

# **Sprinkler Protection Criteria for Consumer Fireworks Storage in Retail Facilities**

## ***Concept Test Plan***

**Prepared by:**

***Aon Fire Protection Engineering Corporation***



**THE  
FIRE PROTECTION  
RESEARCH FOUNDATION**  
*Research in support of the NFPA mission*

# **FIRE RESEARCH**

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## **FOREWORD**

In 1999, the scope of NFPA 1124 was expanded to include requirements for retail sale of consumer pyrotechnics and the Pyrotechnics Committee was charged with the development of a new chapter on permanent facilities (both fireworks only and mixed commodity facilities), and temporary stands, tents and other retail sales facilities. In 2007, the Foundation conducted a hazard assessment and gap analysis for the standard. An identified gap in information is sprinkler protection criteria for the storage of this commodity in retail facilities.

This report presents the results of a field survey of stored consumer fireworks in retail facilities; a hazard assessment based on that survey and other information, and a research plan to evaluate required sprinkler protection design criteria.

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

# **Sprinkler Protection Criteria for Consumer Fireworks Storage in Retail Facilities**

## **Concept Test Plan**

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# Concept Test Plan

*Sprinkler Protection Criteria for Consumer Fireworks Storage in  
Retail Facilities*

*Quincy, Massachusetts*

*September 9, 2011*

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## INTRODUCTION

This document presents concepts proposed by Aon Fire Protection Engineering (Aon FPE) for the testing of consumer fireworks in retail display and storage. The findings are based upon data compiled during site survey of retail consumer fireworks locations, literature search of relevant technical resources, and the findings of *Fire Safety in Consumer Fireworks Storage and Retail Facilities – Hazard Assessment*, published by Aon FPE (formerly Schirmer Engineering) in 2007.

Fire tests, both full and small scale, will be used to establish the sprinkler protection required to protect consumer fireworks in retail facilities. The specific details of the program will be developed by the consultant selected to manage the program. An order of magnitude cost opinion is also included to facilitate project budgeting.

## REFERENCED STANDARDS

Standards are enforced in various locations throughout the country which address retail storage of fireworks. The following standards were referenced for comparison purposes and have provided baseline criteria for analyzing collected research and survey data.

- National Fire Protection Association (NFPA) 1124, *“Code for the Manufacture, Transportation, Storage, and Retail Sales of Fireworks and Pyrotechnic Articles,”* 2006 Edition.
- American Pyrotechnics Association (APA) 87-1, *“Standard for Construction and Approval for Transportation of Fireworks, Novelties, and Theatrical Pyrotechnics,”* 2001 Edition.

## SITE SURVEY SUMMARY

Eleven fireworks stores were surveyed during the period of June 13-21, 2011. The retail stores contained both public shopping areas and storage areas. In addition to eleven fireworks stores surveyed, additional fireworks stores were visited for reference. The following trends were observed while compiling the data for the retail areas of these stores:

### Public Shopping Areas

Fireworks stores are similar to grocery stores with respect to layout and product distribution. All of the stores had large quantities of products displayed on shelves, racks, pallets, and/or in bins. Stores were arranged for easy movement of occupants with shopping carts (provided in all of the stores surveyed) and aisles were nearly all at least 48 inches in width (as required by NFPA 1124).

All products were on display in original packaging (cardboard and/or plastic). Most of the products were neatly stacked and organized, with no visual damage to packaging. One of the stores sold products with damaged packaging in Ziploc bags. A store employee was observed removing damaged products from a



shelf during one of the site visits. Three stores visited (two of these not included in survey results) had damaged products located on the shelves for sale at regular or discounted prices.

Products were generally placed next to other products with similar characteristics and functions (i.e. all roman candles were located next to each other). Packaged products were commonly stacked on top of each other (similar to stacking canned goods or cardboard boxes in a grocery store).

All products observed were provided with fuse covers or protective packaging (as required by NFPA 1124). Where provided, fuse covers consisted of plastic caps (similar to wire nuts) or fuse protector tape. Products without fuse covers had product packaging as protection. One store visited (not included in the survey results) had small products on display in bins without fuse covers.

Shelving size and shape varied among the stores surveyed. The shelving consisted of single level bins to frames with up to five shelves. One of the stores used rack storage array to display products around the perimeter of the retail area.

