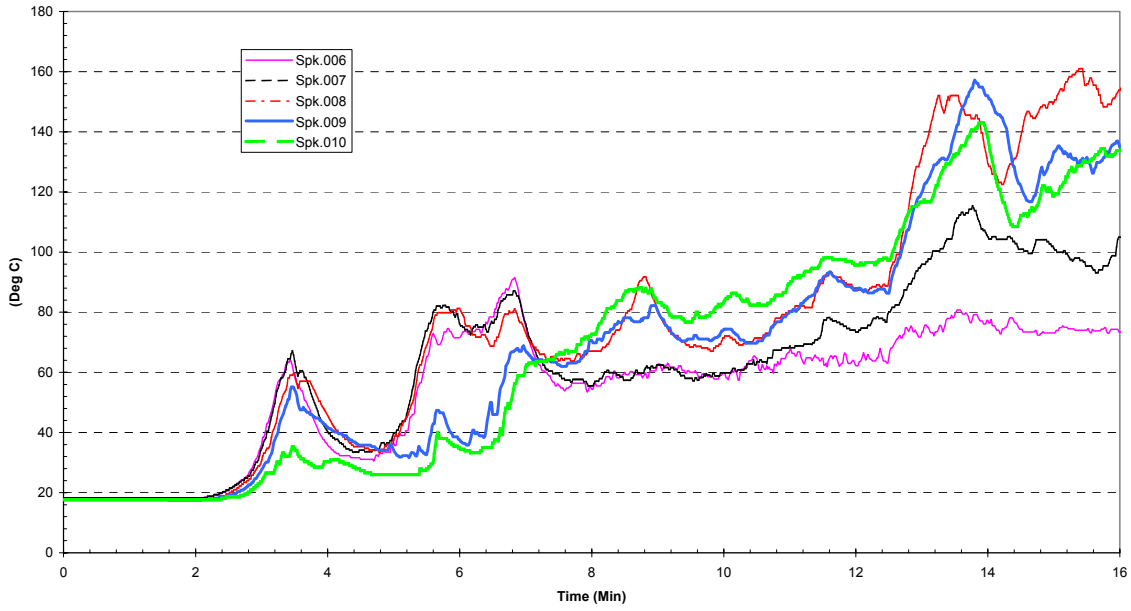

Figure A-2. Sprinklers 6, 7, 8, 9, and 10

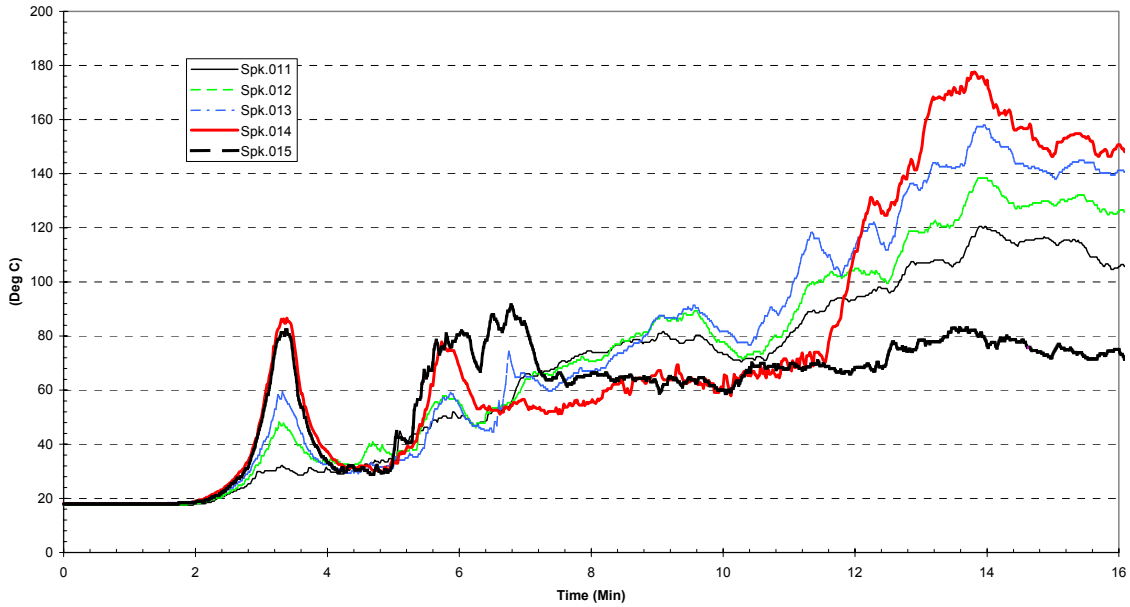

Figure A-3. Sprinklers 11, 12, 13, 14, and 15

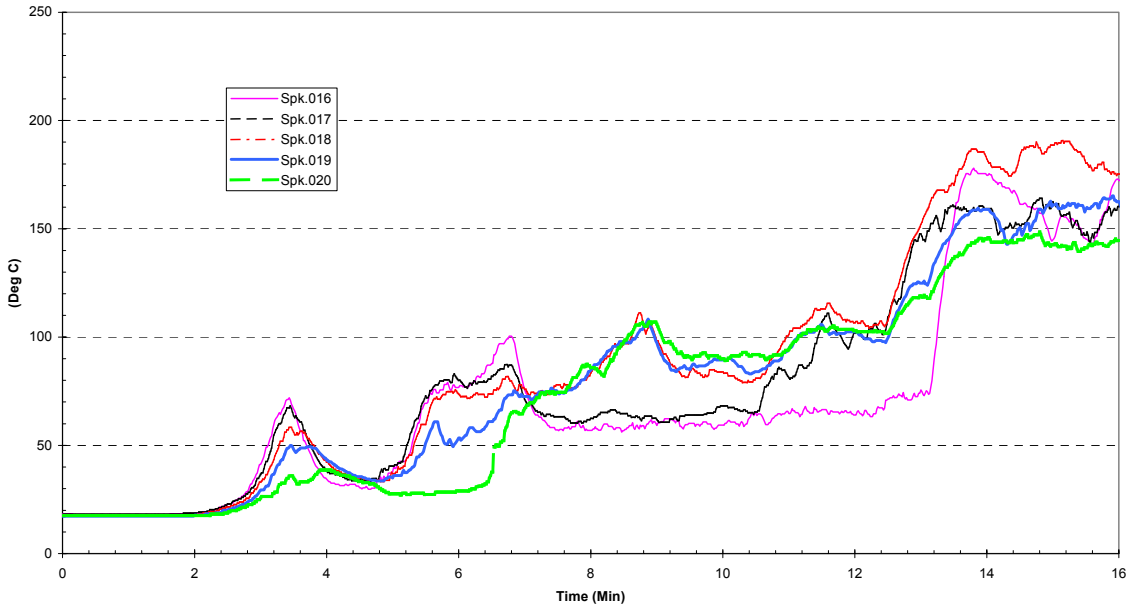

Figure A-4. Sprinklers 16, 17, 18, 19, and 20

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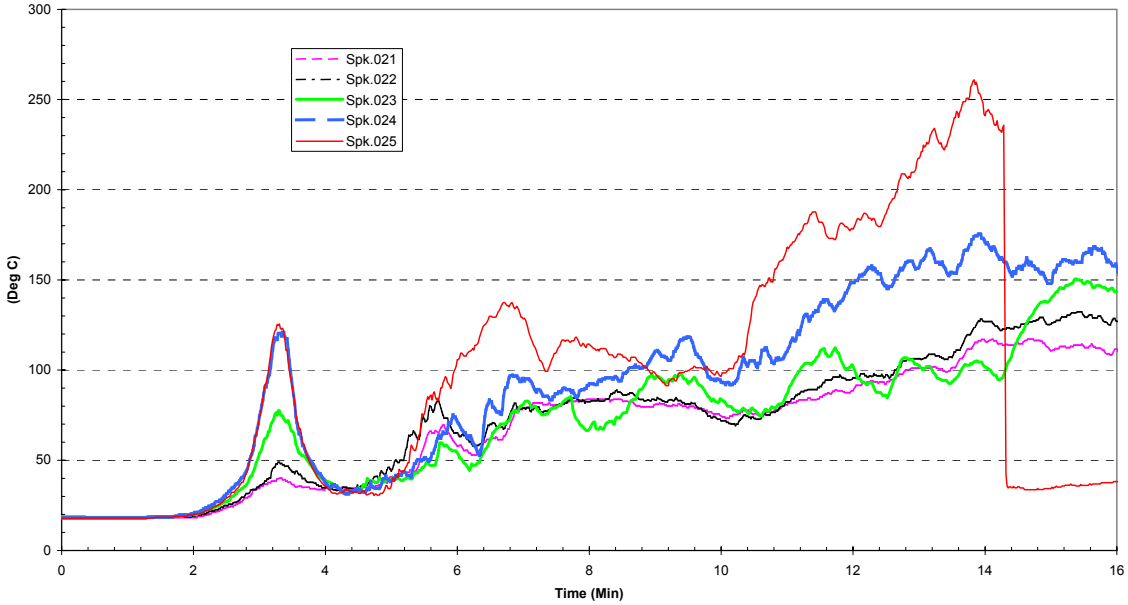

