Test Burn of a Temporary Fireworks Stand

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This article is based on a report prepared by the Clark County, WA Fire Marshal documenting and discussing the results of a test fire involving a stocked temporary retail fireworks stand. Note that a similar article has been published previously.[1]

ABSTRACT

In 1997, a burn test was performed on a temporary retail fireworks stand stocked with 900 pounds (400 kg) of a range of consumer fireworks. A maximum interior temperature of 1,400 °C was recorded inside the test stand and flashover occurred within approximately one minute of involvement of the fireworks. Ignited fireworks were observed traveling more than 250 feet (75 m) beyond the stand's partially open front side. The greatest heat flux [calculated to be 60 kW/m² at a distance of 5 feet (1.5 m)] was also observed on the stand's front side. It was concluded that a setback distance of 20 feet (6 m) was required on sides of the stand without openings, and that a setback distance of 40 feet (12 m) was required where there were large openings in the stand.

Keywords: fireworks stand, consumer fireworks, test burn, flashover, heat flux, setback distance

Summary

In September of 1997 the Clark County, WA Fire Marshal's Office conducted a test with the assistance of the Washington State Association of Fire Marshals, the Oregon State Fire Marshal, the Western Fire Center, fireworks retailers and wholesalers, fire departments and fire districts. Approximately 900 pounds (400 kg) of consumer fireworks legal for possession, sale and use in Washington State were loaded into a wooden structure typical of the type used for the temporary retail sale of fireworks. The purpose of the burn was to document the thermal effects of the fire and to evaluate the sufficiency of proposed code amendments. No attempt was made to quantify the ignitability or extinguishability of either the fireworks or the stand. Stand construction techniques and firework display and storage configurations were established to generally replicate the actual methods and configurations used to sell consumer fireworks. Materials within the stand were ignited, and temperature and heat flux monitoring equipment, and still and video photography documented the test burn. No attempt was made to extinguish the fire once ignited, and the stand and firework packaging materials were allowed to burn completely once ignited.

A maximum interior temperature of 1,400 °C was recorded and flashover occurred in the stand within approximately one minute of confirmed fireworks ignition. Substantially all of the fireworks in the stand ignited within approximately three minutes after confirmed ignition. Once the pyrotechnic materials were consumed, device packaging materials and the stand itself continued to burn. The structure's ¼-inch (6-mm) plywood construction generally contained the firework devices and provided initial thermal protection to exposures except where openings were present. Ignited fireworks were observed traveling more than 250 feet (75 m) beyond the stand's partially open front side. Fireworks exiting the other three sides were minimal. Thermal effects to exposures were greatest along the partially open front side with a maximum peak heat flux of 60 kW/m^2 calculated at a point 5 feet (1.5 m) in front of the stand. Thermal effects on the three sides without openings were considerably less.

Pyrotechnic hazards existed for about the first three minutes of the test. Ignited devices exiting the front of the stand provided ignition sources in high heat flux areas and remote from the test site. Heat flux and temperature recordings outside of the stand peaked at about five minutes into the test—after the firework devices had discharged. By five minutes into the test only the stand construction materials and the firework packaging remained as fuel for the fire.

Test data indicated that on the sides of the structure without openings a 20-foot (6-m) setback provided an adequate level of thermal protection to exposures. Where openings are present, particularly a large open front sales area, 40-foot (12-m) setbacks are required to provide a similar level of thermal protection. Ignited fireworks exiting through structure openings provide ignition sources in high heat flux areas and in locations remote from the site. Setbacks adequate for thermal protection are probably inadequate to protect against the hazards created by the exiting fireworks.

Once the pyrotechnic materials in the fireworks had burned, the fire was reduced to one of a room and contents. The fireworks paper packaging material provided a substantial fuel load to be consumed even after the fireworks discharged. Within three minutes of firework ignition most of the pyrotechnic materials in the test stand had ignited and discharged. Fire departments arriving at fires in similarly constructed and stocked retail fireworks stands will encounter heavy fire conditions in the stand and perhaps involving near and remote exposures but the hazards associated with the fireworks themselves will be substantially absent.

The results of this test were obtained based upon a specifically defined fire load and method of stand construction. Any deviation in the mix of fireworks or stand construction methods or materials could affect the applicability of the results outlined in this report. Additional testing is needed to better understand, document and evaluate fire protection and life safety needs in fires involving consumer fireworks under similar and different configurations and circumstances.