Dimensions of shelving varied throughout all of the buildings. For the most part, shelving was less than 72 inches tall (maximum permitted by NFPA 1124) and 32 feet in length (extended distance at which flame breaks are required by NFPA 1124 when packaging is used as a flame break for lesser intervals). Most shelf widths were 48 inches or less (for both pallets and double-sided grocery style shelving). One of the stores had groups of four wooden tables (each table 4 feet by 8 feet) adjacent to each other as displays.

Storage heights varied in all of the stores and within the stores. Generally, most displays in the center of the retail areas were below 72 inches (height permitted by NFPA 1124). A small number of displays had heights of up to 90 inches. Storage heights around the perimeters of the retail areas varied, with a maximum height of 110 inches (144 inches permitted by NFPA 1124). Two stores visited (not included in the survey results) had products displayed at heights well above 72 inches (exact dimensions were not obtained).

Packaged assortments were located throughout the stores visited. Assortment boxes were used as a method of separating different types of products in several locations (permitted as flame breaks in NFPA 1124).

Quantity of products (based on floor area covered) from greatest to least were:

- Cakes
- Mine/Shell Devices
- Assortments
- Aerial Shell Kits
- Roman Candles
- Fountains
- Sparklers/Dipped Sticks
- Other (Sky/Bottle Rockets, Helicopters, Missiles, Firecrackers, Wheels)
- Novelties



## Storage Areas

The fireworks stores surveyed, with the exception of one location, each contained a storage area for receiving fireworks shipments. All storage areas were protected by sprinklers and/or separated from the remainder of the buildings by one-hour construction in accordance with NFPA 1124 Section 7.5.3. Storage in these rooms varied; however, nearly all the fireworks were kept in their original *DOT approved* shipping boxes/packaging. Five of the storage areas contained rack storage, but the predominant method of storage was solid piles of hand stacked boxes (with or without pallets underneath). The maximum storage height observed was 166 inches for racks and 120 inches for solid pile storage.

## PRIOR RETAIL FIREWORKS SPRINKLER TESTS

A review of prior testing of retail showroom fireworks arrangements was performed. Two test series were reviewed. Appendix A contains tables (Tables A and B), which contain data from the individual tests in these series.

### Battelle Tests

The first test series (Table A) reviewed was conducted by Battelle in 1999-2000 for the State of Ohio and the Fireworks Fire Suppression Task Force. The Battelle test configuration consisted of a mock showroom of 1,000 ft<sup>2</sup> with an 11'-8" ceiling height. Fireworks, in quantities intended to simulate a fireworks showroom fire load, were stored within standard gondola shelving. Two sprinkler system design approaches were tested, Control Mode Density Area sprinklers and Early Suppression Fast Response sprinklers. The test area was protected with 10 sprinklers for both tests. The test showroom was provided with a single door opening and a ceiling smoke venting system capable of removing 7,700 cfm. The system was activated for two of the four tests. An important aspect of the Battelle tests is that fireworks products used did not have fuse covers. Key observations of the Battelle test results are as follows:

- The Battelle tests used a room environment with defining ceilings and enclosing walls.
- The sprinklers were observed to activate in very short time frames, the first sprinkler operated at 5 seconds and all 10 sprinklers operated within 35 seconds after ignition.
- Projectile behavior of fireworks was common in all tests.
- Smoke and temperature untenable conditions (6 ft smoke layer height, 200°F) developed rapidly in some tests with best control on temperatures (majority of test below 200°F) seen with ESFR sprinklers.
- The 7,700 cfm smoke evacuation system was ineffective.

From a test approach perspective, the Battelle tests used very limited fuel package arrangements which consisted of three 12 feet long gondolas with shelf volume utilization estimated to be only 25-50 percent. The vast majority of the room was empty floor space void of any shelving or product display. The limited amount of combustibles greatly reduced the severity of the fire and limits the conclusions which can be drawn from this test series.