Figure A-5. Sprinklers 21, 22, 23, 24, and 25

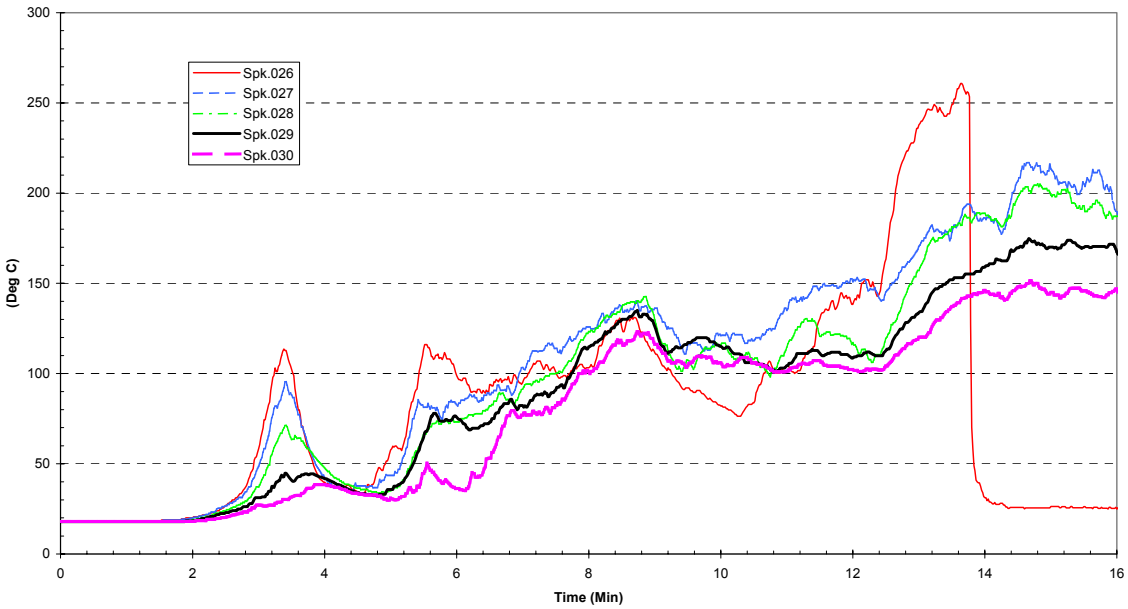

Figure A-6. Sprinklers 26, 27, 28, 29, and 30

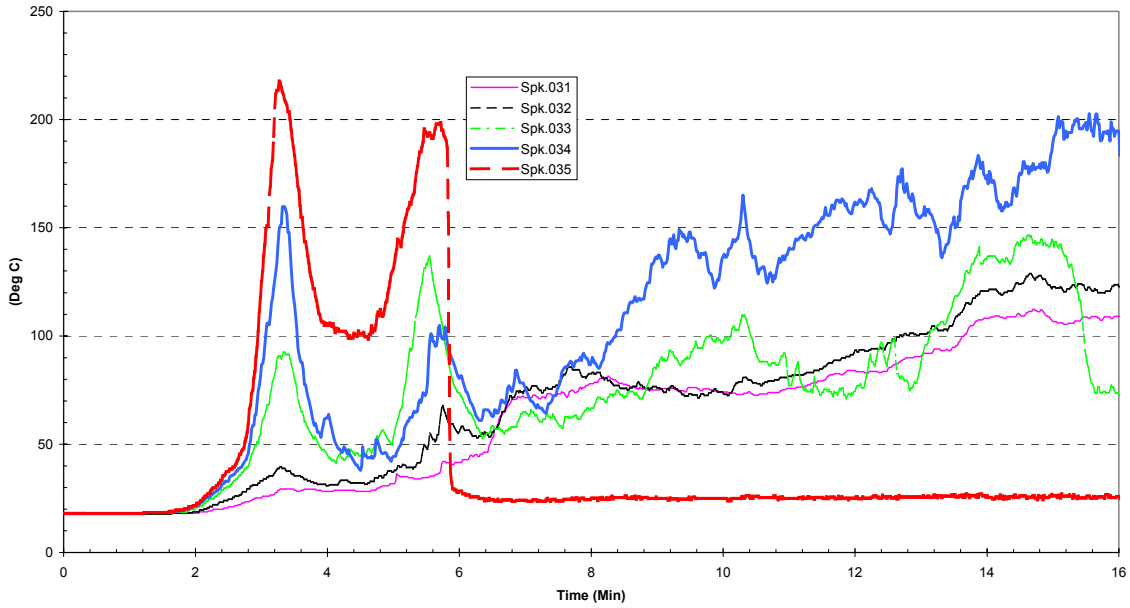

Figure A-7. Sprinklers 31, 32, 33, 34, and 35

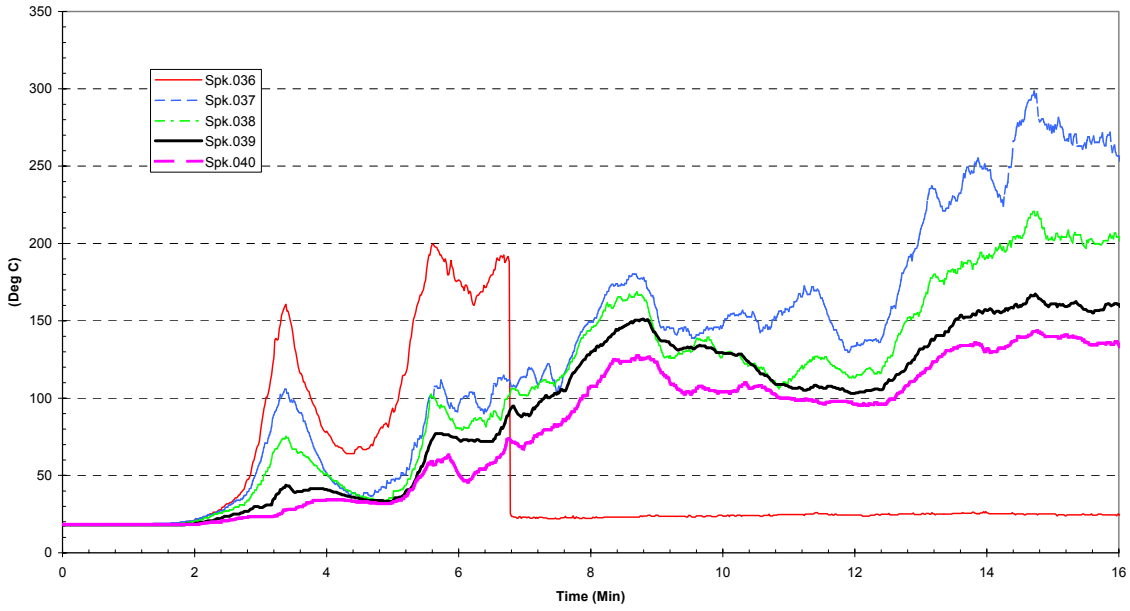

Figure A-8. Sprinklers 36, 37, 38, 39, and 40

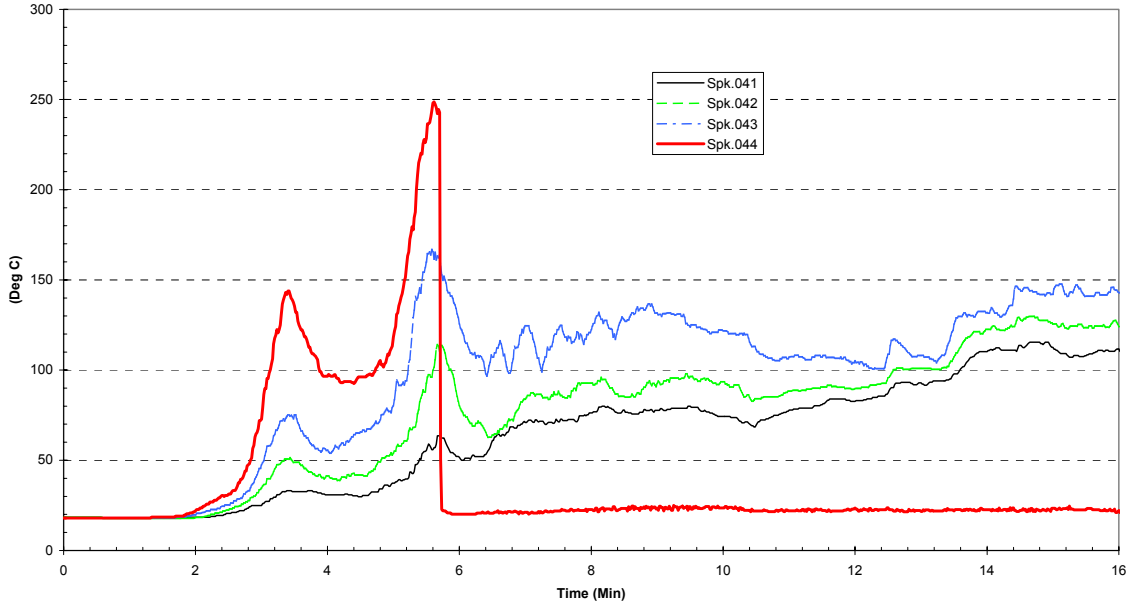

Figure A-9. Sprinklers 41, 42, 43, and 44

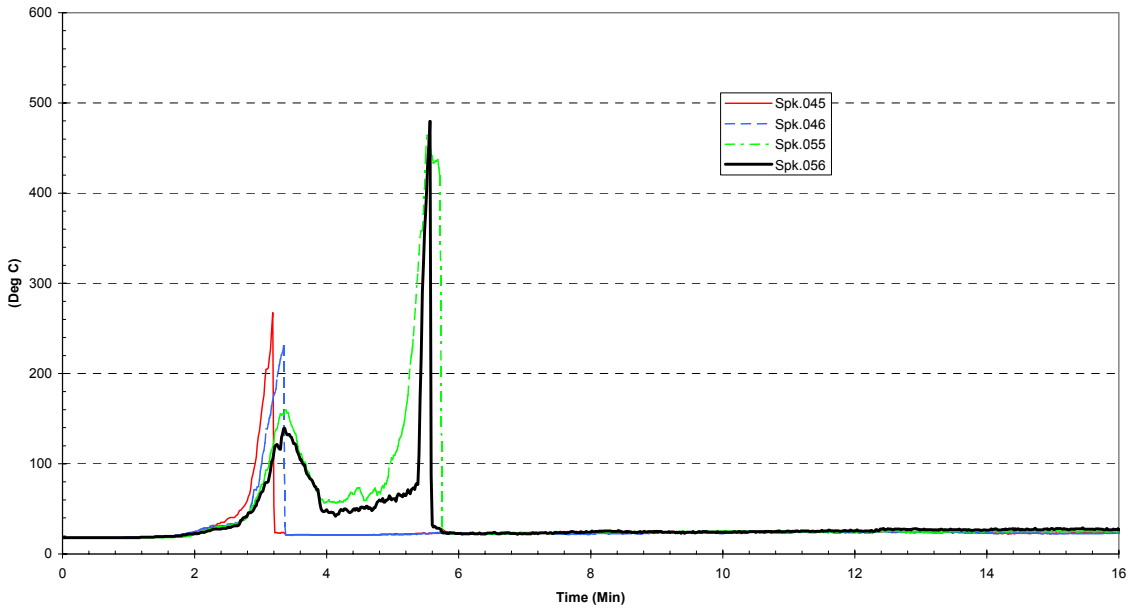

Figure A-10. Sprinklers 45, 46, 55, and 56

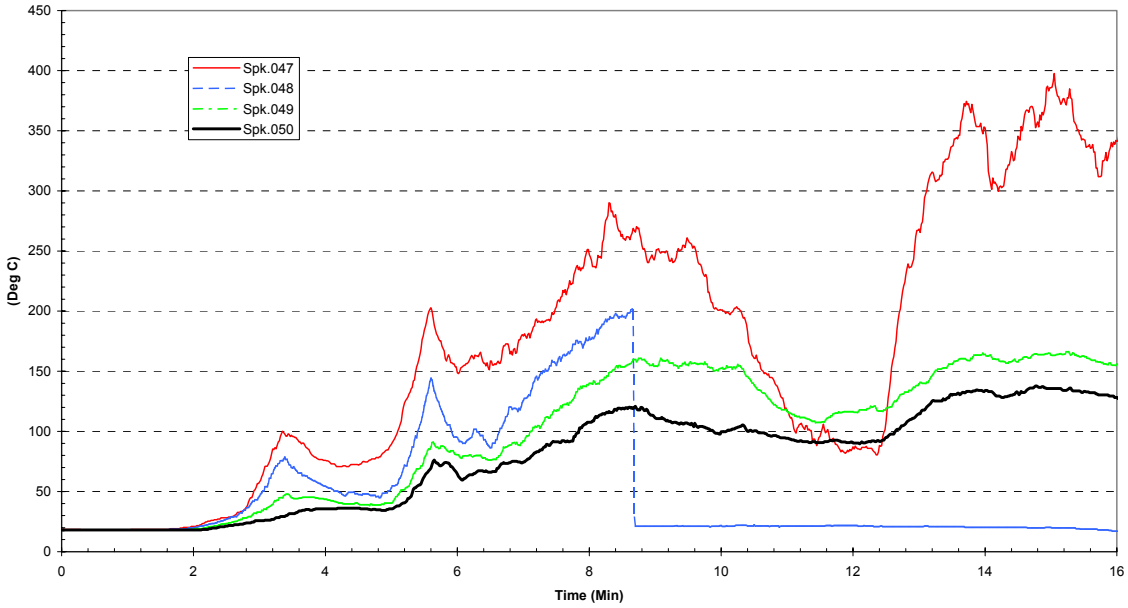

Figure A-11. Sprinklers 47, 48, 49, and 50

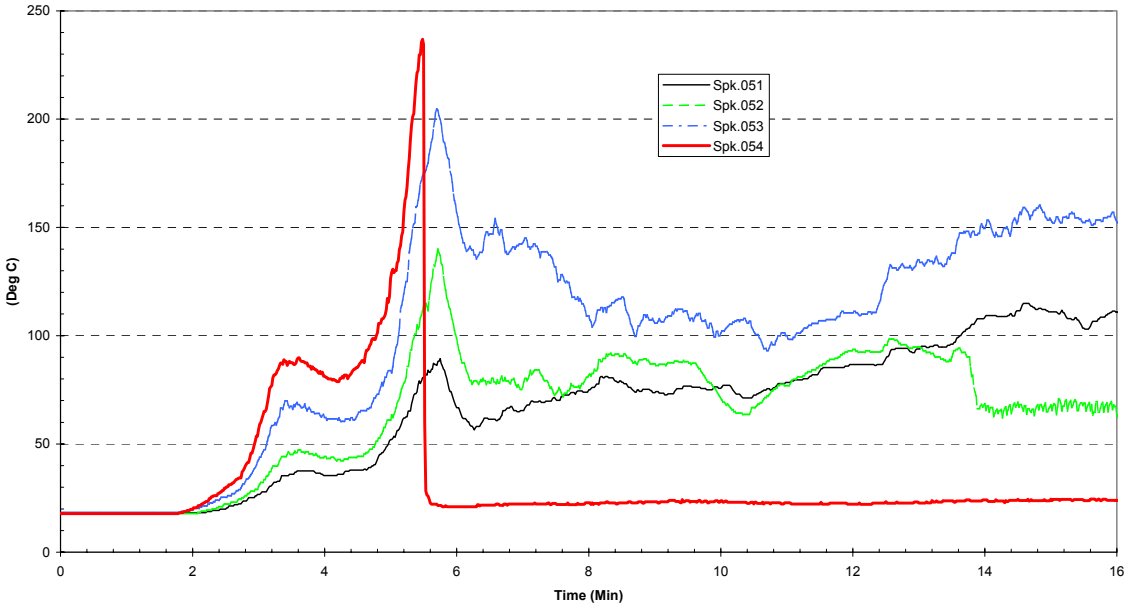

Figure A-12. Sprinklers 51, 52, 53, and 54

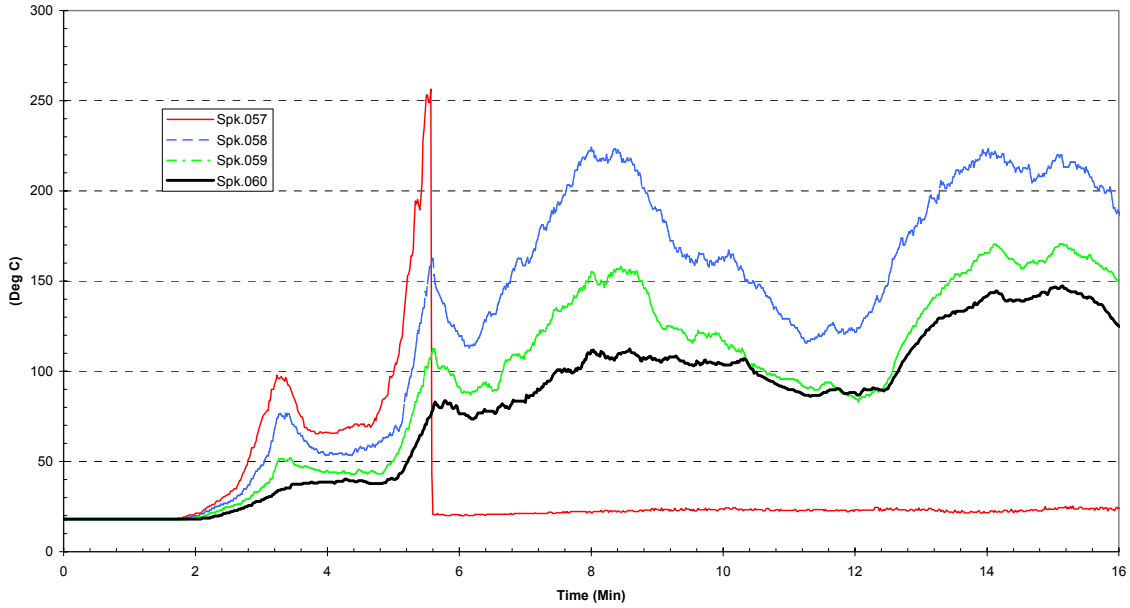

Figure A-13. Sprinklers 57, 58, 59, and 60

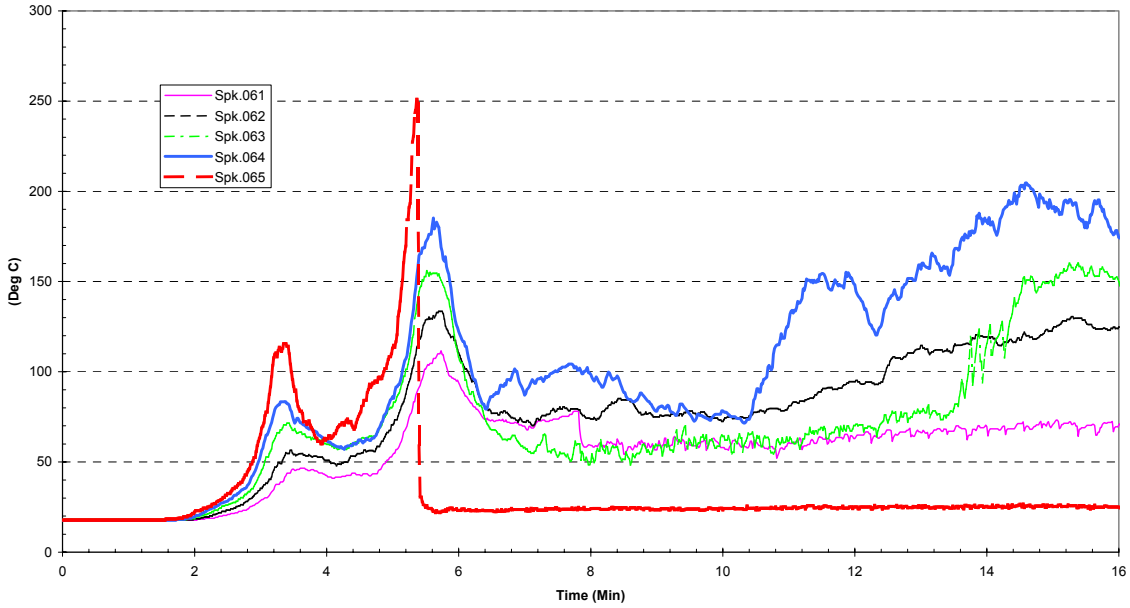

Figure A-14. Sprinklers 61, 62, 63, 64, and 65

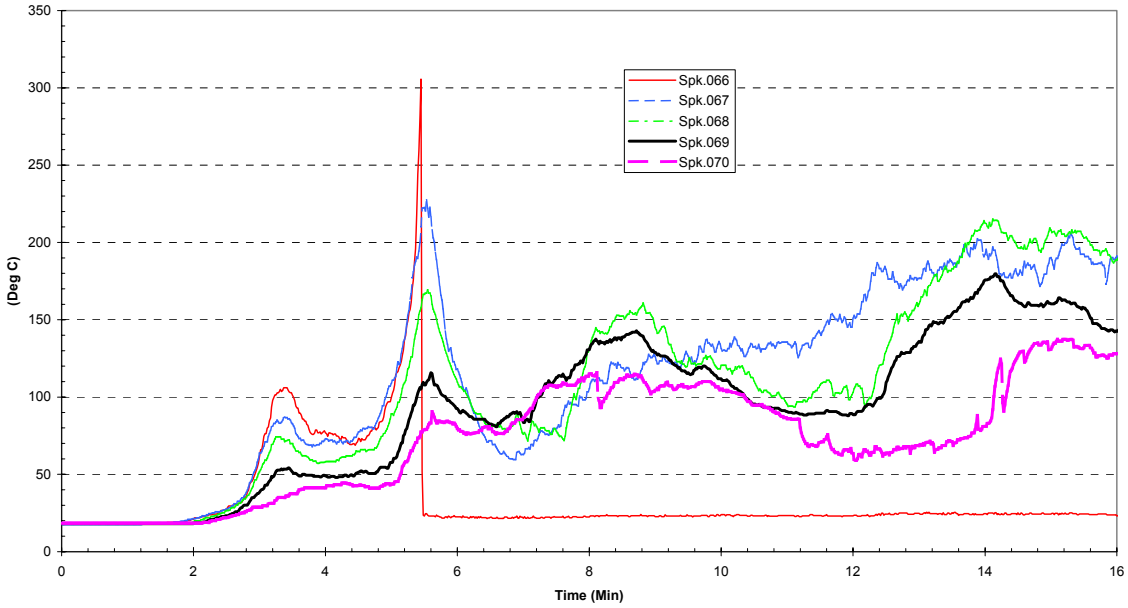

Figure A-15. Sprinklers 66, 67, 68, 69, and 70