Introduction

In 1995 the Washington State Legislature amended state law to require that the state fire marshal develop and adopt administrative code language controlling the sale of fireworks from temporary structures. The new code, developed with substantial input from fire service providers and the fireworks industry, stipulated among other things, requirements for the type of construction and setbacks for temporary structures used for the retail sale of fireworks. Much of the proposed code language was excerpted from local ordinances in place across Washington State. Little information, literature or test data existed to quantitatively support the code requirements. As a result, the proposed language was a qualitative assessment based upon a collective experience with the Uniform Fire and Uniform Building Code where the sufficiency of a 20-foot (6-m) setback to exposures and combustibles for buildings of non-rated construction without abnormal fire loads or hazards is generally accepted. This 20-foot (6-m) dimension and its code acceptance formed the basis for similar setback requirements to temporary fireworks stands.

A full scale test burn designed to replicate, measure, and document the effects of a fire in a fully stocked temporary fireworks structure constructed consistent with Washington Administrative Code requirements was designed and accomplished as an aid in evaluating the sufficiency of the state's administrative code. The purpose of the test was to evaluate the sufficiency of proposed code language. No attempt was made to evaluate the ignitability or extinguishability of individual or collective firework devices. The Western Fire Center[2] provided technical assistance in the test's design, methodology, instrumentation, documentation, data collection and analysis. A fireworks stand and stand firework loading requirements were provided by Western Fireworks.[3] Fireworks retailers provided technical assistance as to the manner of storage and display of the fireworks within the stand. Fireworks for the test were obtained through enforcement seizures conducted by fire and law enforcement agencies throughout the Portland, Oregon metropolitan area.

Site and Environmental Conditions

The test site was an abandoned eighty-acre, privately owned sand and gravel quarry, graded level and surrounded on its perimeter by berms 20 to 30 feet (6 to 9 m) high. Groundcover vegetation was absent from the site, surface materials being bare rock, sand and gravel. For three

Figure 1. Test structure and site.

days prior to the test temperatures ranged between 55 and 70 °F (13 to 21 °C) with intermittent and sometimes heavy rain and high humidity. Rain fell intermittently throughout the morning of the test and continuously for thirty minutes prior to and during the test burn. Site temperature at test time was approximately 60 °F (16 °C). The ground surrounding the test structure was completely saturated by rainfall with water standing on the ground surface within 10 feet (3 m) of the structure at test time.

Stand Construction

An 8 × 16 foot (2.5 × 5 m) temporary structure (Figure 1) that had previously been used for retail fireworks sales was erected on the site. The structure consisting of ¼-inch (6-mm) plywood over 2 × 2-inch (50 × 50-mm) framing, was pre-assembled in 4-foot (1.2-m) sections. The 4-foot (1.2-m) sections were bolted together at the site such that the fully assembled stand had a solid back with no openings, two sides with 28-inch (710-mm) door openings, a front section open

Figure 2. Fireworks on shelves.

Figure 3. Fireworks on shelves.

its entire 16 foot (5 m) width from a height of approximately 4 feet (1.2 m) to a height of approximately 7 feet (2 m) and a solid roof that sloped from a front end height of 8 feet (2.4 m) to approximately 7 feet (2 m) at the back wall. The roof and sides were not weather tight but the stand was otherwise sturdy. The structure was painted inside and out but was not otherwise protected. The side doors were held closed during the fire test. Three shelves—constructed of 1/4- and 3/8-inch (6- and 9-mm) plywood supported by plywood brackets—were attached across the full width of the back stand interior. A counter top constructed similarly was attached across the full length of the structure's front opening. Having been exposed to the weather for some time prior to the test, the stand materials were wet.

Fire Loading

Approximately 900 pounds (400 kg) of consumer (formerly common or Class C) fireworks of the types that are legal for sale, possession and discharge in Washington state[4] were placed on the shelves and on the ground under the shelves within the structure in a manner consistent with normal retail operations (Figures 2 and 3). The approximately 10,000 individual firework pieces provided a mix of products typically offered for sale and included variety packs, hand held sparklers, novelty items, ground spinners, spinning wheels, cones, whistles, fountains, candles, aerial devices, smoke pieces, shells and mortars and a variety of night time ground pieces. Empty cardboard boxes were placed under the counter along the front of the stand to simulate personal items and bags or boxes provided to the customer upon sale of fireworks. Sufficient fireworks to exactly replicate a typical stand were not available. Table 1 compares the number and type of devices in a typical stand with those provided in the test stand.

Table 1. Product Mix.