## Southwest Research Institute Tests

The second test series reviewed (Table B) consist of five sprinkler tests from a 12 test series sponsored by the American Fireworks Standards Laboratory. The tests were conducted at Southwest Research Institute (SwRI) in 2007-2008. The SwRI tests differed significantly from the Battelle tests in that all fireworks products were provided with fuse covers and several of the tests used wire mesh cages as a method to limit projectile behavior of aerial fireworks devices. Gondola shelves were used in four tests and a fifth test used a palletized display of fireworks assortment packs. The test area was 4,225 ft<sup>2</sup> with a ceiling height of 17 feet. The sprinkler system was designed to provide a density of 0.2 gpm/ft<sup>2</sup> using standard response, 165°F rated, CMDA sprinklers spaced at 10 feet by 10 feet. Key observations of the SwRI test results are as follows:

- Ignition of the fuel arrays was attempted several times using a fireworks product (fountain), but achieving a growing fire was not always successful. One successful ignition source was a ¼-inch wire mesh basket containing 15 sheets of crumpled paper ignited by gas torch.
- In Test 6, the first sprinkler activated at 2 minutes 45 seconds after ignition. For the other tests, slow to develop fires resulted in first sprinkler activations at approximately 13-21 minutes after ignition in four of five tests. Two or four sprinklers operated in each of the test.
- Product on the two lowest gondola shells generally continued to burn for the duration of the test due to shielding of the water spray by the shelving units.
- In Test 9, without mesh caging around aerals, the behavior noted was “lots of fireworks were injected into the aisle between the gondolas” and “some of the aerial devices were launched outside of the immediate fire area.”

From a test approach perspective, the SwRI tests used very limited fuel package arrangements which consisted of three 16-foot long gondolas with shelf volume utilization estimated to be only 25-50 percent. The vast majority of the room was empty floor space void of any shelving or product display. The limited amount of combustibles greatly reduced the severity of the fire and limits the conclusions which can be drawn from this test series.

## RESEARCH ANALYSIS

The following sections describe key components/factors that impacted the concept test plan. The components include product density, fuse covers, and sprinkler operation.

### Product Density

One of the most significant issues regarding future testing of fireworks is the product density / continuity of combustibles in storage arrangements. The site visits show that fireworks stores utilize shelving space at or near 100% volume capacity and that products are displayed in dense, relatively continuous arrangements until an aisle occurs. Conversely, the Battelle and SwRI tests used fireworks shelving displays that were not representative of the actual merchandising conditions noted in field surveys. Photos 1 and 2 show the difference in product loading observed during site visits verses the loading used on the gondolas in the SwRI tests.



**Photograph 1 – Merchandising of fireworks in one of the surveyed stores**



**Photograph 2 – Loading of fireworks in one of the SwRI tests**

During the development of this report, a number of questions were raised regarding the significance of product density on the shelves. The questions concerned whether or not a higher density of product impedes fire development, compared to a less dense array with more ventilation for burning and potential for projectile release. Aon FPE has developed several reasons that justify a dense product display as being the worst-case scenario for fire development.

- There is ample ventilation available to the fireworks product on the aisle faces and end cap faces of gondola shelving, which are assumed to be the likely side of an array to initially be exposed to an ignition source. Ventilation may be limited at the back and top sides of densely arranged product in various shelf arrangements; however, air gaps were observed above and around all packages in stores surveyed. Other display arrangements such as products displayed in stacks on tables or on pallets have adequate ventilation on all exposed sides.
- Upward flame spread must be considered. With fully packed shelves the open sided faces present a relatively continuous combustible surface for flame propagation which is an accelerating phenomenon. In scenarios where product is not densely stocked, the open space between the top of stored product and the next shelf above provides a discontinuity of the combustible surfaces, acting as a natural fire break which is likely to slow upward flame spread.
- Fireworks products are significantly different than typical retail store products. Fireworks products are assemblies of paper, cardboard, plastic, fuses, fuel, and oxidizing chemicals, which are intermingled with cavities and airspaces to create a finished firework product. The greater the density of firework product on the shelves, the greater fuel/oxidizer content per unit area of shelf space. The increased fuel/oxidizer content increases the potential heat release rate and fire propagation hazard per unit area.
- The high-density fireworks product arrays (such as noted in the site surveys), once ignited, will result in a greater probability of product ignition and fire spread due to confinement of energy and re-radiation within the shelves. For example, it is expected that firework fountains discharging upward into a densely packed shelf will have hot sparks and heat energy confined to a smaller area and, therefore, subject otherwise un-ignited product to a denser energy source. In the scenario of the lower density of product, the sparks from a fountain will more readily deflect off the back and undersides of shelves into the aisle and away from the immediately adjacent products. Although the

less dense scenario potentially exposes more products to the fountain spark release, the sparks ability to escape a less confined space allows the spark energy to dissipate and be less threatening to the adjacent product.