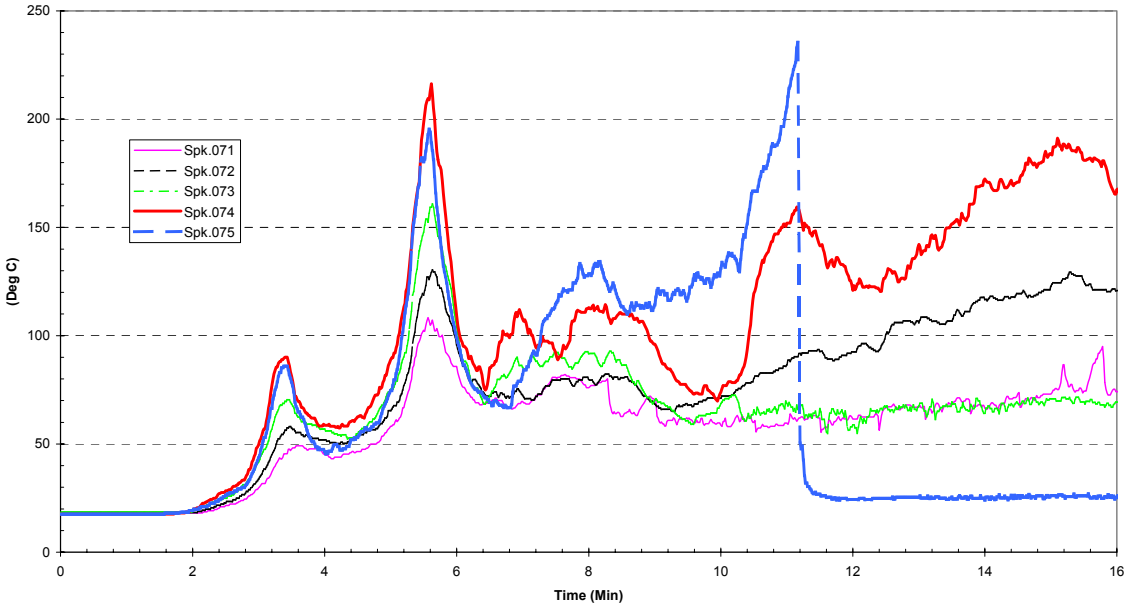

Figure A-16. Sprinklers 71, 72, 73, 74, and 75

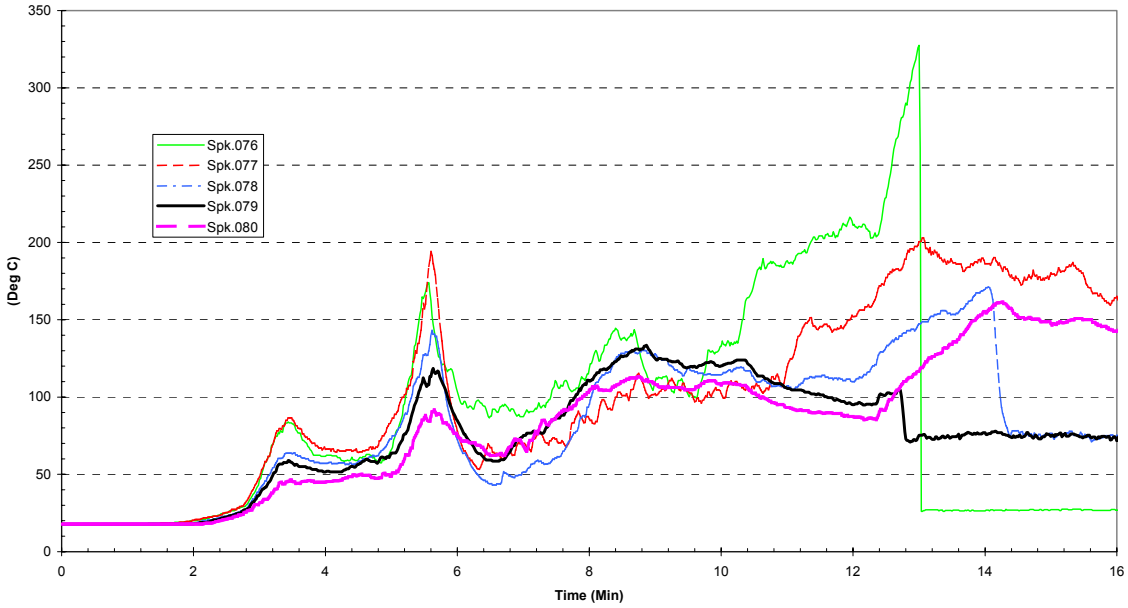

Figure A-17. Sprinklers 76, 77, 78, 79, and 80

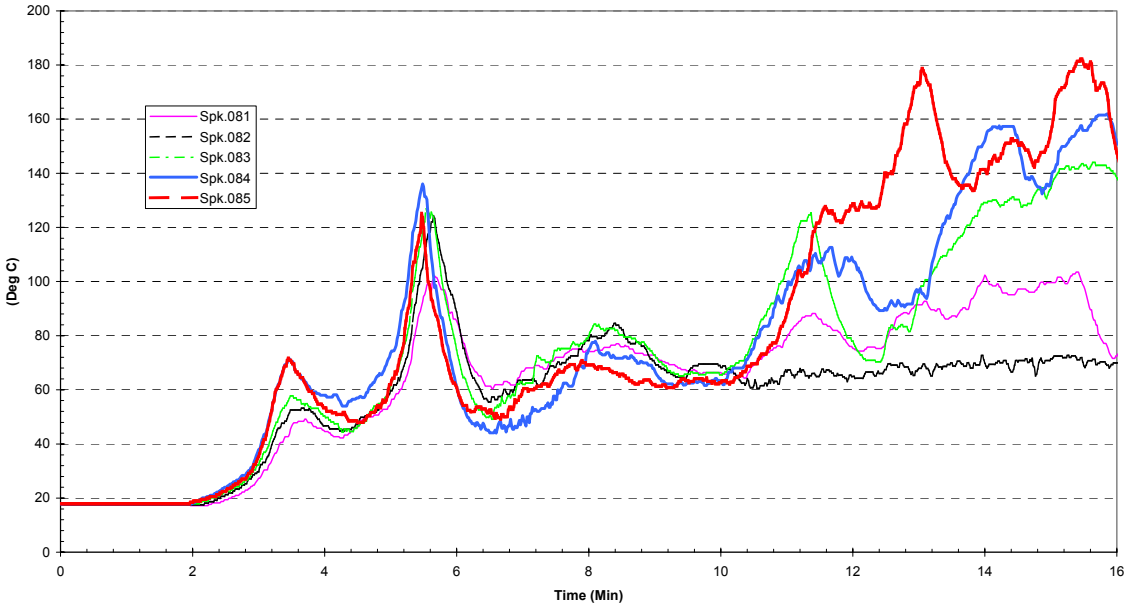

Figure A-18. Sprinklers 81, 82, 83, 84, and 85

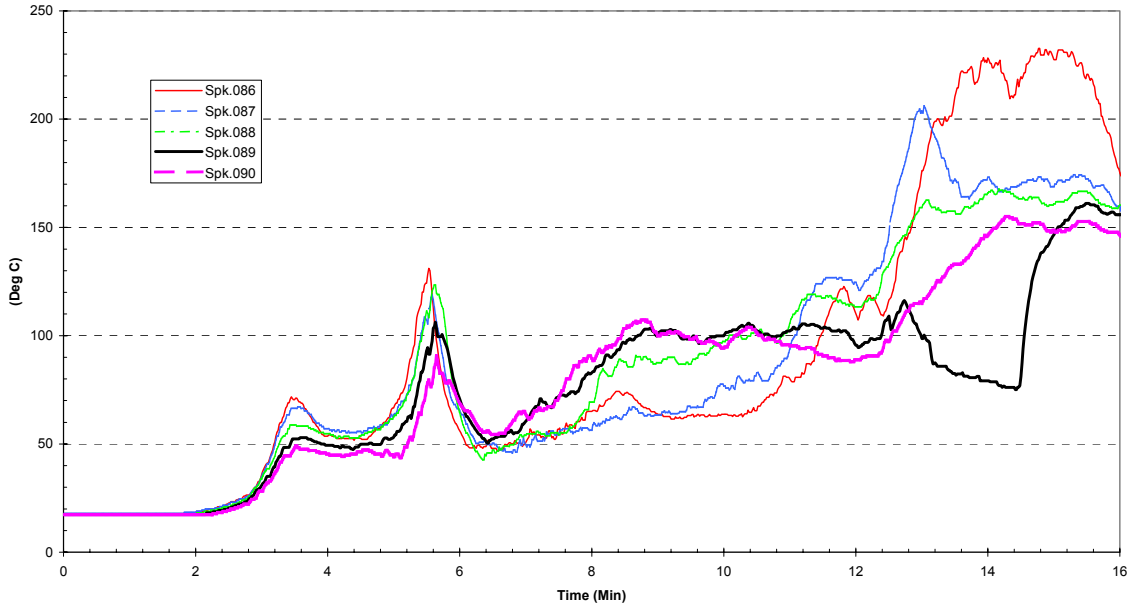

Figure A-19. Sprinklers 86, 87, 88, 89, and 90

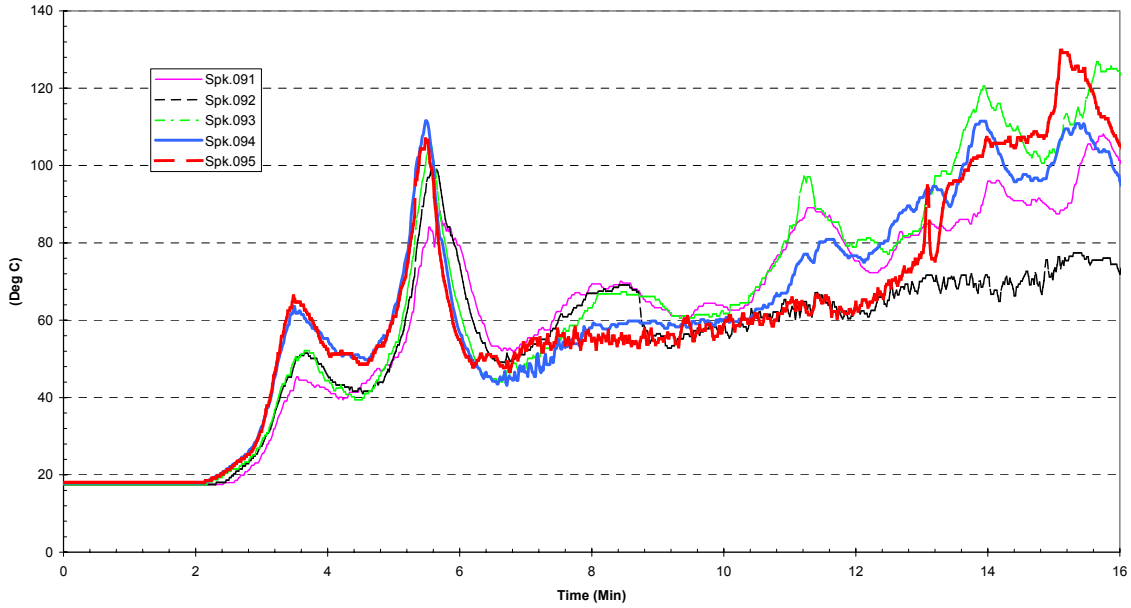

Figure A-20. Sprinklers 91, 92, 93, 94, and 95

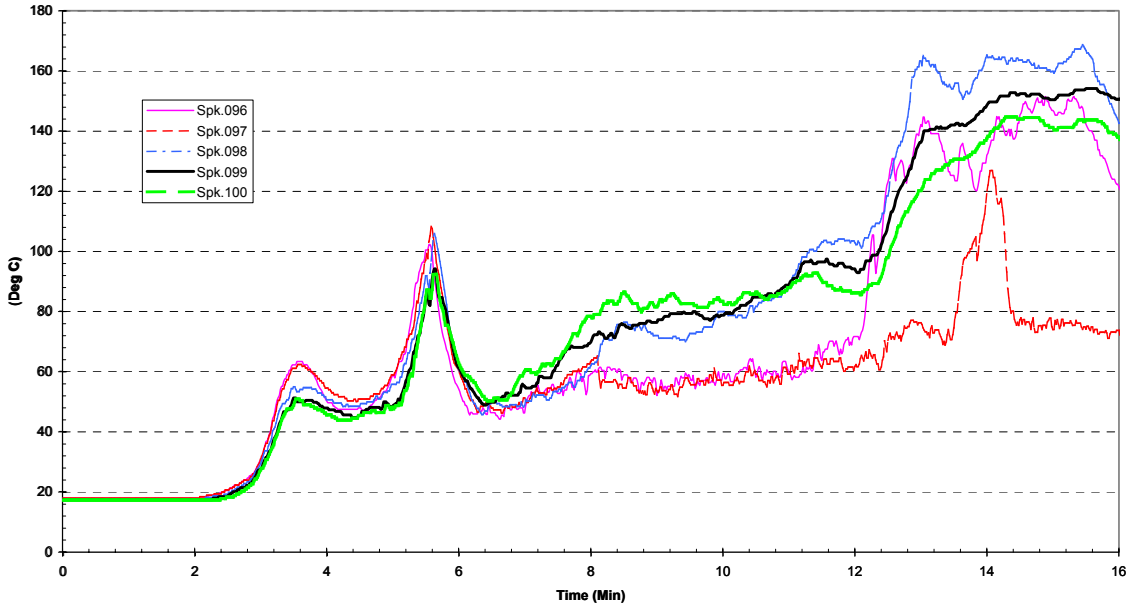

Figure A-21. Sprinklers 96, 97, 98, 99, and 100

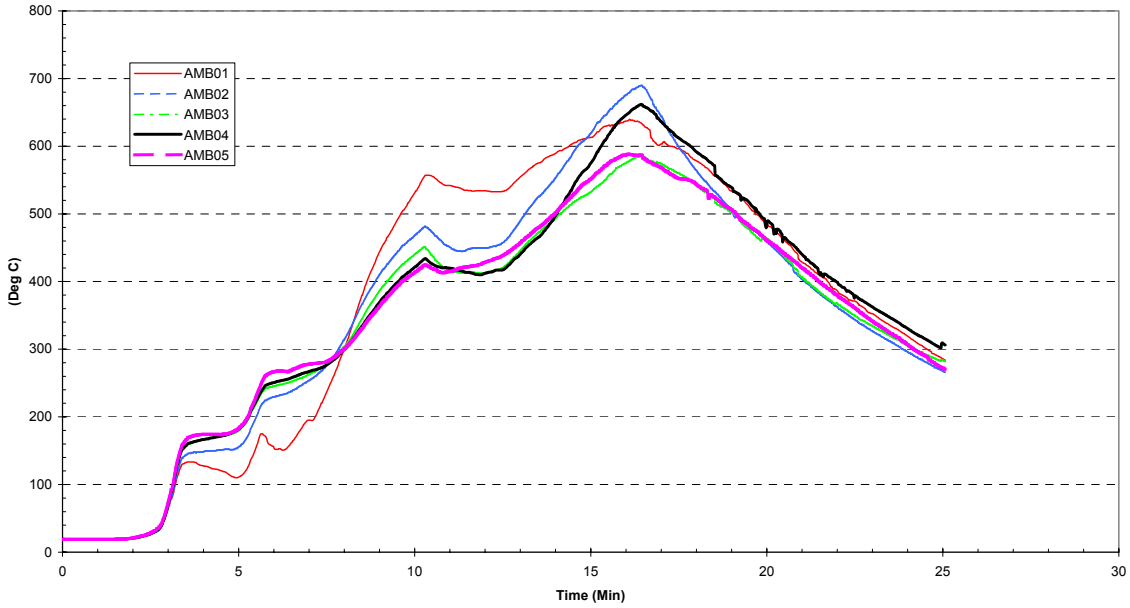

Figure A-22. Steel Beam Temperatures

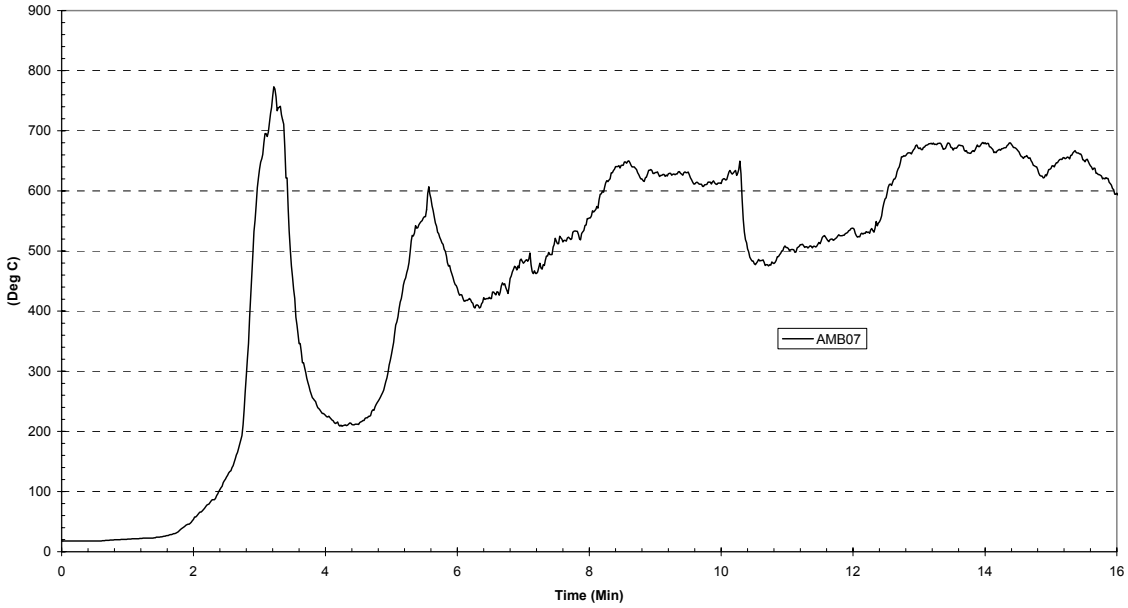

Figure A-23. Air Above Ignition Temperature

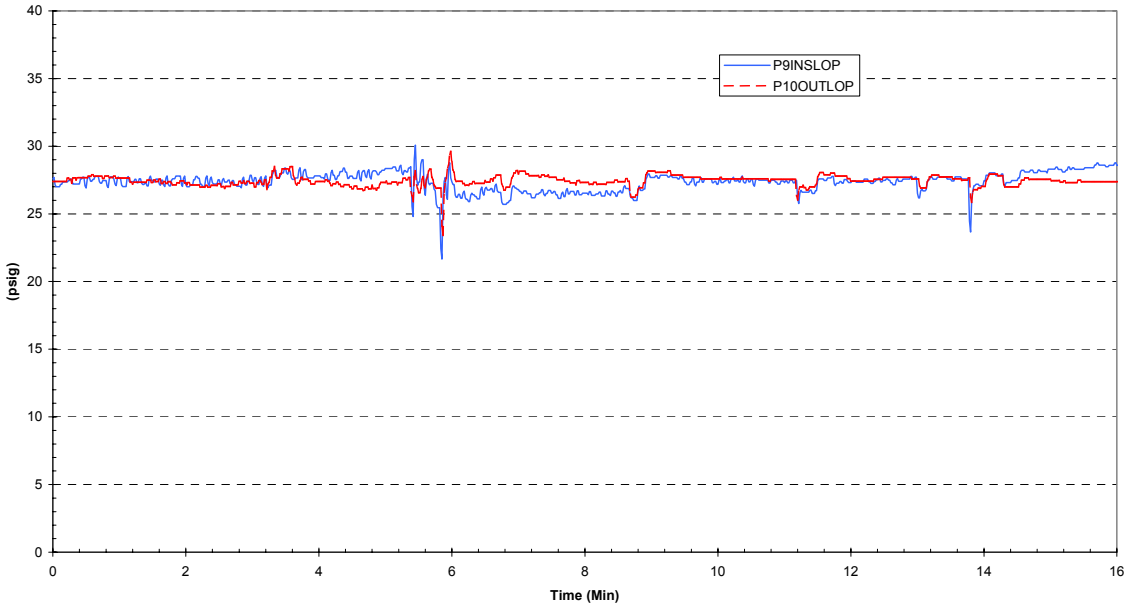

Figure A-24. System Pressure

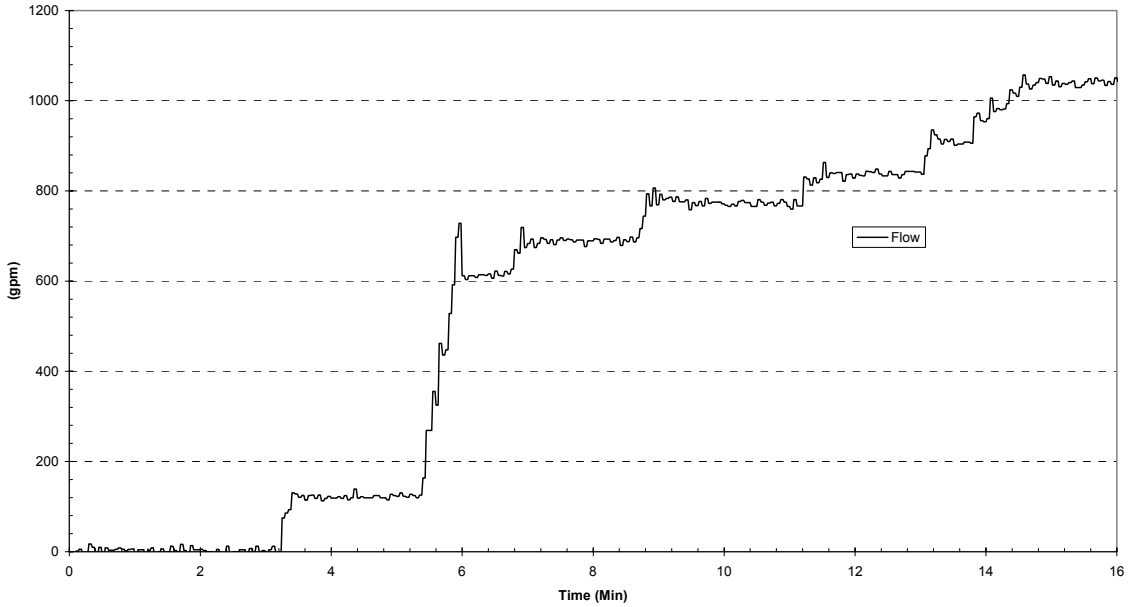

Figure A-25. System Flow

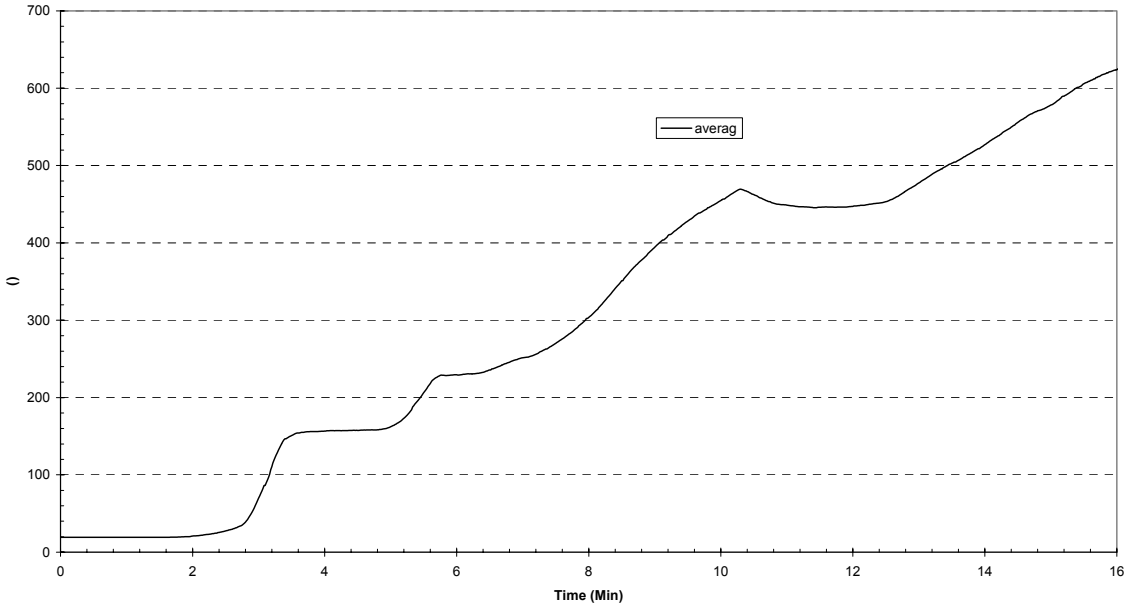

Figure A-26. Average Steel Beam Temperature

APPENDIX B

Test 2 Graphs

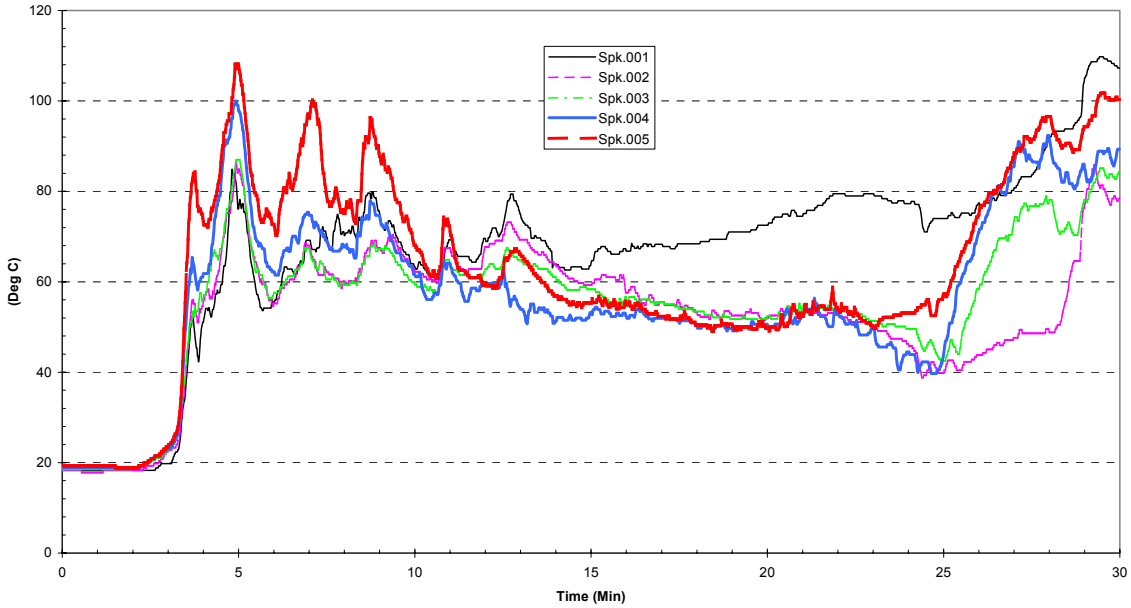

Figure B-1. Sprinklers 1, 2, 3, 4, and 5

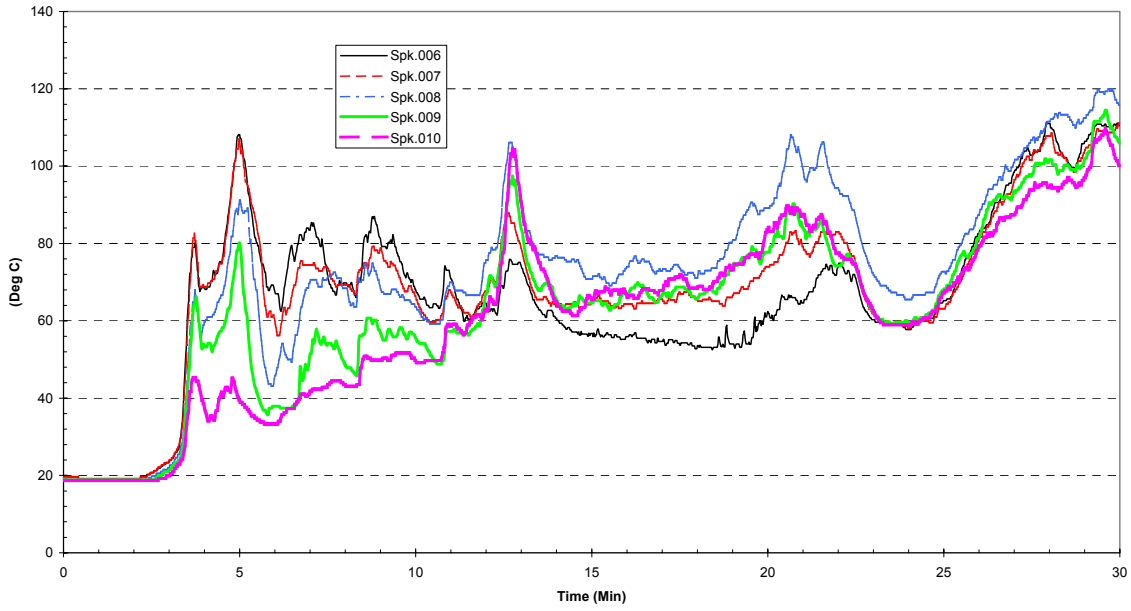

Figure B-2. Sprinklers 6, 7, 8, 9, and 10

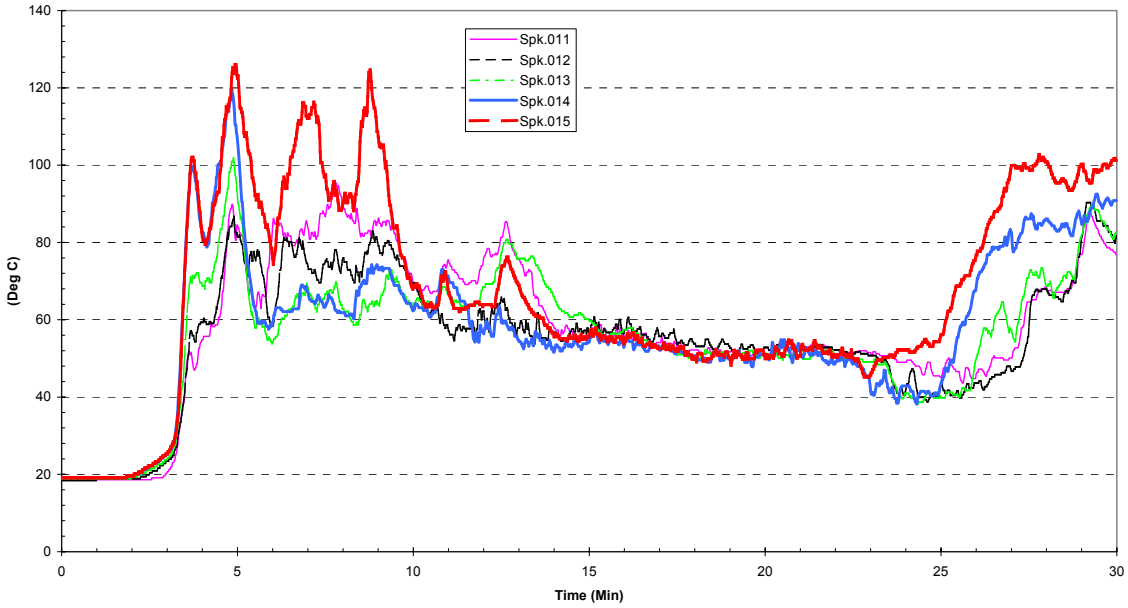

Figure B-3. Sprinklers 11, 12, 13, 14, and 15

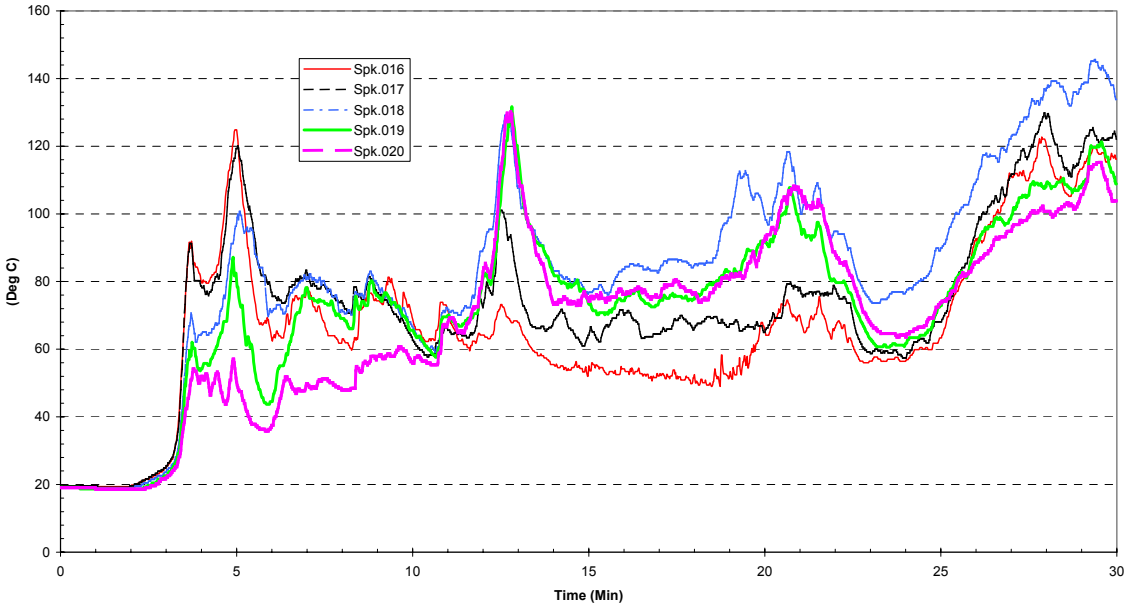

Figure B-4. Sprinklers 16, 17, 18, 19, and 20

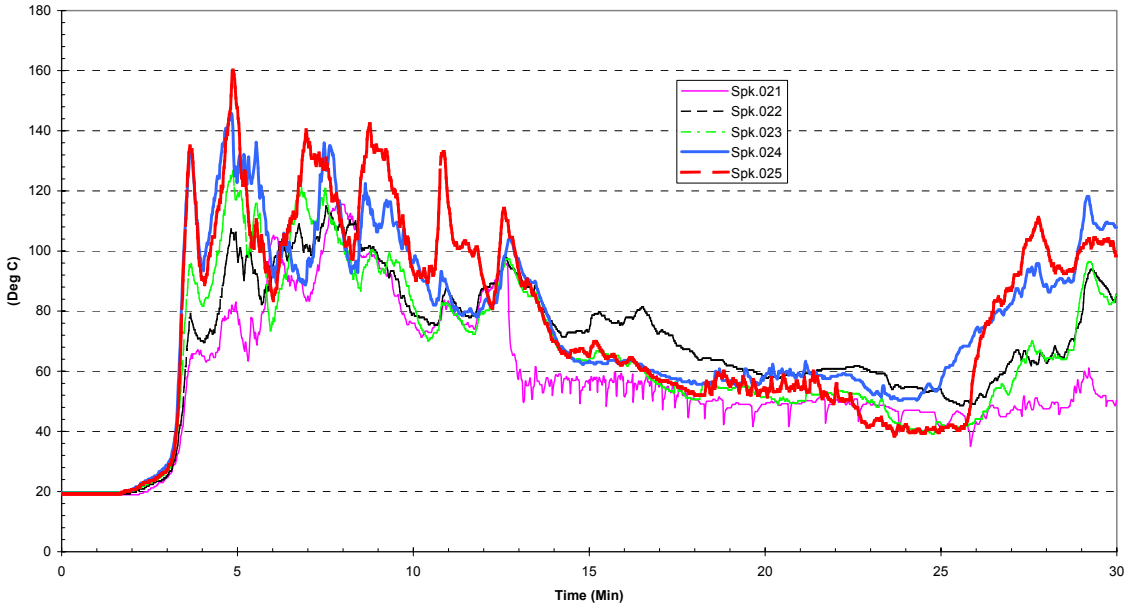

Figure B-5. Sprinklers 21, 22, 23, 24, and 25

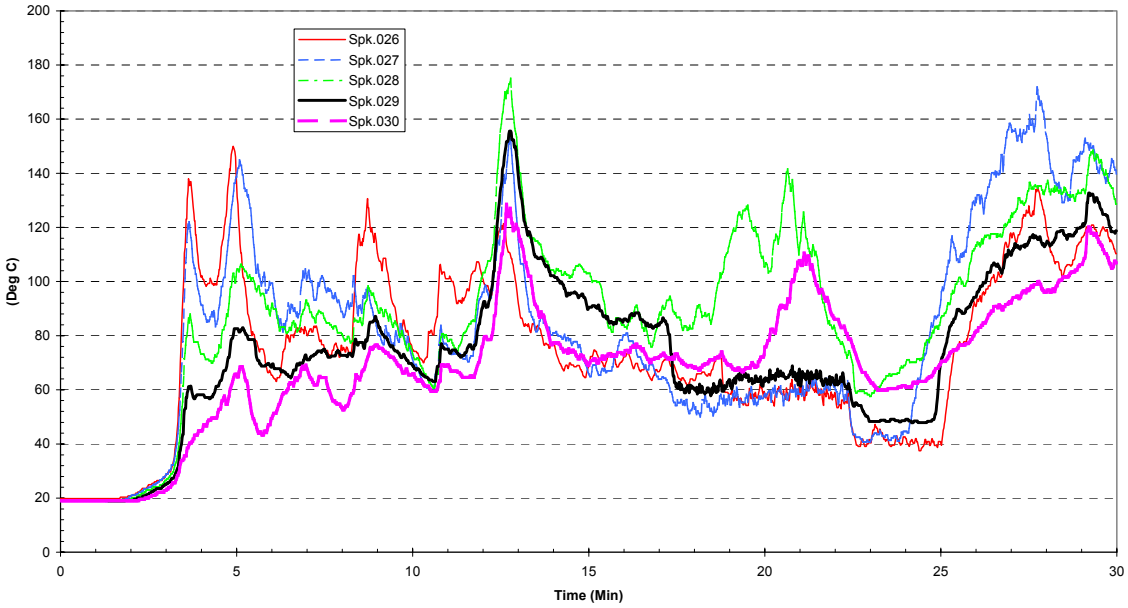

Figure B-6. Sprinklers 26, 27, 28, 29, and 30

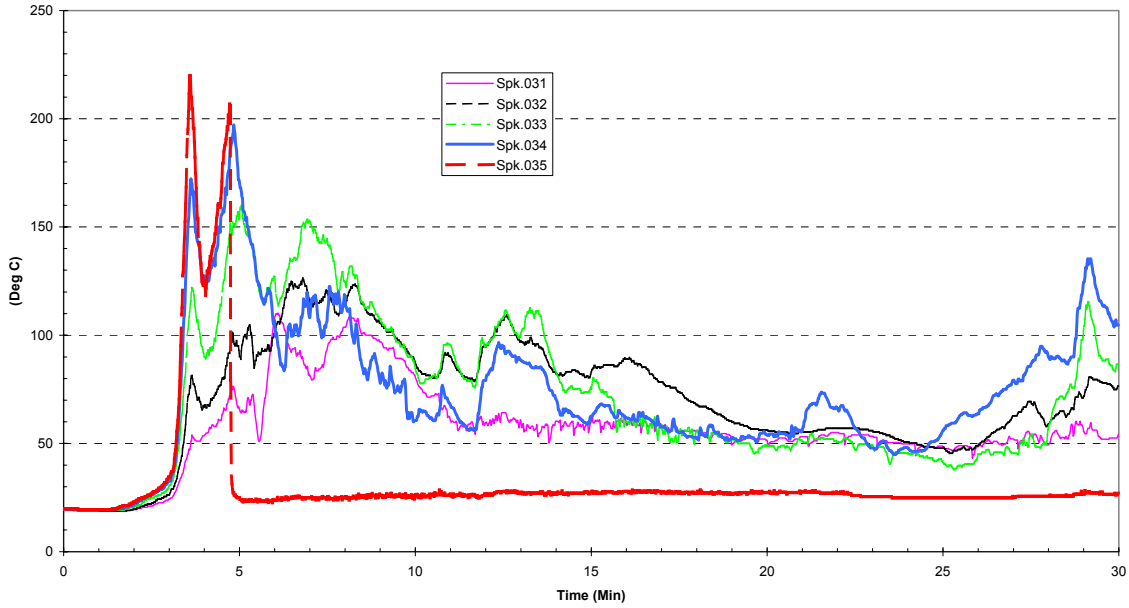

Figure B-7. Sprinklers 31, 32, 33, 34, and 35

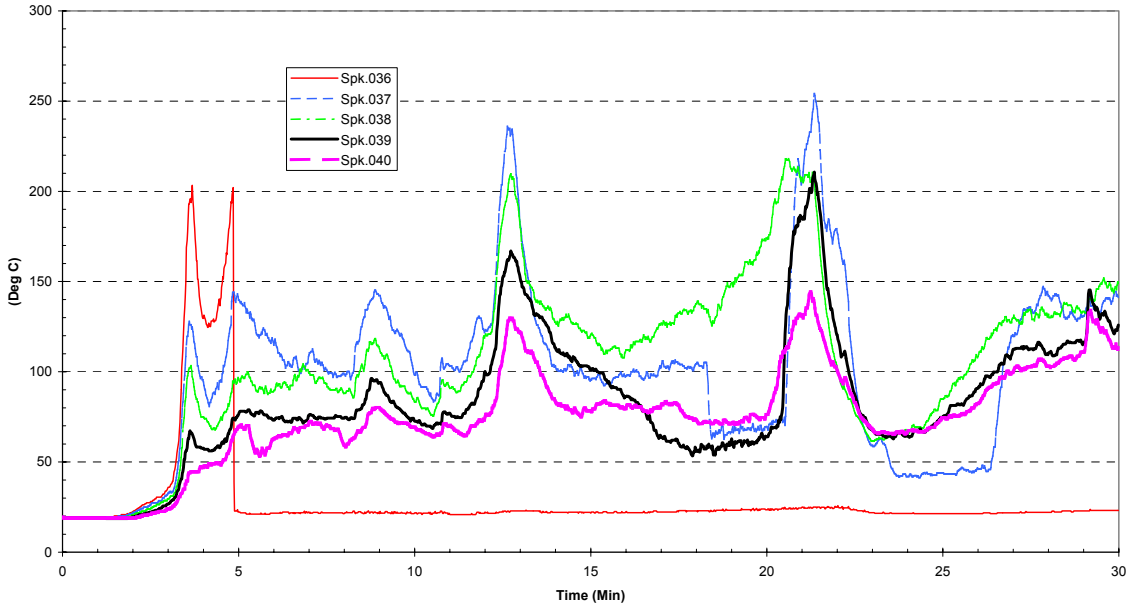

Figure B-8. Sprinklers 36, 37, 38, 39, and 40

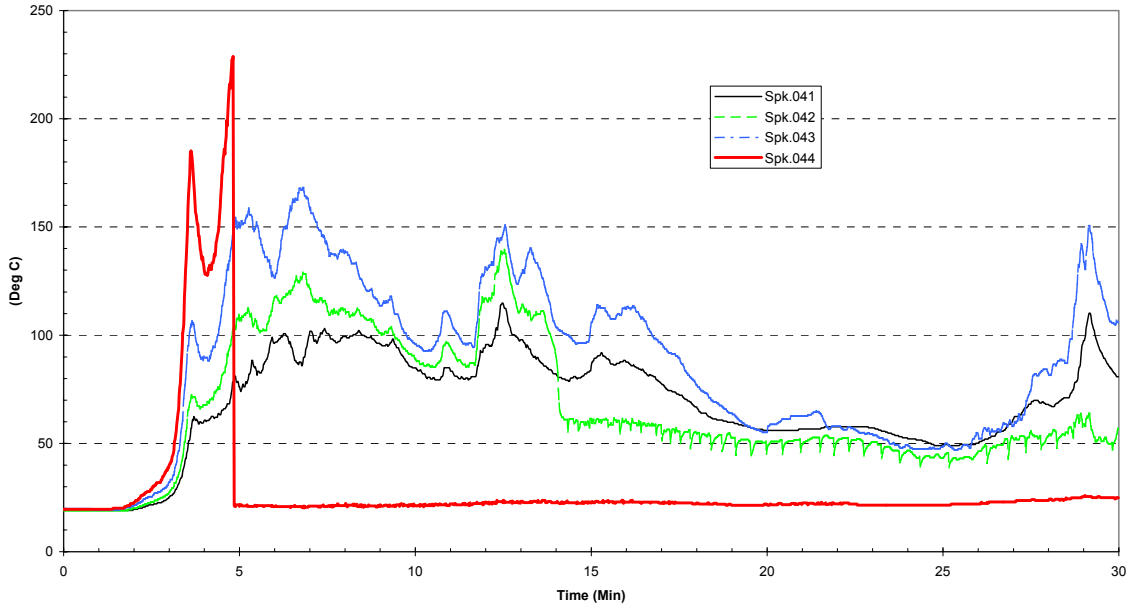

Figure B-9. Sprinklers 41, 42, 43, and 44

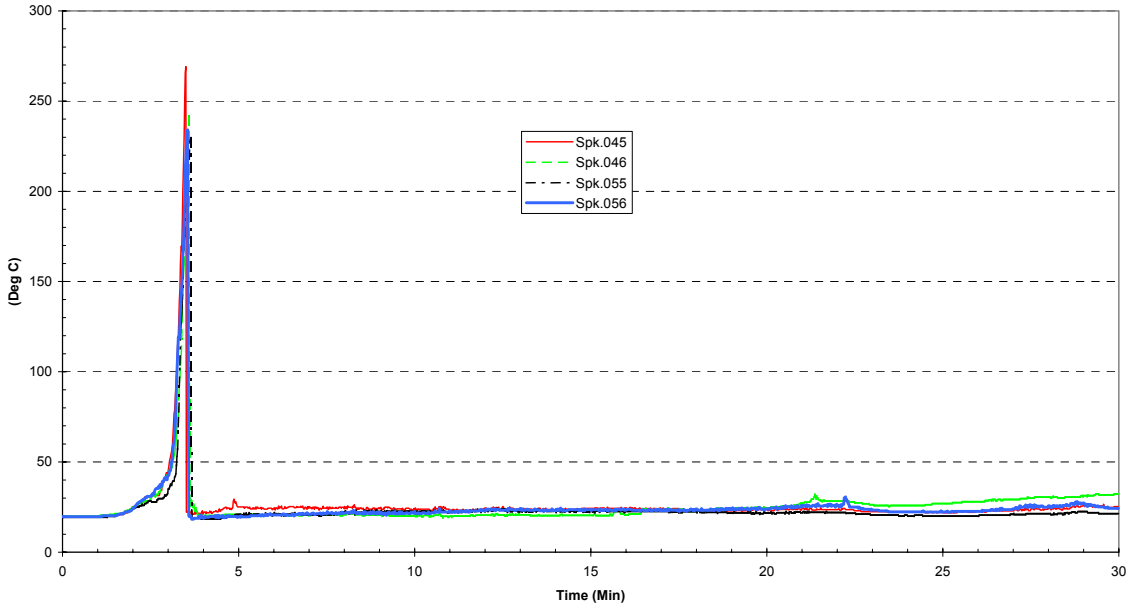