## Fuse Covers

Prior fire tests were not consistent regarding the use of fuse covers. The Battelle tests did not use fireworks outfitted with fuse covers, the SwRI tests did. Two of the SwRI tests, that did not incorporate sprinklers, demonstrated the potential value of fuse covers. In SwRI Test 1, the fireworks had no fuse covers and the result was reported as *"the fuse was ignited, and almost immediately, other devices where involved in the fire."* The next test, Test 2, utilized fuse covers and required a stronger ignition source (mesh wastebasket with crumpled newspaper) to develop a growing fire. With the fuse covers, Test 2 observations were reported as *"the fuse covers had an observable impact in preventing or delaying a fire event..."*

The use of fuse covers is consistent with the current requirements of NFPA 1124 and site observations of fireworks on display in the various facilities surveyed. Therefore, it is anticipated that future testing should be conducted with fuse covers. The fuse covers should be consistent with NFPA 1124 requirements and industry practices or any proposed standard for fuse covers that develops prior to testing (Note: NFPA has recently approved a project for development of a fuse cover standard).

## Sprinkler Operation

The fire development and sprinkler operating times for the Battelle and SwRI tests were distinctly different. The Battelle tests are characterized as having a confined room area, relatively low ceiling, no fuse covers and no containment of aerial devices. The SwRI tests did not use a confined room geometry (floating ceiling in test space), included a ceiling height of 17 feet, and fireworks products were outfitted with fuse covers.

The lack of an enclosed room geometry in the SwRI tests and increased ceiling height are factors that would result in longer sprinkler operating times than those observed in the Battelle tests; however, the use of fuse covers did delay the fire development. The relative contribution to sprinkler delay of the fuse covers verses the ceiling height verses lack of confining walls is not clear and has not been analyzed (outside this project scope of work).

The SwRI test results typically showed first sprinklers operating approximately at 3, 13, 14, 19, and 21 minutes after ignition in five independent tests, with a total of two or four sprinklers operating per test. Based on test results, there appeared to be control of the fire, although it was noted that fire continued to burn on the lower two gondola shelves. However, it is not clear if fire control would be achieved if longer shelving units or a room full of products were tested.

Three of four SwRI gondola shelf tests used wire mesh to fully cage in aerial devices; however, this method of confinement was not observed in any site survey. Additionally, it is not clear if this solution for containment would be a practical approach for operating facilities.

In both the Battelle and SwRI tests, the majority of the room was empty floor space void of any shelving or product display. As a result, the continuity of combustibles was lacking and any indication of fire control being achieved can not be concluded from the SwRI test series or the Battle tests in which all available sprinklers (10) operated.

## RESEARCH PLAN

The evaluation of the hazard of a commodity usually focuses on the energy produced by the burning of the commodity, its packaging, and its container. Given the amount of energy produced, as well as the array factors, the appropriate sprinkler system design parameters can be selected based upon a pre-established commodity ranking system found within sprinkler design standards such as NFPA 13. This is a relatively simple task given one uniform commodity; evaluation of a mixture of commodities with various hazard rankings is however, challenging.

Current engineering practice is to use the characteristics of the worst-case commodity to establish the overall commodity ranking and therefore the sprinkler system design parameters. This is obviously a simplified solution intended to address such complex issues as commodity mixing variation and the related energy release.

Consumer fireworks are unique, in addition to releasing energy while burning; such products can deflagrate, spray sparks, or launch projectiles to adjacent areas. Additionally, fireworks contain their own oxidizer. These characteristics must be addressed to quantify the hazard and establish appropriate sprinkler design parameters.

Following are the categories of consumer fireworks defined in NFPA 1124, Appendix C. The characteristics of the product, beyond that of energy release due to burning, are also shown:

- Ground/handheld sparkling devices: Spark spread potential
- Aerial devices: Deflagration, projectile launching potential
- Audible devices: Deflagration potential
- Multiple tube devices: Spark spread potential
- Novelties: No special hazards

It is proposed that a worst-case product or groups of products are identified to be the focus of the testing program. This approach is consistent with the general manner of product storage and display found during site survey of consumer firework retail facilities. Simplification of the test program will also result.