Figure B-10. Sprinklers 45, 46, 55, and 56

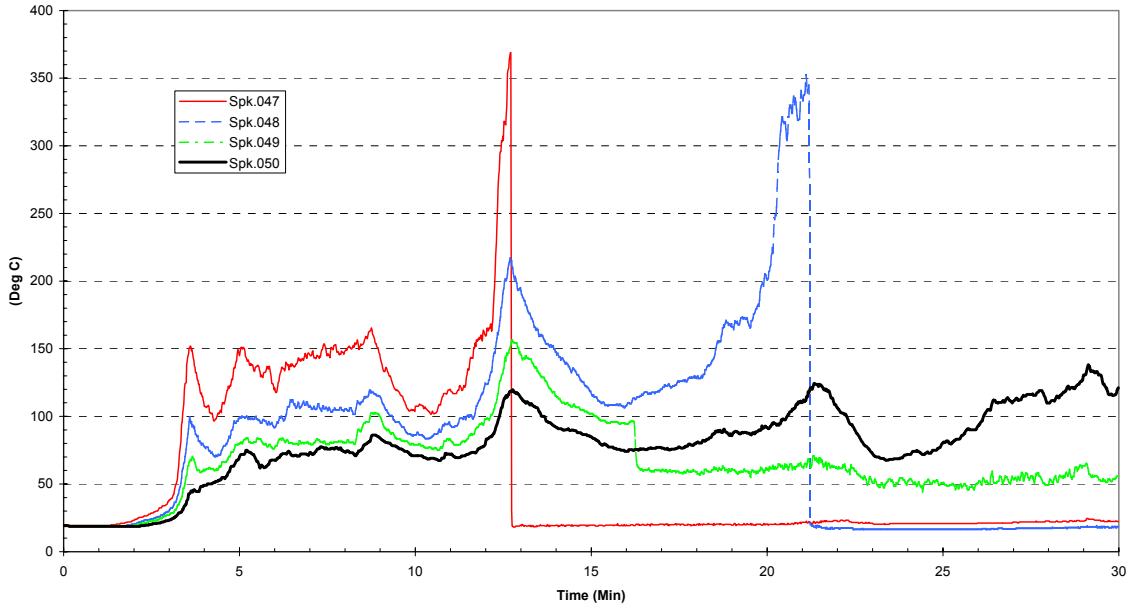

Figure B-11. Sprinklers 47, 48, 49, and 50

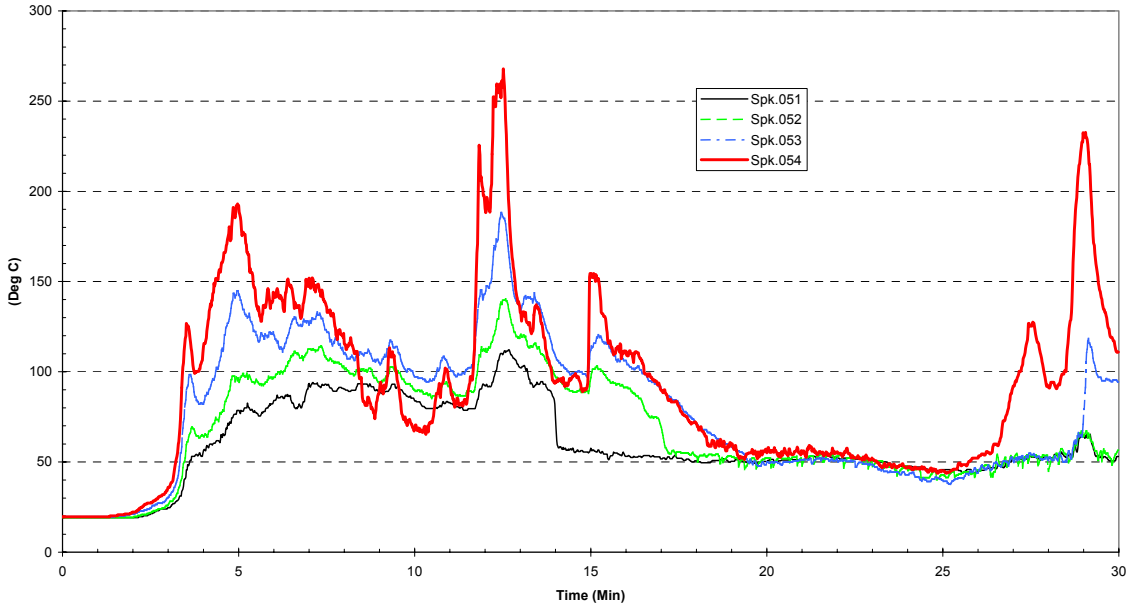

Figure B-12. Sprinklers 51, 52, 53, and 54

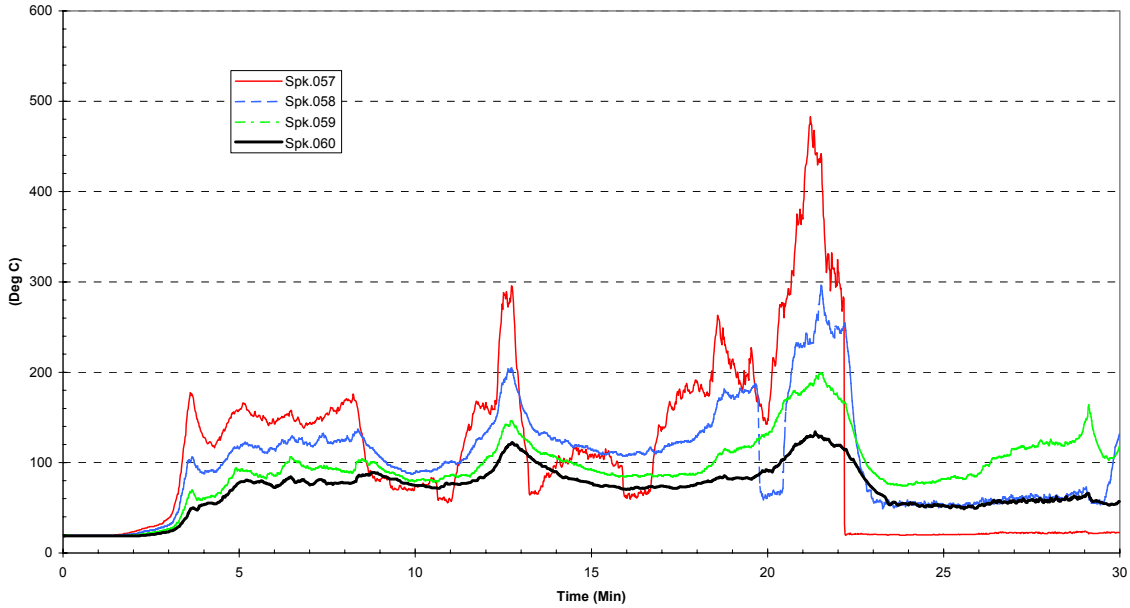

Figure B-13. Sprinklers 57, 58, 59, and 60

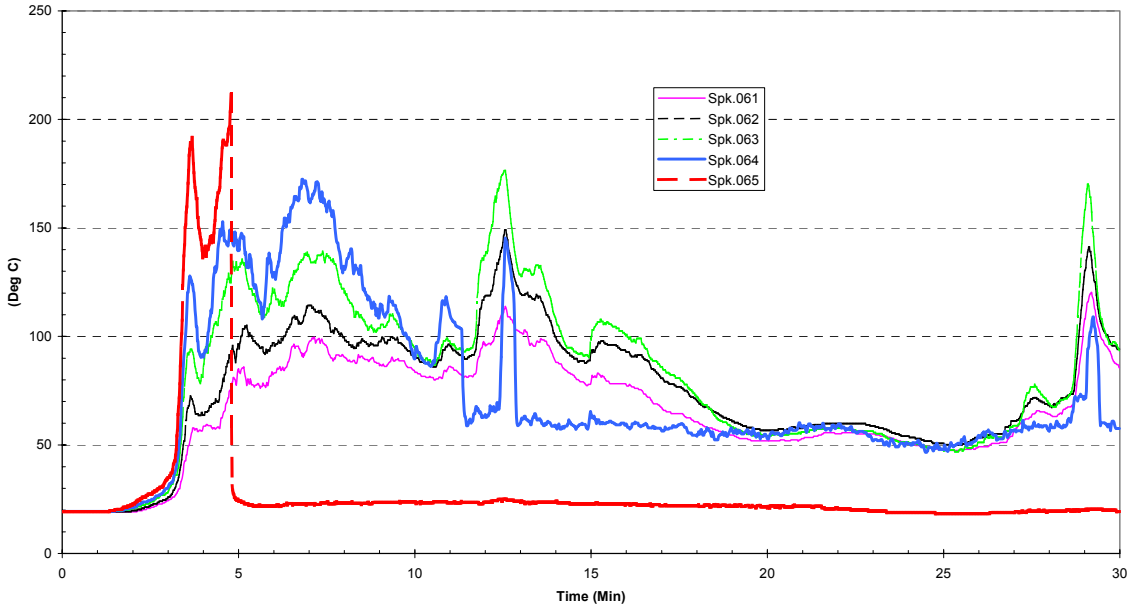

Figure B-14. Sprinklers 61, 62, 63, 64, and 65

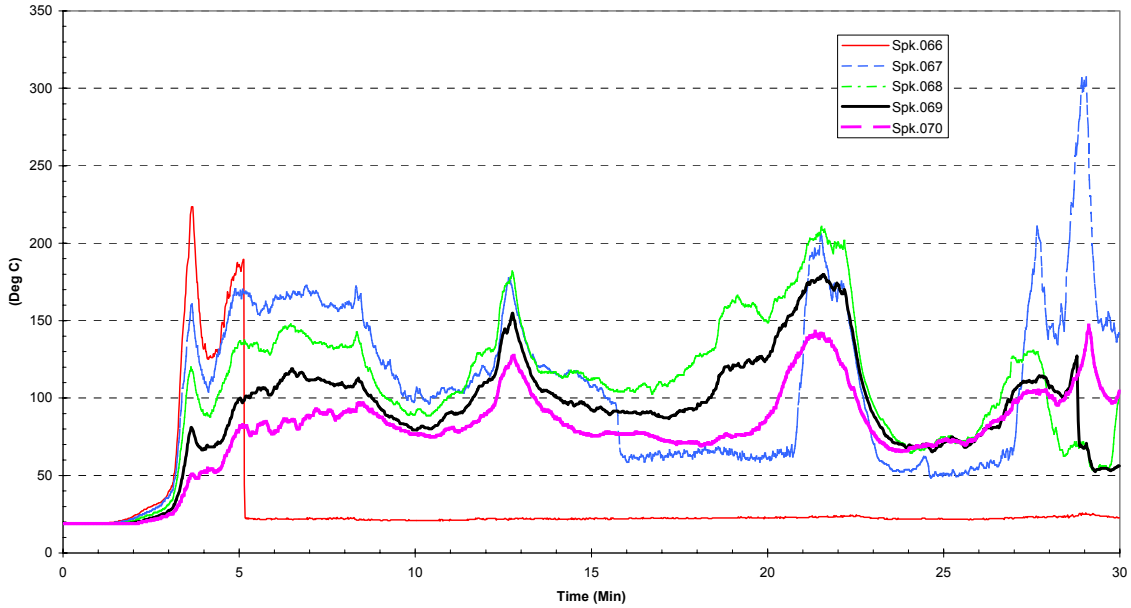

Figure B-15. Sprinklers 66, 67, 68, 69, and 70

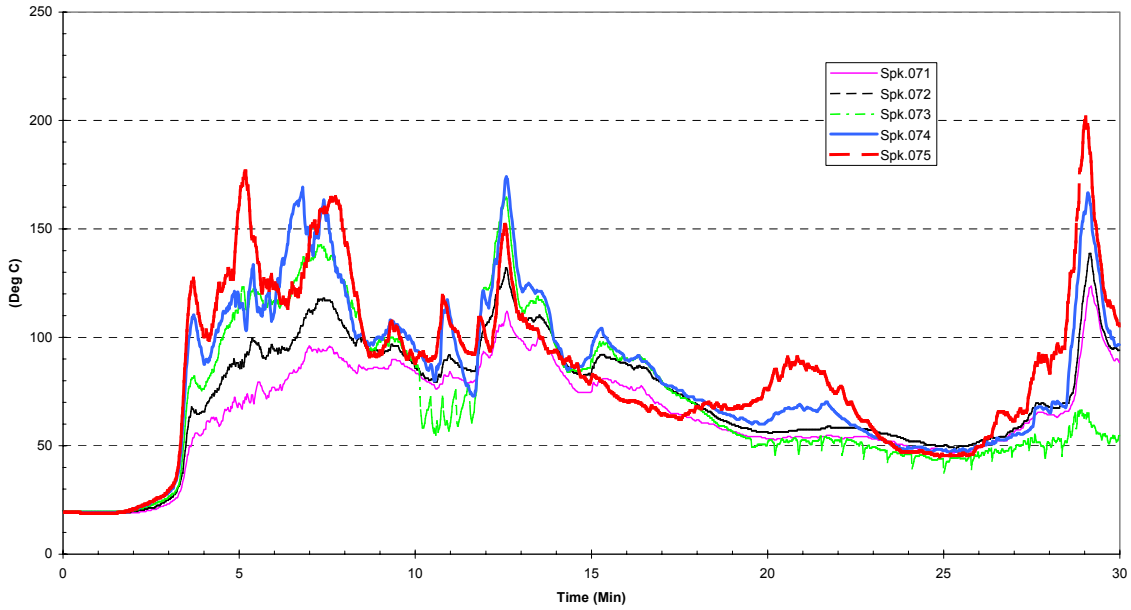

Figure B-16. Sprinklers 71, 72, 73, 74, and 75

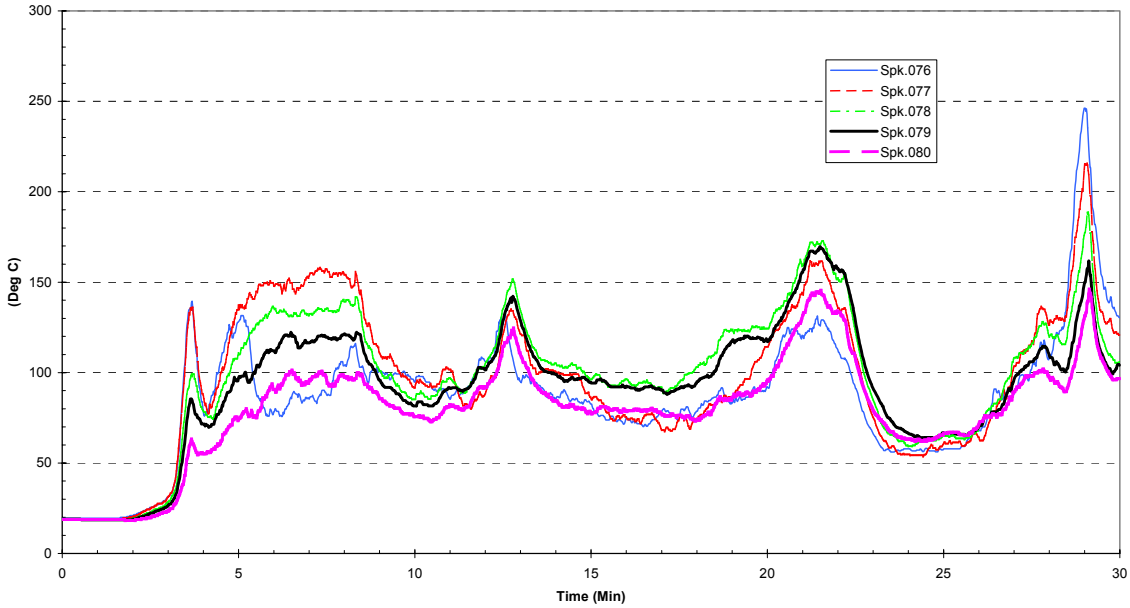

Figure B-17. Sprinklers 76, 77, 78, 79, and 80

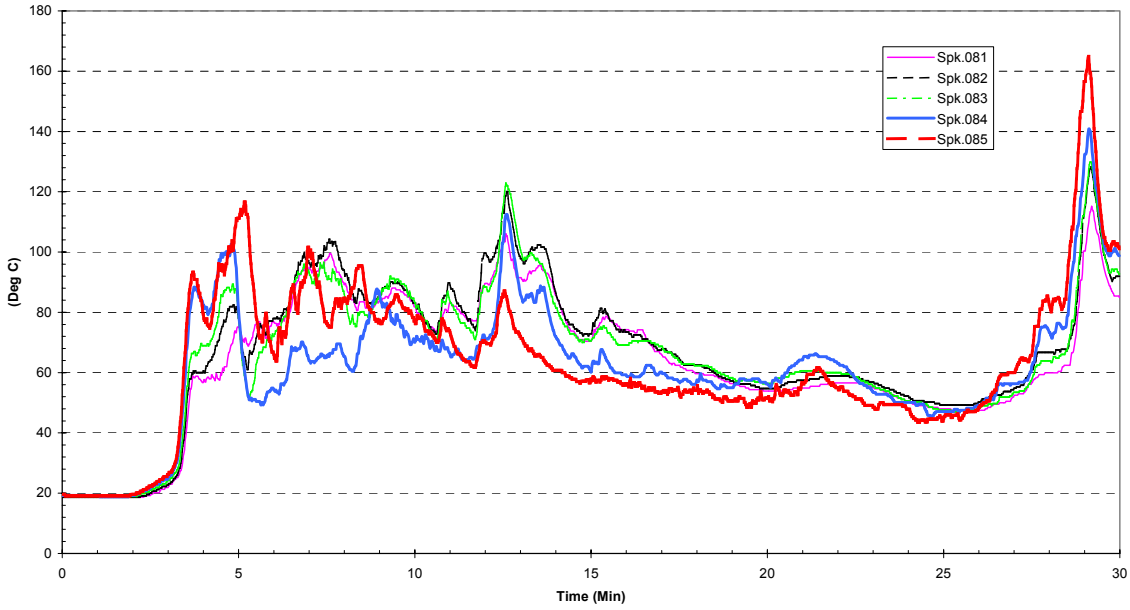

Figure B-18. Sprinklers 81, 82, 83, 84, and 85

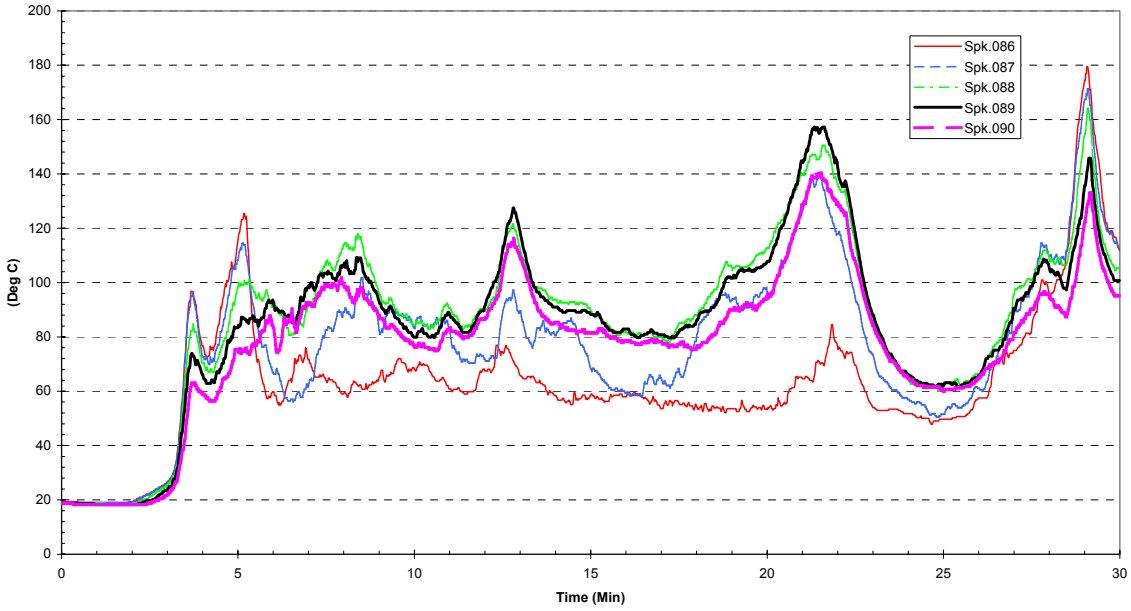

Figure B-19. Sprinklers 86, 87, 88, 89, and 90

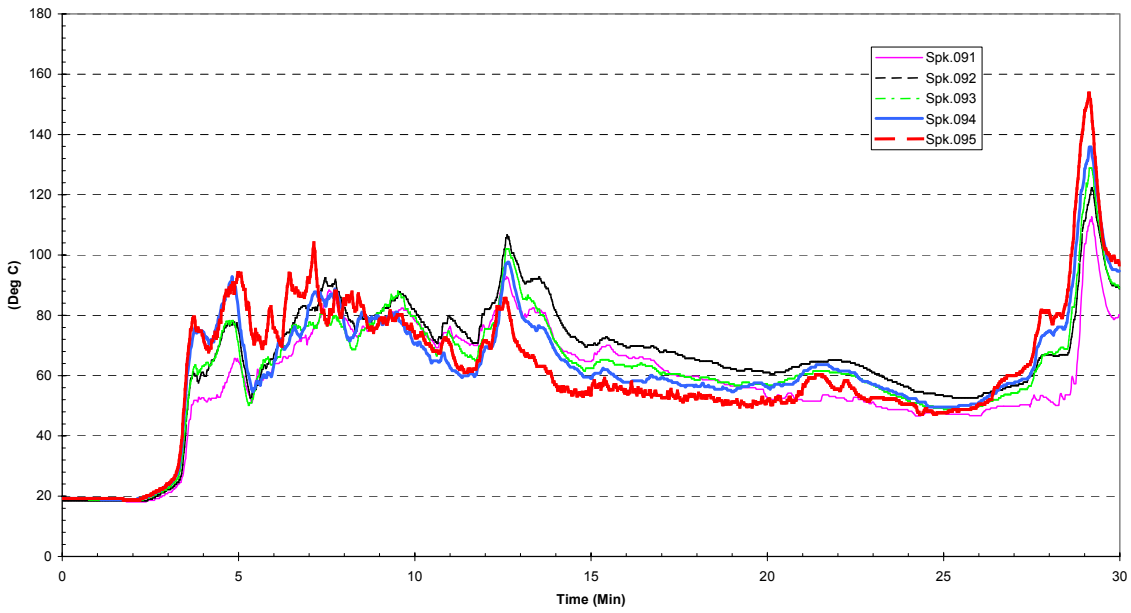

Figure B-20. Sprinklers 91, 92, 93, 94 and 95

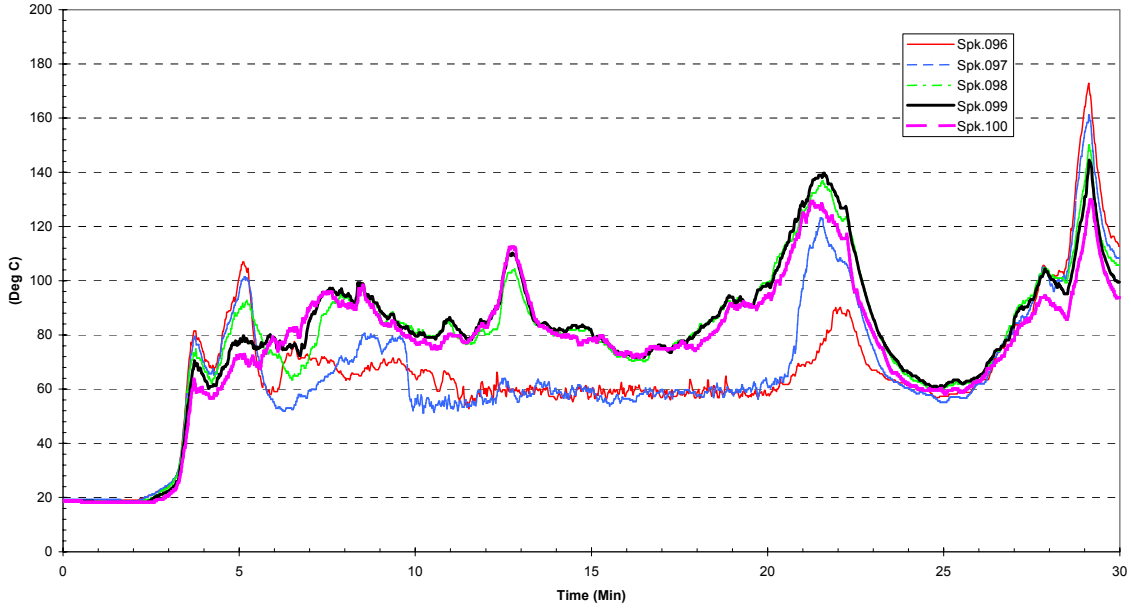

Figure B-21. Sprinklers 96, 97, 98, 99, and 100

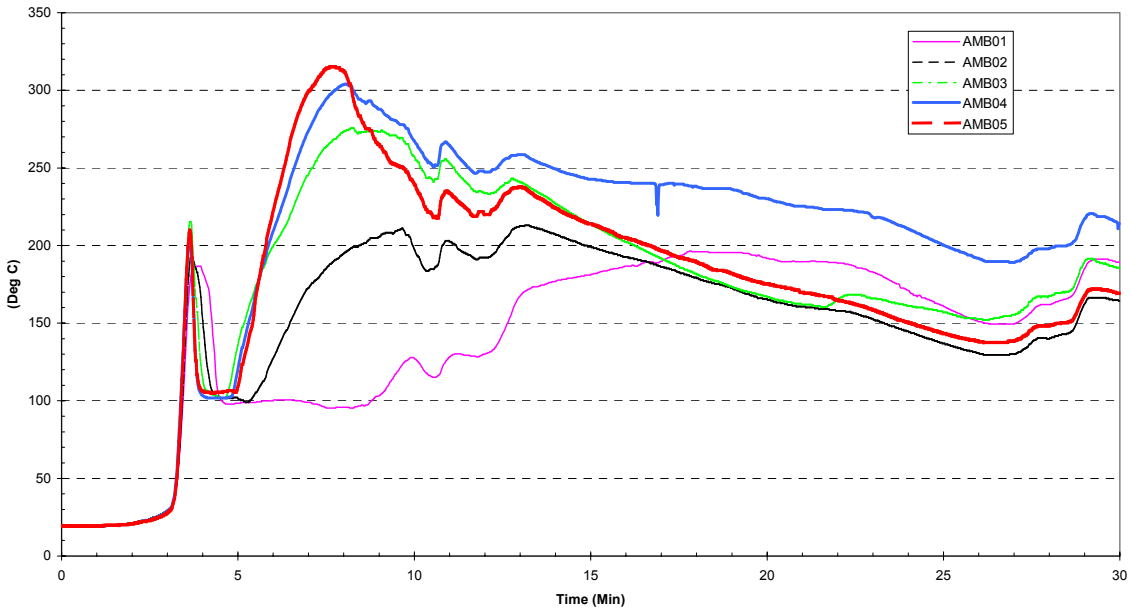

Figure B-22. Steel Beam Temperatures

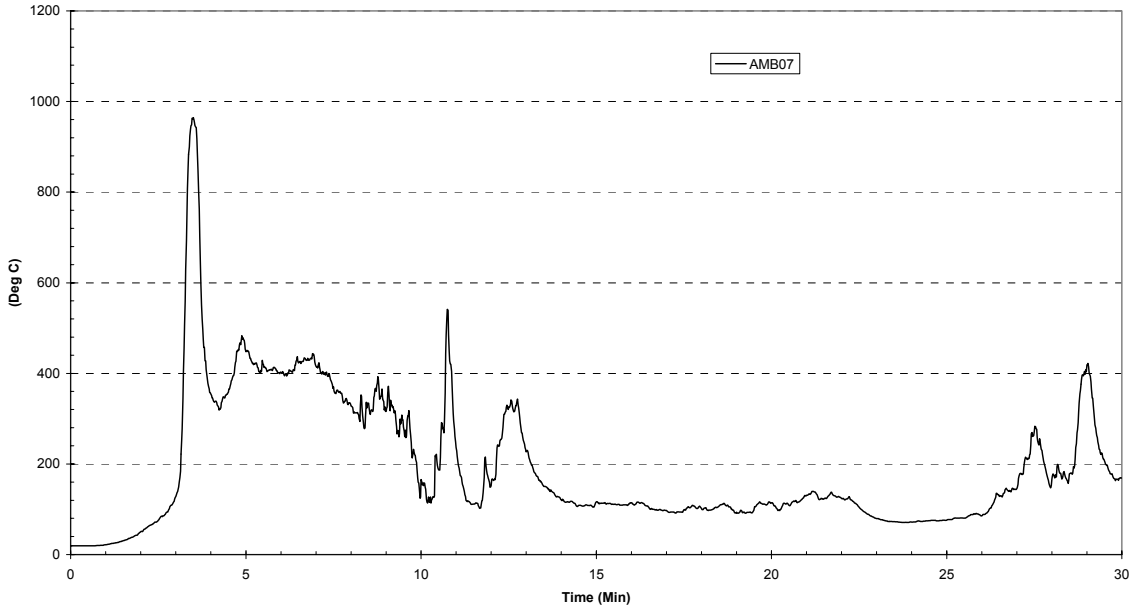

Figure B-23. Air Above Ignition Temperatures

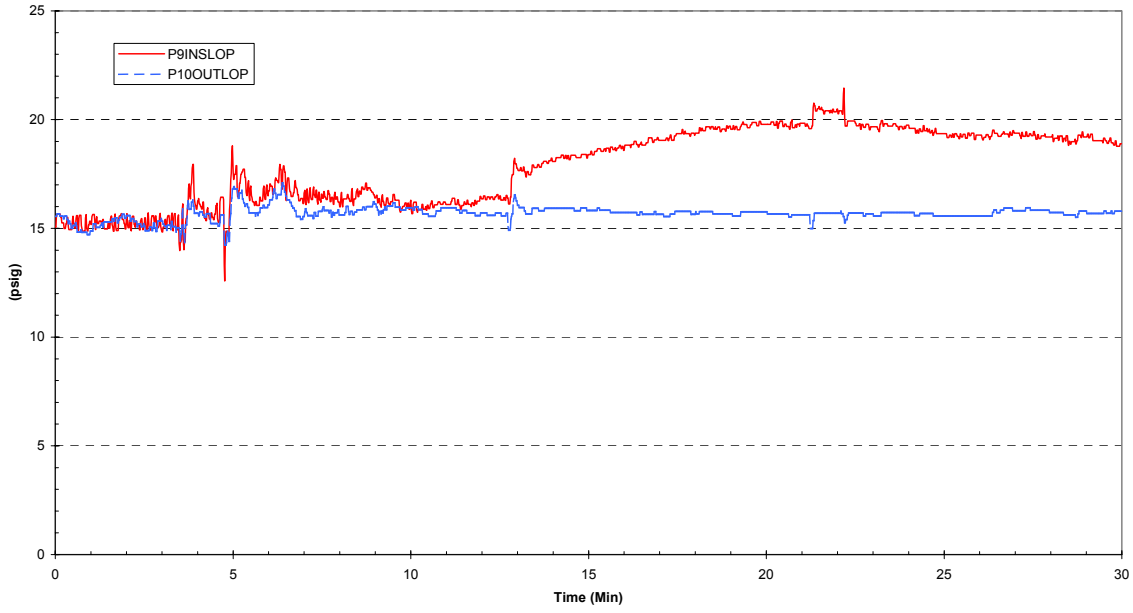

Figure B-24. System Pressure

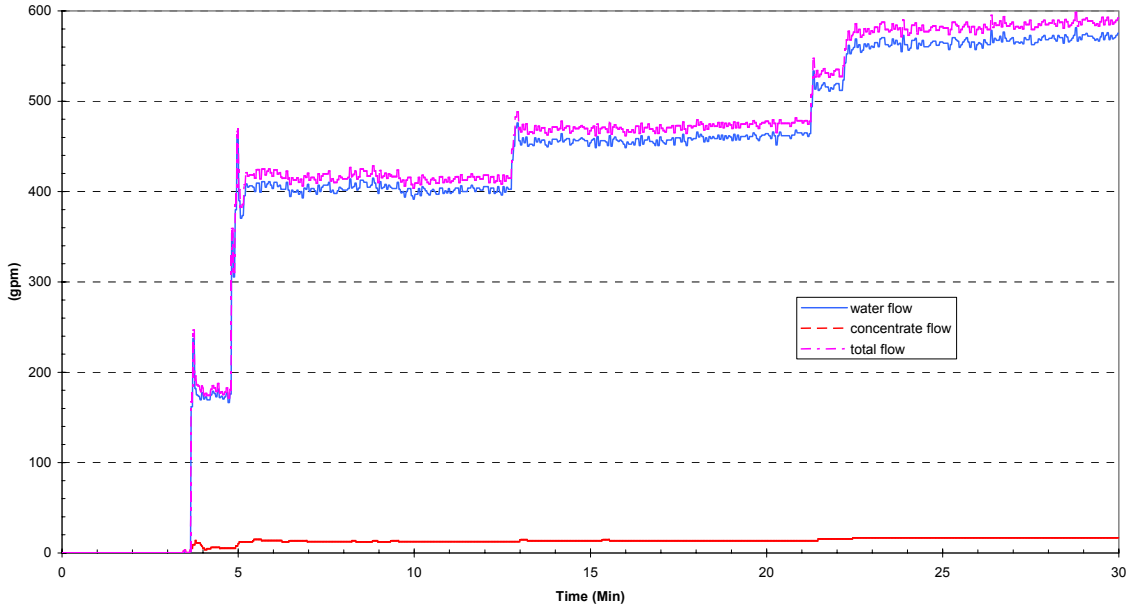

Figure B-25. System Flow

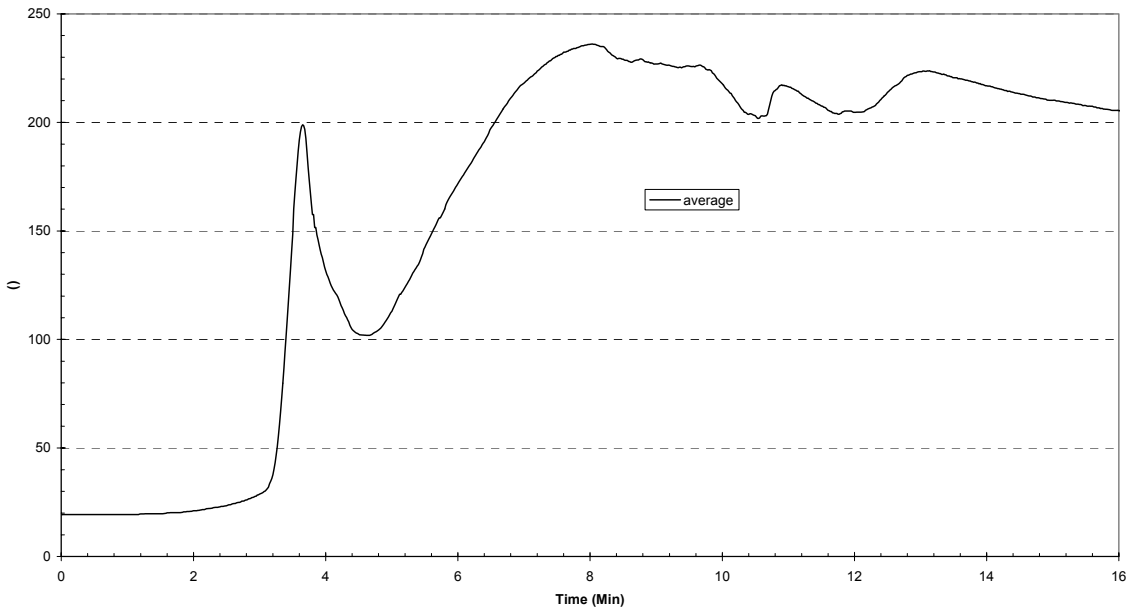

Figure B-26. Average Steel Beam Temperature

APPENDIX C

Test 3 Graphs

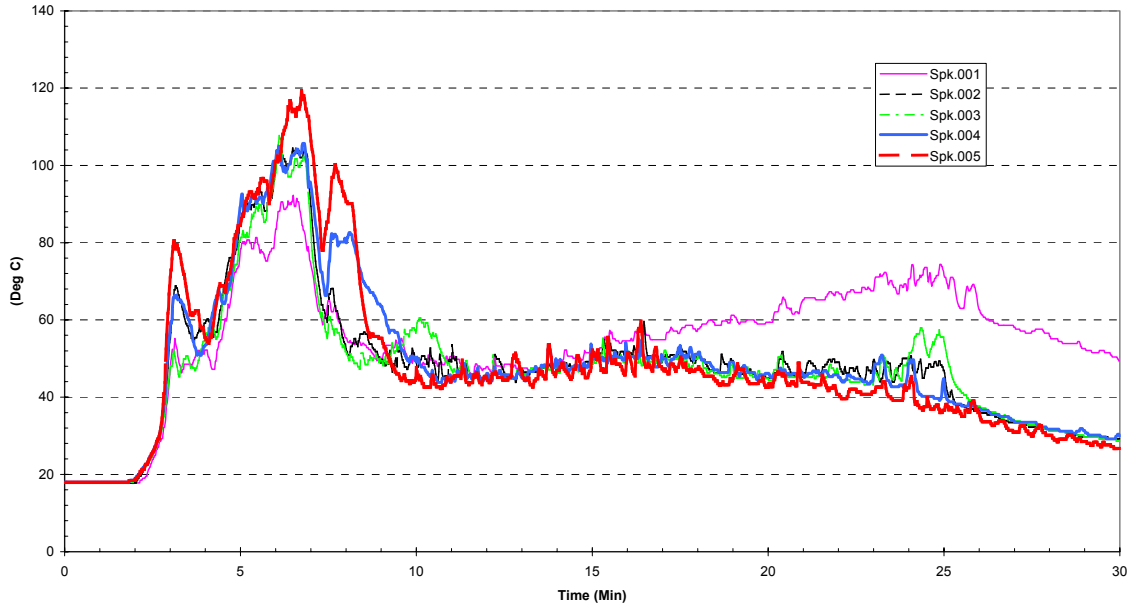

Figure C-1. Sprinklers 1, 2, 3, 4, and 5

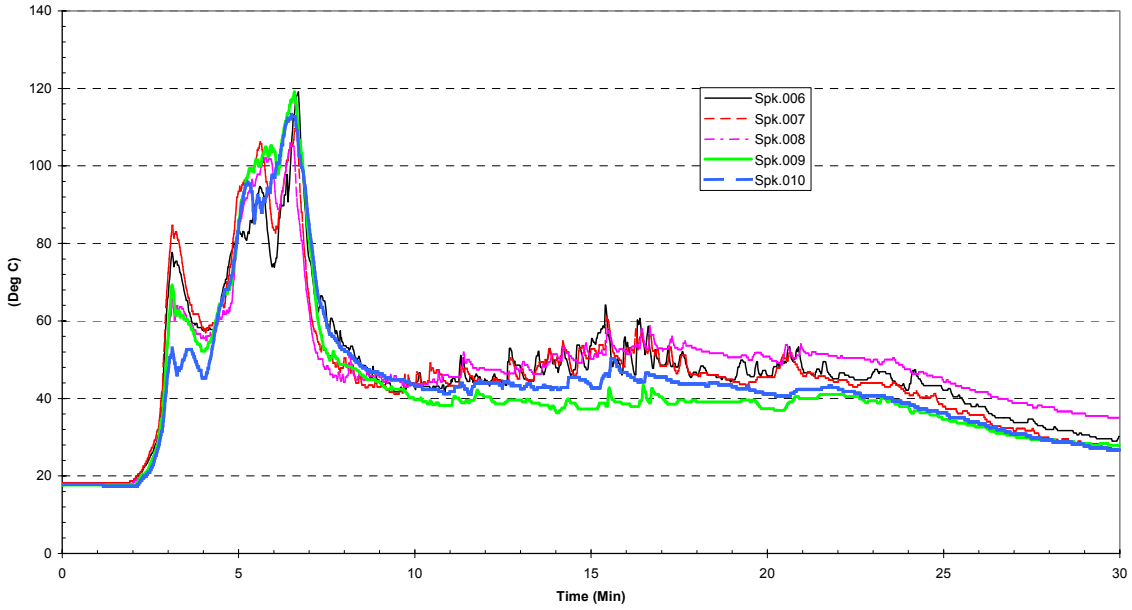

Figure C-2. Sprinklers 6, 7, 8, 9, and 10

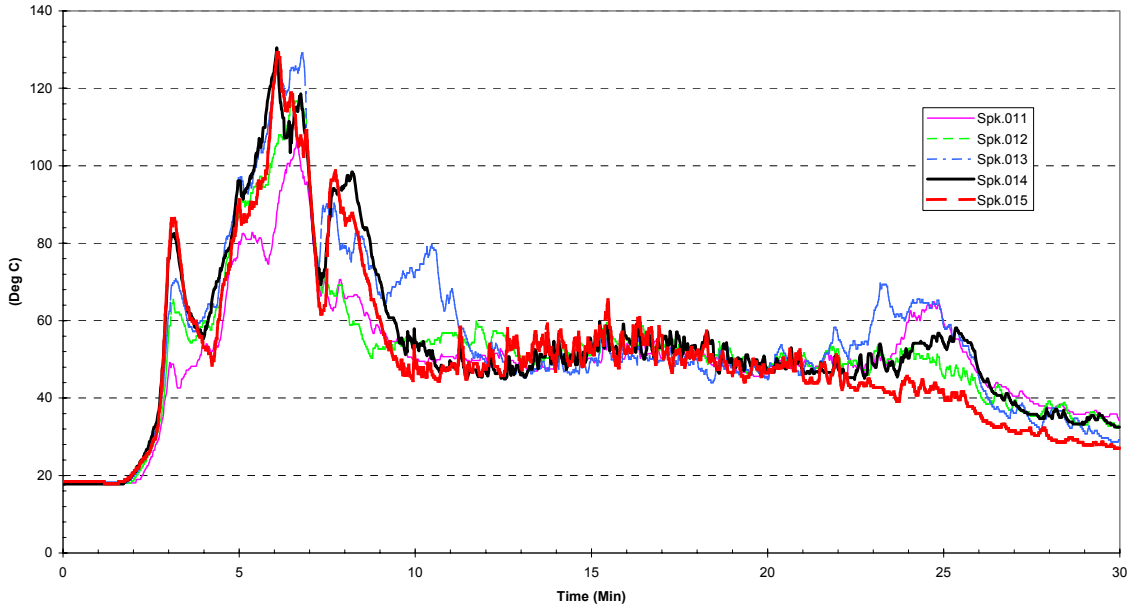

Figure C-3. Sprinklers 11, 12, 13, 14, and 15

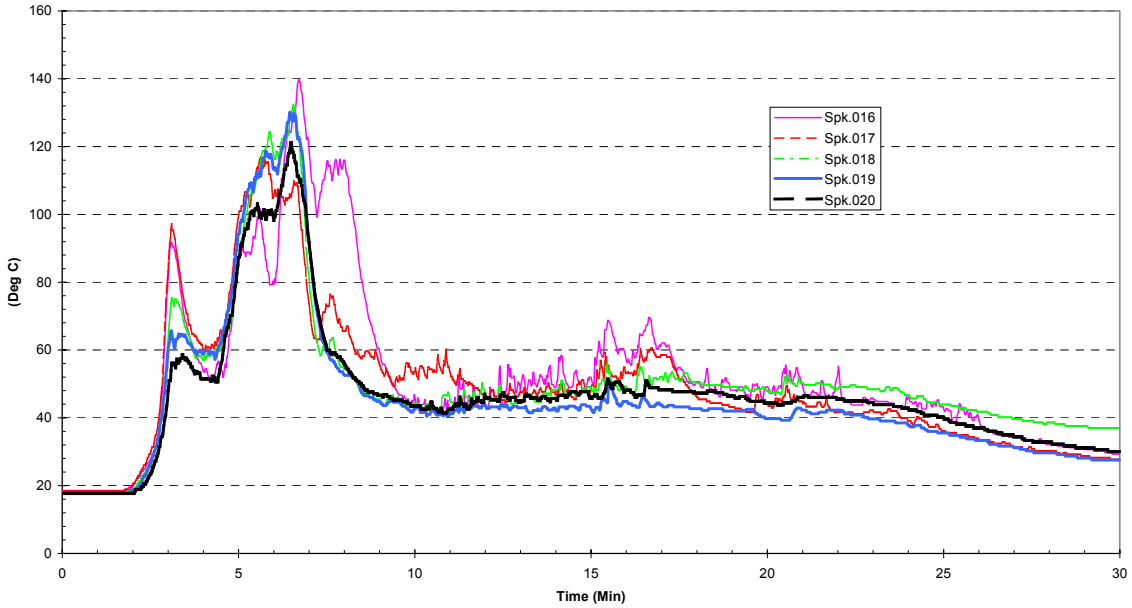

Figure C-4. Sprinklers 16, 17, 18, 19, and 20