## Test Method

The first step will be to determine the products, or groups of products, with the highest heat release rate by conducting calorimeter tests. Arrays, although smaller in length, will simulate actual configurations found during site surveys. It is anticipated that both shelf and palletized arrays will be tested. The highest heat-release rate products will then be used in full scale testing.

The effect that projectile launching or spark spread will have on the characteristics of a fire is more difficult to quantify. The obvious concern is that sparks or projectiles will spread the fire to others locations within the store, which could negatively affect sprinkler performance or accelerate fire spread. These characteristics will be evaluated in full scale testing. It is proposed that all full scale testing will occur within a mock up of a typical retail store, including walls and ceiling. The influence of projectile launching and spark spread on fire growth and fire spread will be documented using this configuration.

The sequence of the full scale testing is to first test the high heat release material, without aerial or spark spread products, to verify that ceiling sprinklers can adequately protect these products. The aerial and spark spread products will then be tested separately in the same array. This allows for comparison of the effect of the aerial and spark spread products on fire growth and development and the ability of the sprinklers to control the fire. Success of these tests will also allow flexibility in product merchandising. Failure will result in specific criteria or design measures for the most demanding product. Such measures may include transverse breaks or containment of aerial products.

The parameters of the testing are presented in Table 1 below. For standardization, certain array details will comply with the requirements of Underwriters Laboratory Standard 199 (UL 199) “*Automatic Sprinklers for Fire Protection Service.*” It is anticipated that standard type igniters will be used. After the calorimeter testing the actual size of the igniters, ½ or ¼ sizes, will be determined based upon review of the heat-release rate data.

**Table 1 – Fire Test Parameters**

Fire Tests	Shelf Storage	Palletized	Comments
Test Room Size( sq ft)	3,000-5,000	3,000-5,000	Size of Typical Retail Store
Storage Type	Shelf (Gondola)	Palletized Open Array	
Commodity Type	Consumer Fireworks	Consumer Fireworks	
Nominal Storage Height (ft)	6	6	
Nominal Ceiling Height (ft)	12-17	12-17	
Nominal Clearance (ft)	6-11	6-11	
Array length(ft)	32	21	UL 199
Aisle Width (in.)	48	N/A	
Longitudinal Flue (in.)	N/A	12	
Longitudinal/ Transverse Divider	Longitudinal at 24 inches	NA	UL 199
Ignition Location	Between 2 Sprinklers (Centered)	Between 2 Sprinklers (Centered)	
Igniter Details	2 Half Igniters - 3" by 3" Each with 4 oz Gasoline	2 Half Igniters - 3" by 3" Each with 4 oz Gasoline	
Sprinkler Type/ Temperature Rating (°F)	CMDA 165	CMDA 165	
Sprinkler Orientation	Pendent	Pendent	
Sprinkler Response	Quick Response	Quick Response	



In addition to the fire tests for retail areas, fire tests will also be conducted to evaluate products located in storage areas.

## TEST CONCEPT SUMMARY

Table 2 shows the proposed tests by description and number.

**Table 2 – Test Concept Summary**

Description of Test	Product Type	Number of Tests
<b>Mock Building</b>	Construction of 3,000-5,000 ft <sup>2</sup> mock building	To be used in all full scale tests
<b>Calorimeter – Fuel Package Tests</b>	Samples from categories defined by NFPA 1124, Appendix C	12 - One from each category plus three more
<b>Full scale retail tests (described in Table 1)</b>	Highest heat-release rate products, plus worst case projectile launching products	6 - gondola array, 2 - palletized array
<b>Full scale storage tests</b>	Highest heat-release rate products in DOT approved packaging.	1 - rack storage, 1 - palletized array

## CONCLUSION

A fire test program is presented in this document which endeavors to determine the automatic sprinkler design criteria required to protect consumer fireworks in retail facilities. Further embellishment of the concepts presented herein will be completed by the consultant selected to complete the testing portion of this project.