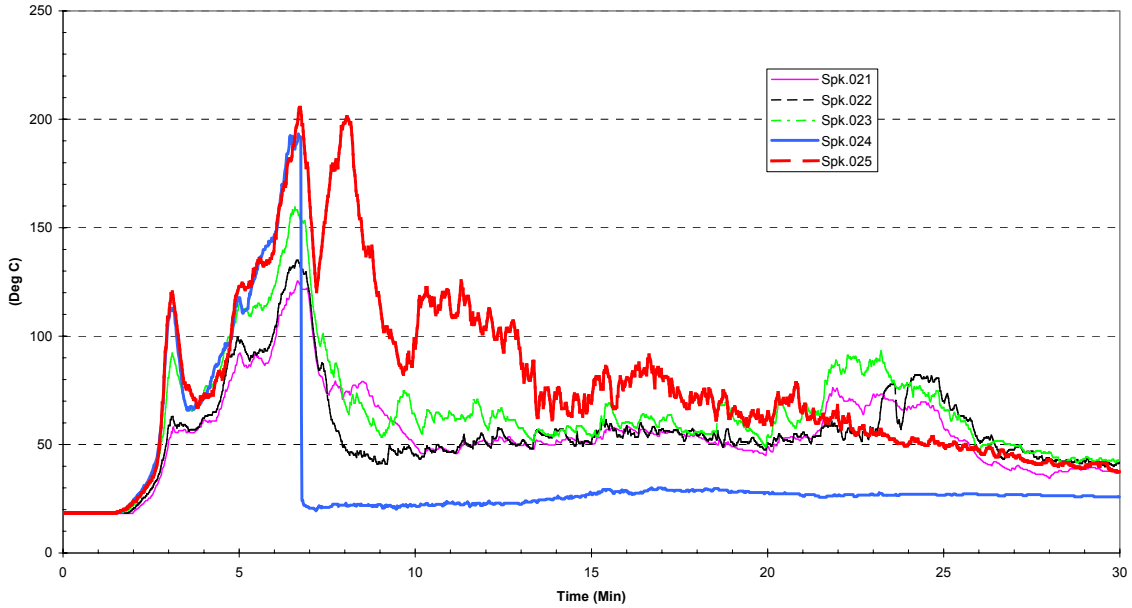

Figure C-5. Sprinklers 21, 22, 23, 24, and 25

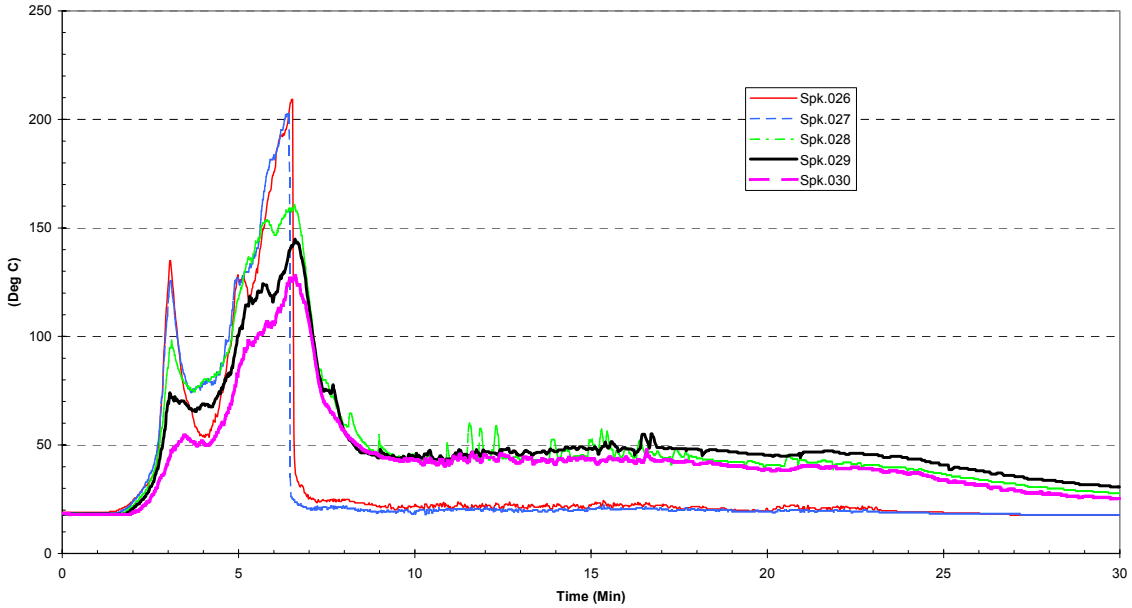

Figure C-6. Sprinklers 26, 27, 28, 29, 30

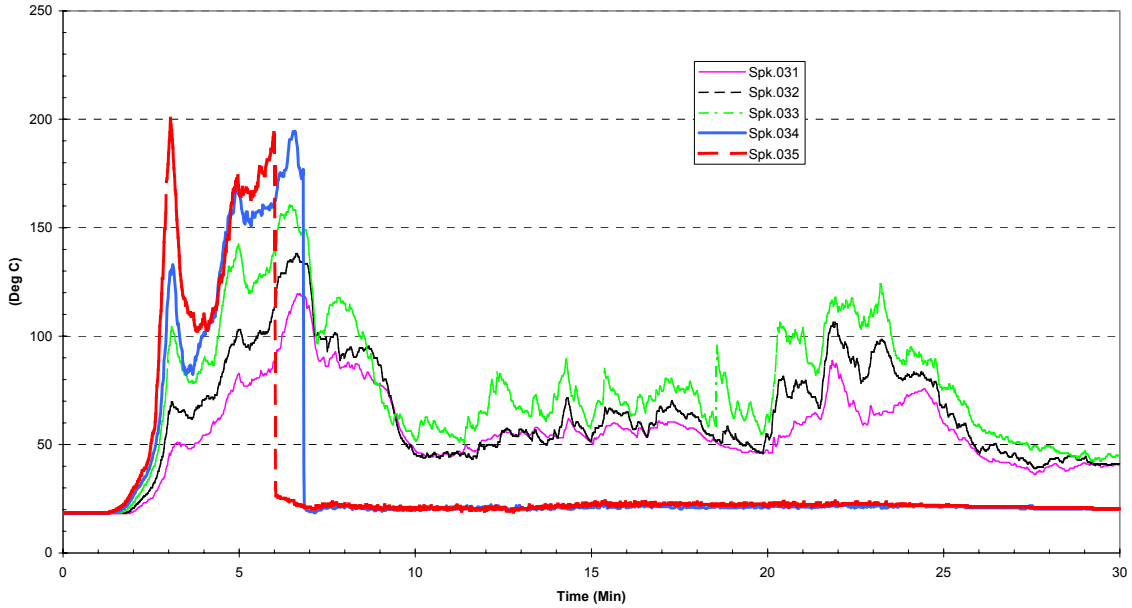

Figure C-7. Sprinklers 31, 32, 33, 34, and 35

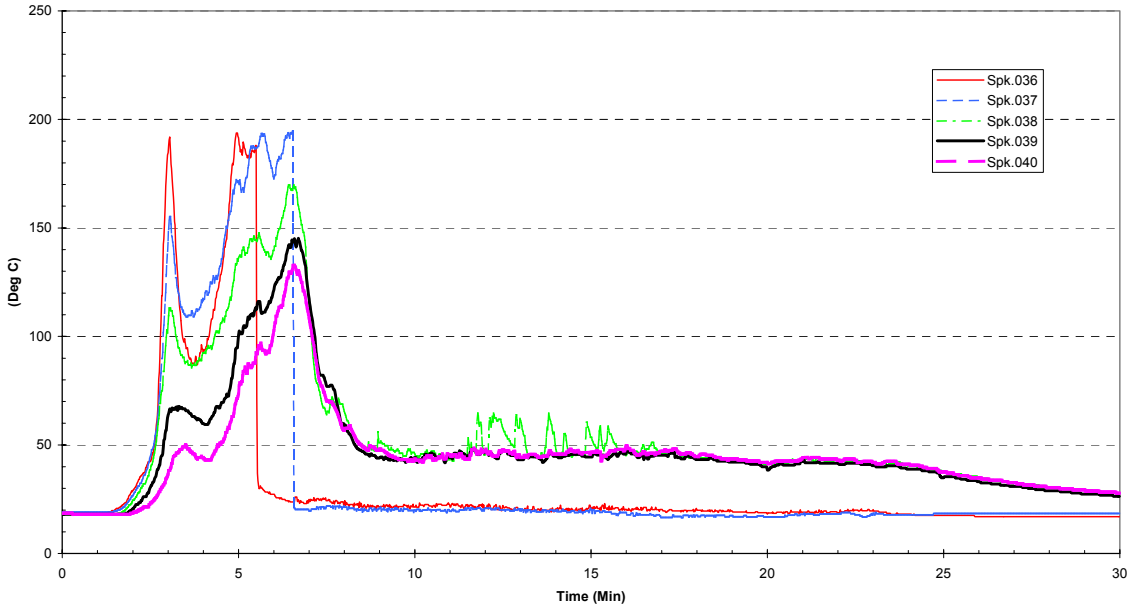

Figure C-8. Sprinklers 36, 37, 38, 39, and 40

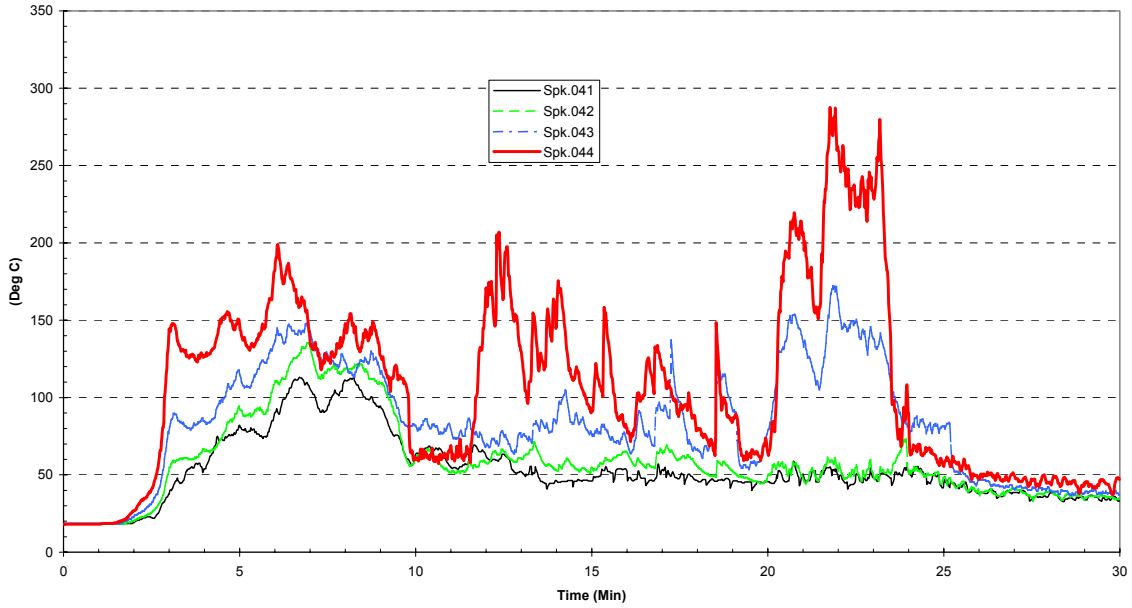

Figure C-9. Sprinklers 41, 42, 43, and 44

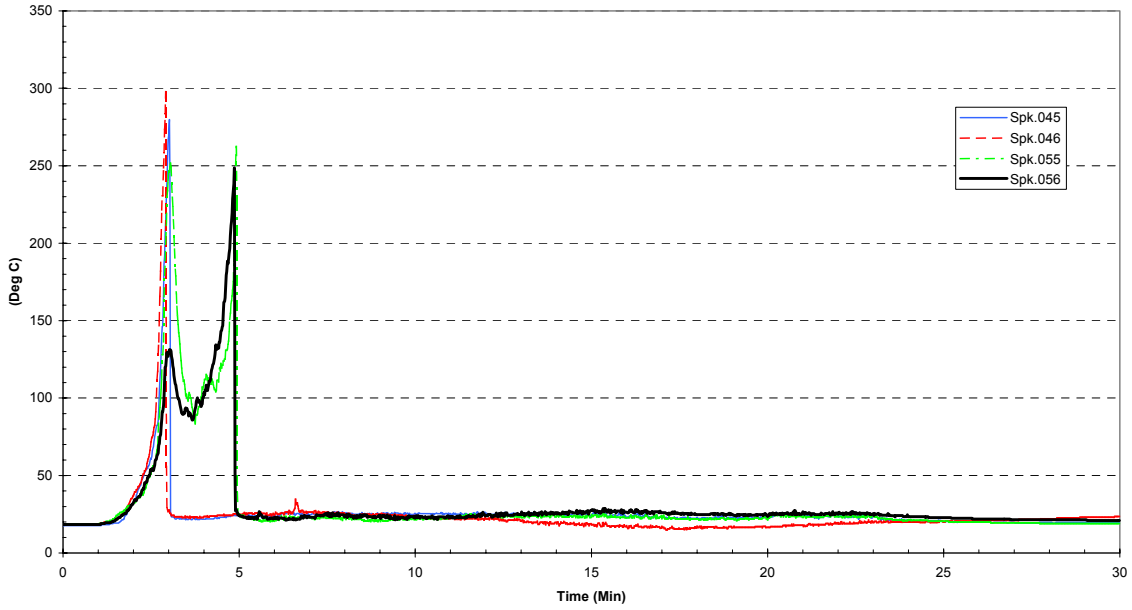

Figure C-10. Sprinklers 45, 46, 55, and 56

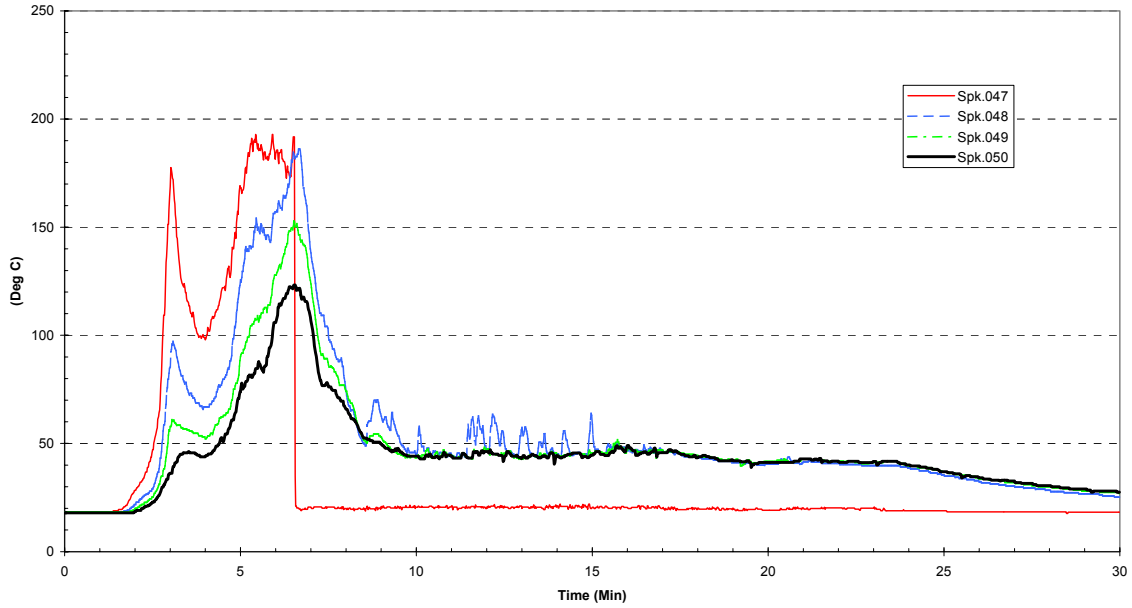

Figure C-11. Sprinklers 47, 48, 49, and 50

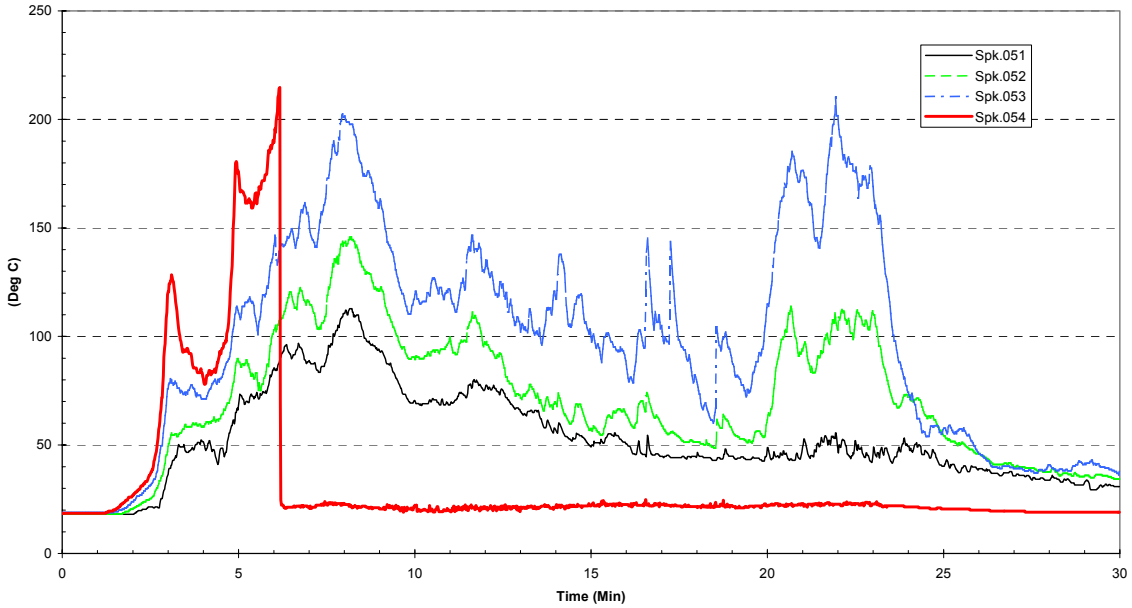

Figure C-12. Sprinklers 51, 52, 53, and 54

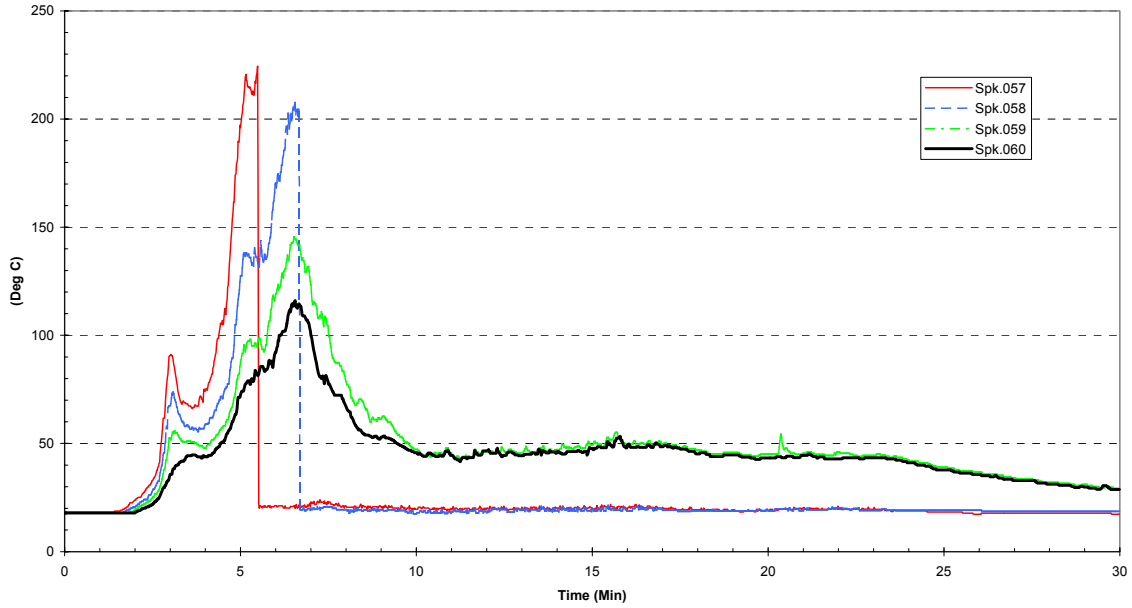

Figure C-13. Sprinklers 57, 58, 59, and 60

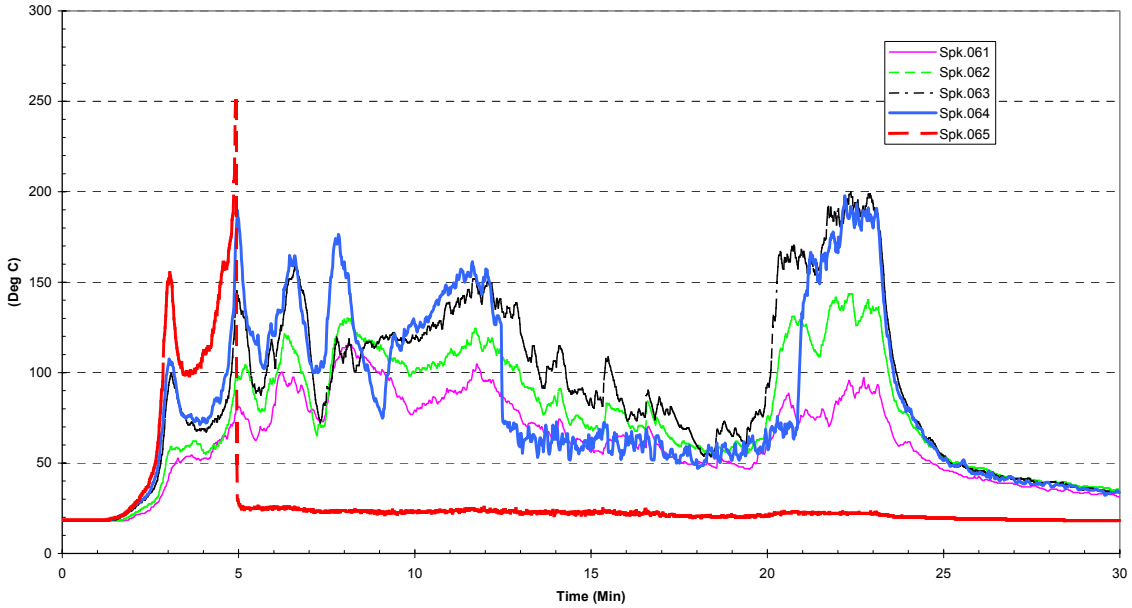

Figure C-14. Sprinklers 61, 62, 63, 64, and 65

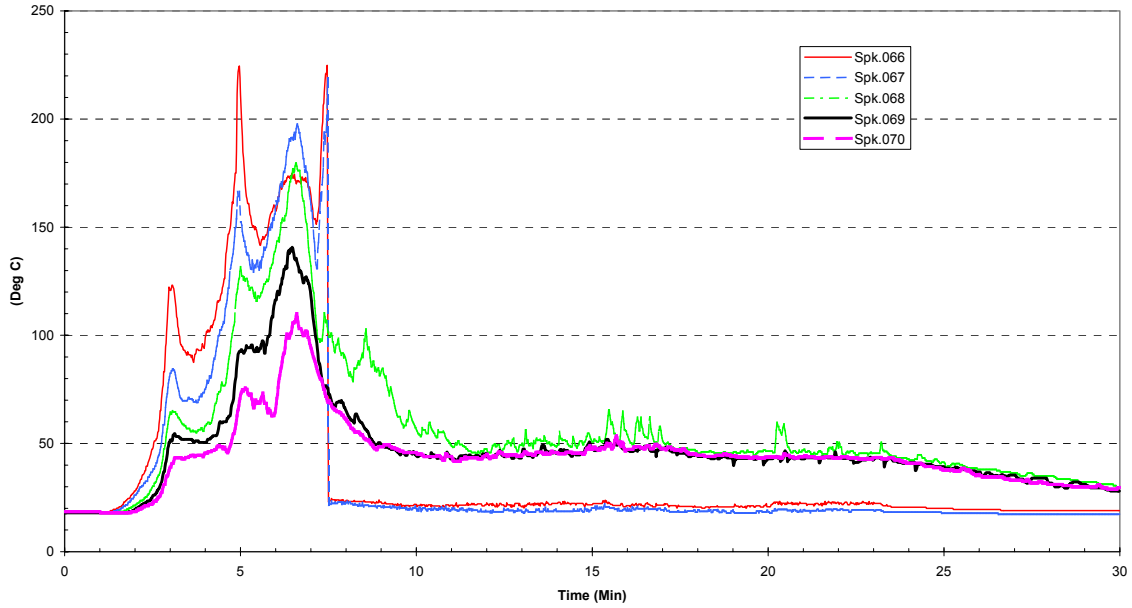