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## APPENDIX A – SPRINKLER TEST COMPARISONS, BATTELLE AND SWRI TESTS



**Table A – Comparison of Prior Known Fireworks Sprinkler Tests**  
**1999-2000 Test Series by Battelle (Note: Fireworks did NOT have fuse covers)**

Test	Ignition Data	Fuel Package	Room Data	Sprinkler Data	Sprinkler Results	Other Results	Comments
<b>Battelle Test 1</b>	One box of Nutty Monkeys ignited using an electronic match, 4 attempts required to get successful ignition	5 cases of fireworks that included Tanks, Rockets, Ground Spinners, Fountains, Roman Candles; 2 <sup>nd</sup> tier of only 1 gondola shelf located against wall	1,000 ft <sup>2</sup> , 11'-8" ceiling, one open door 36" x 80"	Extra hazard, 100 ft <sup>2</sup> spacing, Standard Response, 155° F, two branch lines with five sprinklers on each line; k=5.5, 48 gpm operating at 76 psi	First activation at 8.5 seconds, 1,000° F reached at sprinkler within 30 seconds, all sprinklers fused, event duration was 1 minute 39 seconds	Some items dispersed off shelf and continued to burn on the floor, pegboard backing on the shelves and ceiling tiles were burned with signs of complete flame breakthrough, shelving blocked water penetration and permitted small fire to burn unsuppressed after primary fires slowed, all fireworks consumed in test	Test used fuel array of limited area
<b>Battelle Test 2</b>	Electronic match on single Roman Candle on middle shelf of center gondola	45 cases of fireworks configured on 7 gondola shelves	1,000 ft <sup>2</sup> , 11'-8" ceiling, one open door 36" x 80"	All open sprinklers manually operated, sprinkler characteristics same as Battelle Test 1	Activation temp. for 1 <sup>st</sup> sprinkler (165°F) reached at 5 seconds and at 21 seconds for most remote sprinklers, manual water flow operation at 1 minute after ignition	Uncontrollable nature of event caused erratic TC readings which were impacted by flying objects, temperatures above 2,700°F, shelves knocked off their brackets and pegboard completely consumed, smoke untenable at 18 seconds and temps. untenable at 13 seconds with 6 feet temperature of 1488°F	Manually operated sprinkler system, test used fuel array of limited area
<b>Battelle Test 3</b>	4 oz mortar atop aerial repeater	150 cases of fireworks configured on three 12 feet long gondolas (one on wall and one center gondola) shelving units, 3 & 4 shelves high, 6 feet aisle used	1,000 ft <sup>2</sup> , 11'-8" ceiling, one open door 36" x 80", smoke evacuation vents in ceiling with max capacity of 7,700 cfm	Extra hazard, 100 ft <sup>2</sup> spacing, Standard Response, 155° F, two branch lines with five sprinklers on each line; k=5.5, 48 gpm operating at 76 psi	First sprinkler over ignition operates after 5 seconds, all others fused between 7-18 seconds, backup sprinkler system activated at 58 seconds	Flames up height of shelves in 3 seconds, smoke detection at 5 seconds, aisle jump at 6 seconds, temperatures over 1,200°F within 2 minutes, smoke untenable at 30 seconds and temperatures untenable at 36-55 seconds with 6 feet temperature of 320-1,125°F for respective TCs, drywall mostly destroyed with charring and projectile damage, ceiling tiles destroyed, smoke detectors melted and unrecognizable	Suggests standard response sprinklers cannot be effective, test used fuel array of limited area, provided smoke evacuation system was ineffective
<b>Battelle Test 4</b>	Two sets of 3 electric matches to two different Twitter Glitter 110 shot aerial repeaters (only one set needed for ignition)	Described as 170 cases of fireworks but report notes overall fire loading was similar to Battelle Test 3	1,000 ft <sup>2</sup> , 11'-8" ceiling, one open door 36" x 80", smoke evacuation vents in ceiling operating during test	ESFR, 100ft <sup>2</sup> , 165F, k=25, 83+ gpm operating at 11+ psi	Operating times of 15, 22, 31 seconds, all sprinklers fused by 35 seconds, backup sprinkler system was NOT needed	Fire spread across both aisles, projectile damage to walls, temperatures at 10 feet held below 200°F for test duration, smoke filled space, smoke untenable at 36 seconds and temperatures untenable at 42-50 seconds with 6 feet temperature of 120-350°F for respective TCs, chamber damage was minimal, minor projectile damage, smoke detectors showed no signs of melting	Suggests fast response sprinklers can be effective, room very small, very rapid fire development, projectiles reached to extremes of room, test used fuel array of limited area, provide smoke evacuation system was ineffective after 40 seconds

**Table B – Comparison of Prior Known Fireworks Sprinkler Tests  
2007 Test Series at Southwest Research Institute (SwRI)**