Figure C-15. Sprinklers 66, 67, 68, 69, and 70

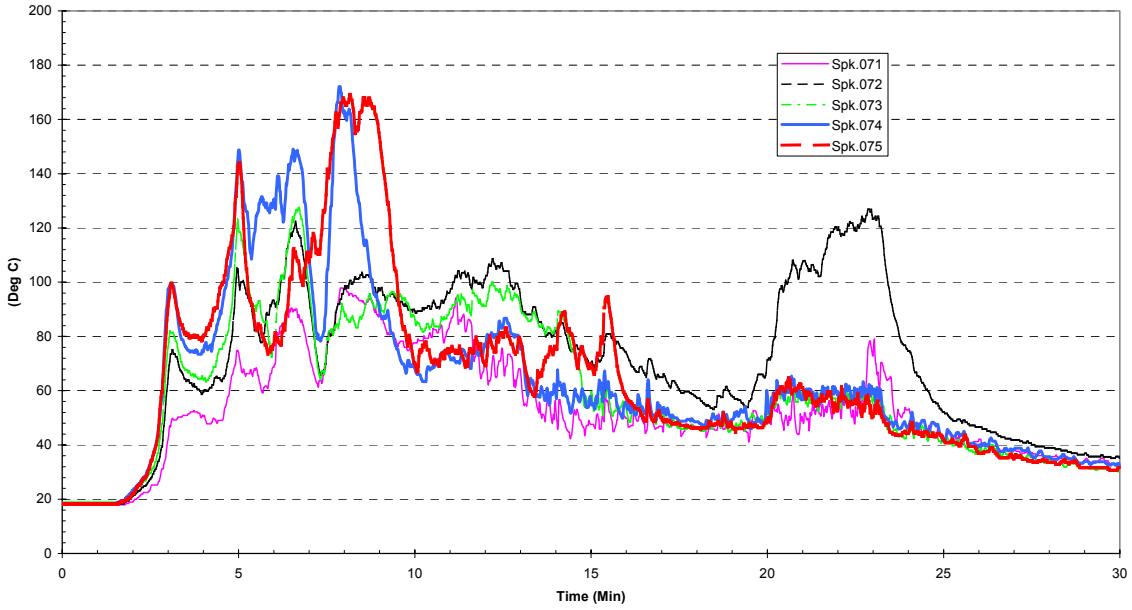

Figure C-16. Sprinklers 71, 72, 73, 74, and 75

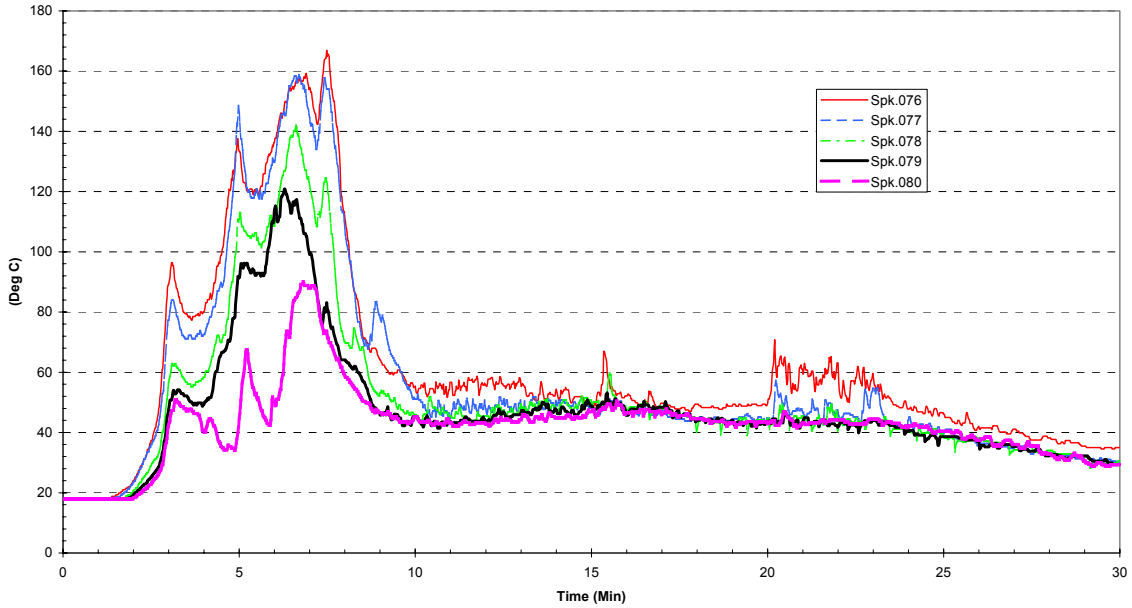

Figure C-17. Sprinklers 76, 77, 78, 79, and 80

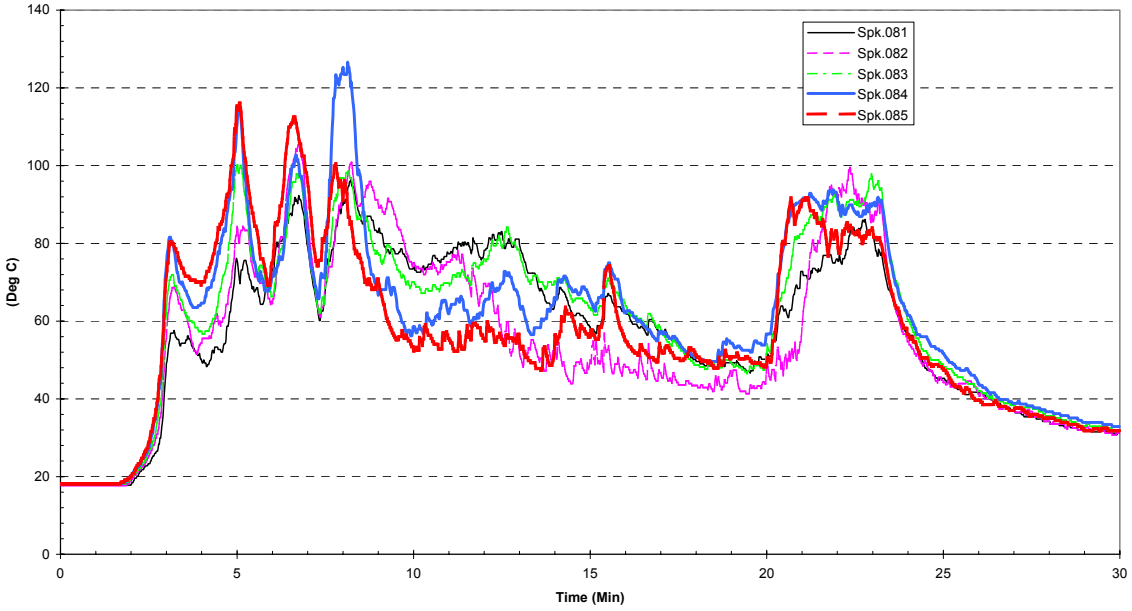

Figure C-18. Sprinklers 81, 82, 83, 84, and 85

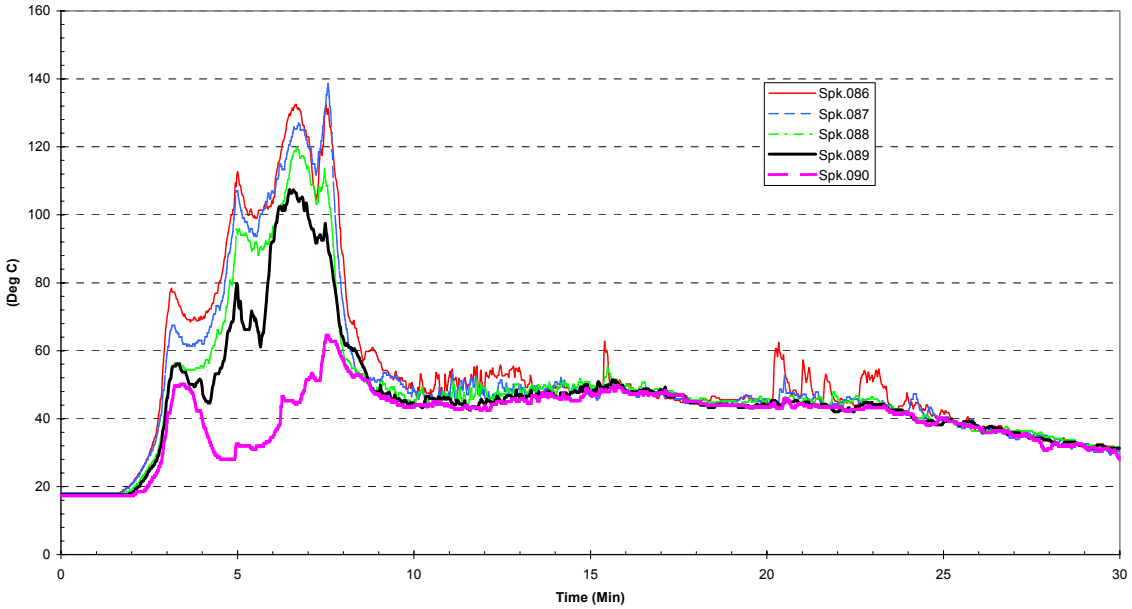

Figure C-19. Sprinklers 86, 87, 88, 89, and 90

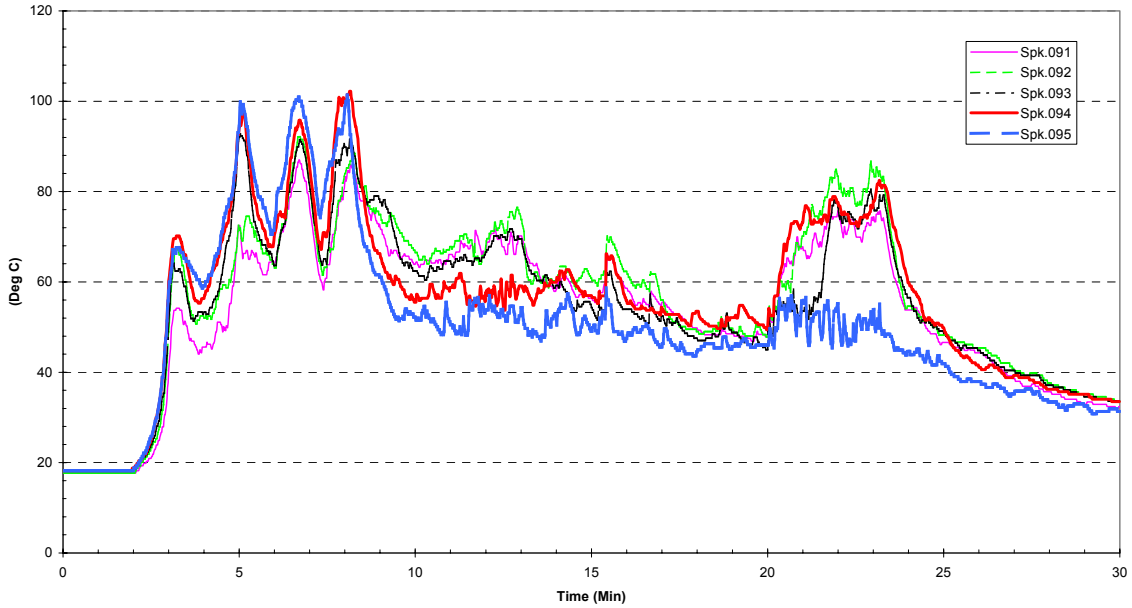

Figure C-20. Sprinklers 91, 92, 93, 94, and 95

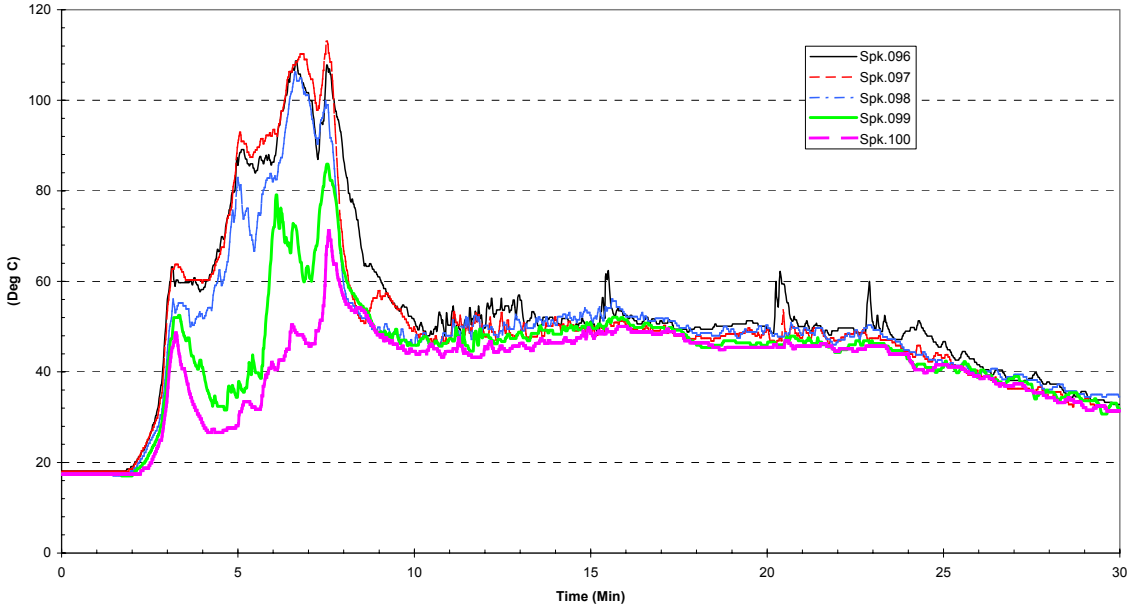

Figure C-21. Sprinklers 96, 97, 98, 99, and 100

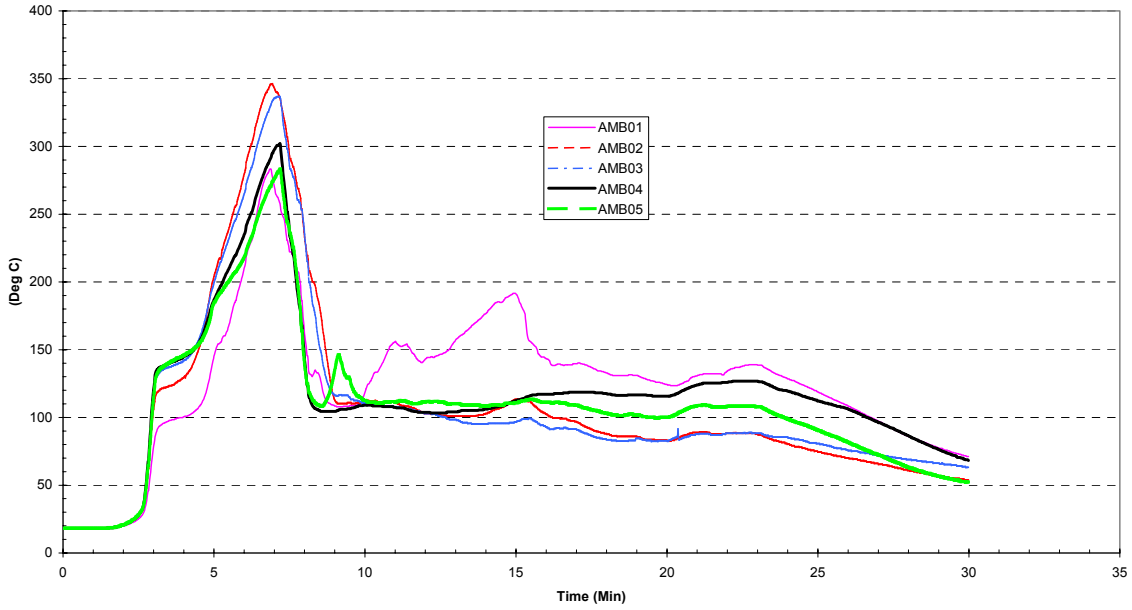

Figure C-22. Steel Beam Temperatures

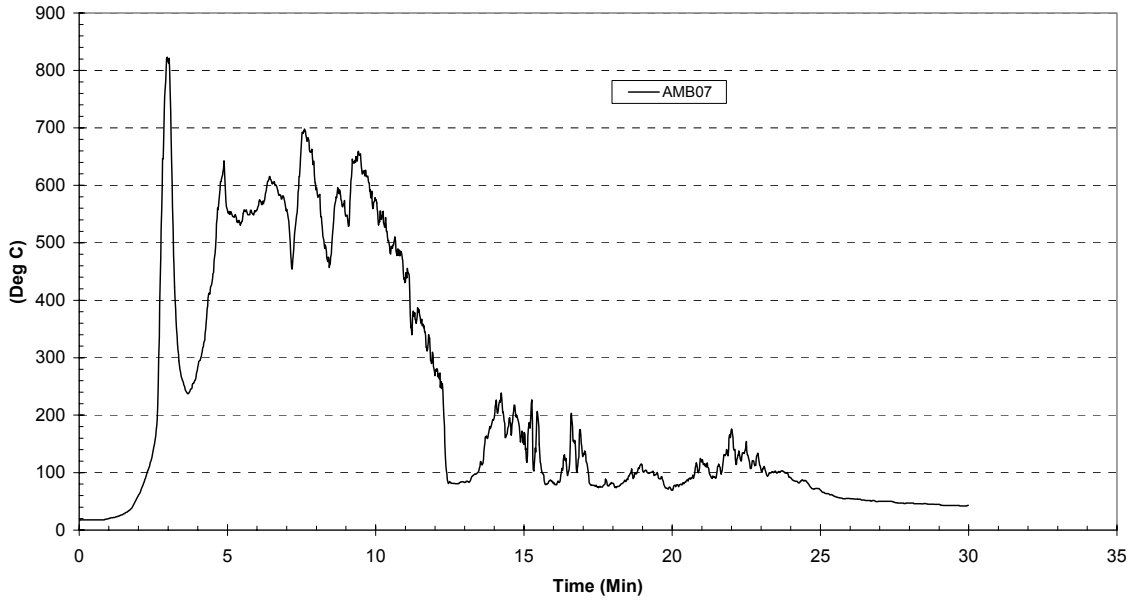

Figure C-23. Air Above Ignition Temperature

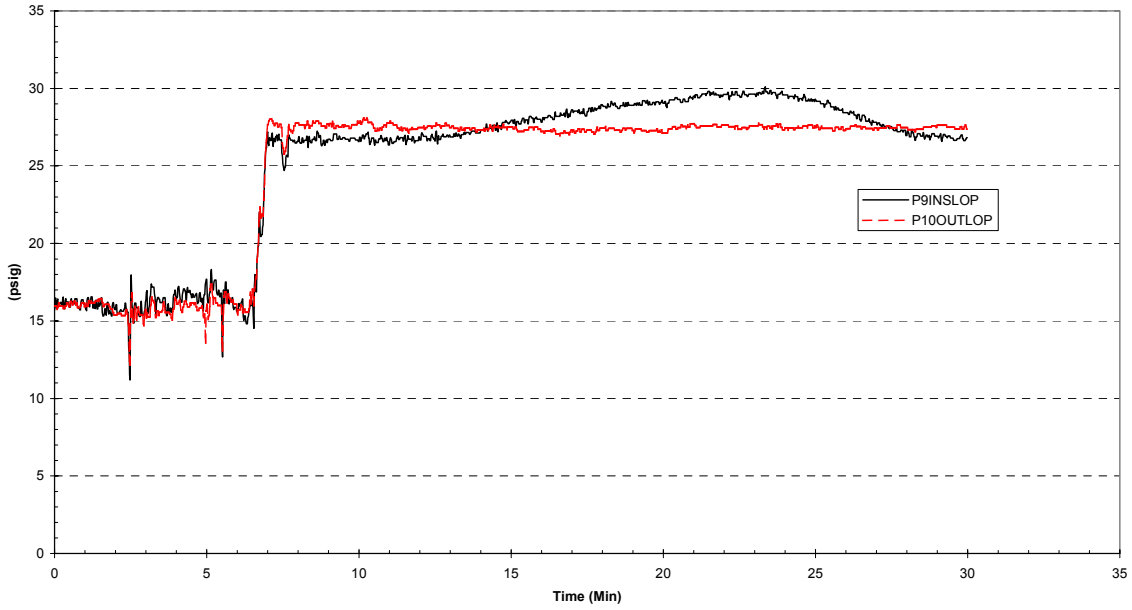

Figure C-24. System Pressure

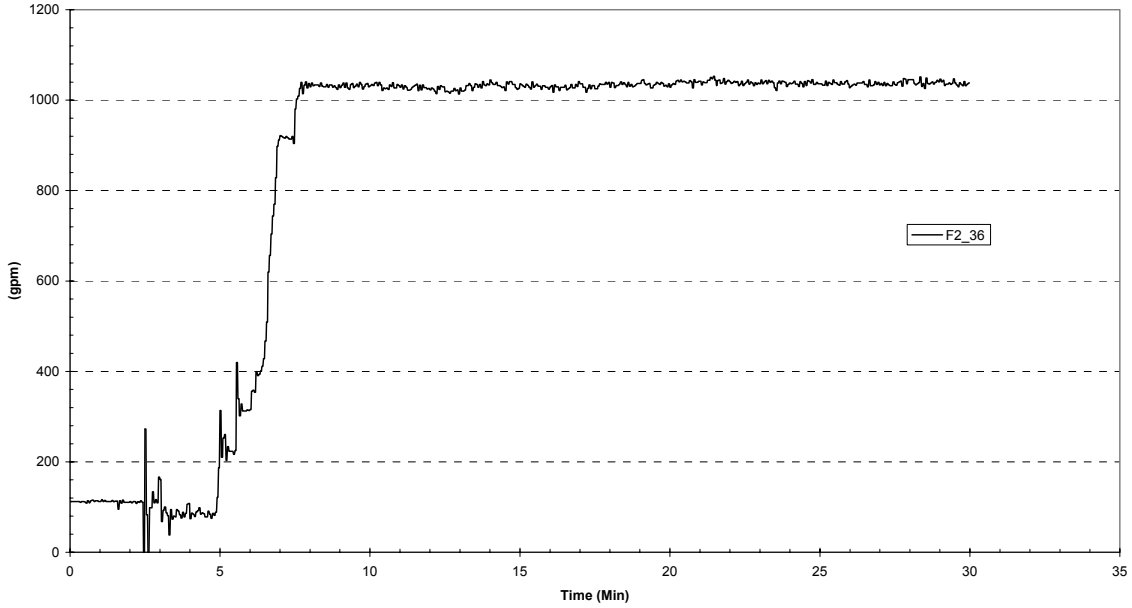

Figure C-25. System Flow