Test	Ignition Data	Fuel Package	Room Data	Sprinkler Data	Sprinkler Results	Other Results	Comments
<b>SwRI Test 6</b>	Surround Sound fountain firework discharge was sufficient to start and sustain fire	Two 16-foot long back-to back gondola shelving, 3 shelves high, 4 feet aisle used, metal flame breaks, 18 gauge sheet steel used as longitudinal flame break, 16 gauge wire mesh (1" x 1/2") bins used to fully cage in aerial devices	4,225 ft <sup>2</sup> room, 17 feet high floating ceiling with test room exhaust operating	10' x 10' grid, Standard Response, 165°F, density of 0.2 gpm/ft <sup>2</sup>	First sprinkler at 2 minutes 45 seconds after ignition, 4 sprinklers activated	2 minutes 20 seconds after ignition until other devices involved, target gondola ignited 2 minutes 40 seconds after ignition, majority of products on top shelves were unburned, fires on lower two shelves continued to burn and were manually extinguished at 23 minutes, report notes fuse covers had an observable effect in preventing/delaying fire event	Floating ceiling at SwRI makes test act as room with no walls, test used fuel array of limited area, projectiles prevented by caging, fuel package not representative of observed 2011 field survey conditions
<b>SwRI Test 7</b>	Two initial fireworks sources failed, third source was a ¼-inch wire mesh basket containing 15 sheets of crumpled paper ignited by gas torch	Same as Test 6	Same as Test 6	Same as Test 6	First sprinkler at 19 minutes 30 seconds after ignition, 2 sprinklers activated, sprinklers contained fire, reduced intensity but did not extinguish lower shelves	Product on top shelves were unburned, fires on lower two shelves continued to burn and were manually extinguished at 68 minutes after ignition, report notes fuse covers had an observable effect in preventing/delaying the fire event, the fully enclosed bins with heavier gauge mesh provide better containment than lighter gauge used in Tests 3 & 4 (unsprinklered tests)	Same as Test 6
<b>SwRI Test 8</b>	Same as Test 7	Same as Test 6	Same as Test 6	Same as Test 6	First sprinkler at 12 minutes 56 seconds after ignition, 4 sprinklers activated, sprinklers contained fire, reduced intensity but did not extinguish lower shelves	Waste basket burned for 2 minutes 30 seconds before igniting adjacent fireworks, products on top shelves were unburned, fires on lower two shelves continued to burn and were manually extinguished at 63 minutes after ignition, report notes fuse covers had an observable effect in preventing/delaying the fire event	Same as Test 6
<b>SwRI Test 9</b>	Surround Sound fountain firework discharge was sufficient to start and sustain fire	Same as Test 6, except wire mesh bins to contain aerial devices were <u>not</u> installed	Same as Test 6	Same as Test 6	First sprinkler at 13 minutes 45 seconds after ignition, 4 sprinklers activated, sprinklers contained fire, reduced intensity but did not extinguish lower shelves, devices ejected into aisle were soaked with water and many did not burn	Report notes "lots of fireworks were injected into the aisle between the gondolas" and "some of the aerial devices were launched outside of the immediate fire area," products on top shelves were unburned, fires on lower two shelves continued to burn due to shelves shielding product from water spray, report notes fuse covers had an observable effect in preventing/delaying the fire event	Floating ceiling at SwRI makes test act as room with no walls, test used fuel array of limited area, compared to Tests 6, 7, and 8 there was an increased number of fireworks ejected off shelves and into aisles
<b>SwRI Test 10</b>	Starfire Fountain device within an individual assortment pack was ignited and led to a slow growing fire that spread through packs	Two wood pallets of display cartons containing fireworks assortment packs with fuse covers but no aerial devices included, approximately 3-foot high fuel package	4,225 ft <sup>2</sup> room, 17 feet high floating ceiling with room exhaust operating	10' x 10' grid, Standard Response, 165°F, density of 0.2 gpm/ft <sup>2</sup>	First sprinkler at 20 minutes 55 seconds after ignition, 2 sprinklers activated, fire noted to be slowing at 21 minutes after ignition	13 minutes 15 seconds after ignition until other devices involved, partial collapse of display at 17 minutes 30 seconds after ignition, report notes many packs remote from ignition area remained unburned	Floating ceiling at SwRI makes test act as room with no walls, test used fuel array of limited area, fuel package not representative of observed field conditions