Product Description	Typical Stand		Test Stand	
	Quantity	Shots[a]	Quantity	Shots
Package Assortment[b]	84	840	2	20
Wooden Stem Sparklers	570	570	0	0
Novelty Items[c]	1104	1104	909	909
Ground Spinners	1824	1824	1440	1440
Fountains and Whistles	1310	1410	951	951
Cones	38	38	64	64
Spinning Wheels	60	60	6	6
Smoke Devices	792	792	792	792
Metal Stem Sparklers	3168	3168	396	396
Year Round Novelty[d]	444	444	440	440
Helicopters[e]	3624	3624	3528	3528
Parachutes[f]	290	398	290	290
Candles[g]	1008	748	864	8362
Mortars / Shells	120	384	120	384
Large Night Displays[h]	303	7106	303	7106
Total	14,449	29,358	10,105	24,688
Weight of Fireworks	1067[i]		920[j]	
Retail Value	$8,000		$7,500	

a Many devices contain more than one individual discharge of fireworks therefore the actual shot count may exceed that indicated.

b Variety Packs contain assortments of at least ten separate devices.

c Includes small single piece items where fireworks are placed into typically paper carriers - for example a fireworks device that shoots out sparks may be fitted to a small paper vehicle or similar product and other devices that emit smoke or sparks as part of a larger piece.

d Those type of novelty fireworks that are legal for sale, purchase and discharge on a year round basis including "Party Poppers" and "Snap Its". "Snap Its" are packaged 50 per box and were counted as a single item.

e Items with wings that when ignited spin into the air.

f Pyrotechnic devices are shot into the air and float back down under one or more parachutes.

g Roman candles and other devices that fire one or more balls of ignited material.

h Typically "Cake" types of products that hold a number of individual devices that discharge into the air in succession.

i Estimated upon comparison with test stand amounts.

j Actual weight measured includes pyrotechnic material and device tube or container.

Test Procedures

The structure was erected at the test site three days prior to the burn. Prior to the test the fireworks were stored in metal shipping containers remote from the site. Fireworks loading began at 08:00 the morning of the test. As an aid in identifying the location of debris or fireworks that might be propelled from the structure, concentric circles were established on the ground around the stand's exterior perimeter in 10 foot (3 m) intervals. Newspapers placed into wax paper cups were positioned around the structure's exterior to represent ground cover vegetation, which was absent from the site. To record radiant heat flux, radiometers were positioned outside—14 feet (4.3 m) directly in front of the center of the stand, 13 feet (4 m) from the center of one side of the stand and 12 feet 4 inches (3.7 m) directly behind the center of the back side of the stand. To record temperatures developed during the test, thermocouples were located inside the stand—24 inches (610 mm) above the ground, centered on the back wall

Test Chronology[a]

T = 00:00	Ignition device energized.
T = 04:10	Temperature at point of origin 400 °C (Initial ignition of cardboard box).
T = 09:10	Ignition of fireworks (Figure 4). Fireworks burning confirmed audibly and visually outside of stand. Temperature inside of stand rising dramatically ranging between 600 and 800 °C. Fireworks begin to exit stand's open front.
T = 09:27	Visibility in stand near zero (Figure 5). Accelerating ignition of fireworks. Number of fireworks propelled from front of stand increases. Heat flux measured in front of stand at 7 kW/m^2, sides and rear heat flux near ambient.
T = 10:17	Flashover (Figure 6). Temperatures in stand range from 600 °C to almost 1,400 °C. Fireworks continue to exit stand, recorded temperatures and heat flux rising.
T = 14:26	Temperature in stand approx. 1,100 °C. Maximum exterior temperatures and heat flux recorded, 200 °C and 22 kW/m^2 in front of stand, 50 °C and 8 kW/m^2 at the side of the stand. The number of fireworks exiting the stand is negligible. Structure actively burning, collapse begins.
T = 35:00	Temperatures approximately 550 °C. Monitoring of instruments ceases.

a Chronology was prepared from analysis of all data sources.

directly over the point of origin; at 67 inches (1.7 m) above the ground on the side wall approximately 8 feet (2.4 m) horizontally from the point of origin; outside of the stand adjacent to the front radiometer; and 16-feet 4-inches (5 m) from the center of the side of the stand. Exterior devices were located approximately 3-feet (1 m) above the ground.

The fire was ignited with an "electric match" —a section of shorted out heat tape that when energized ignites the combustible tape material. A small trench was dug in the ground at the center of the back interior of the stand. The electric match was placed in the small trench. A cardboard box filled with newspapers and cardboard pieces was placed over the top of the

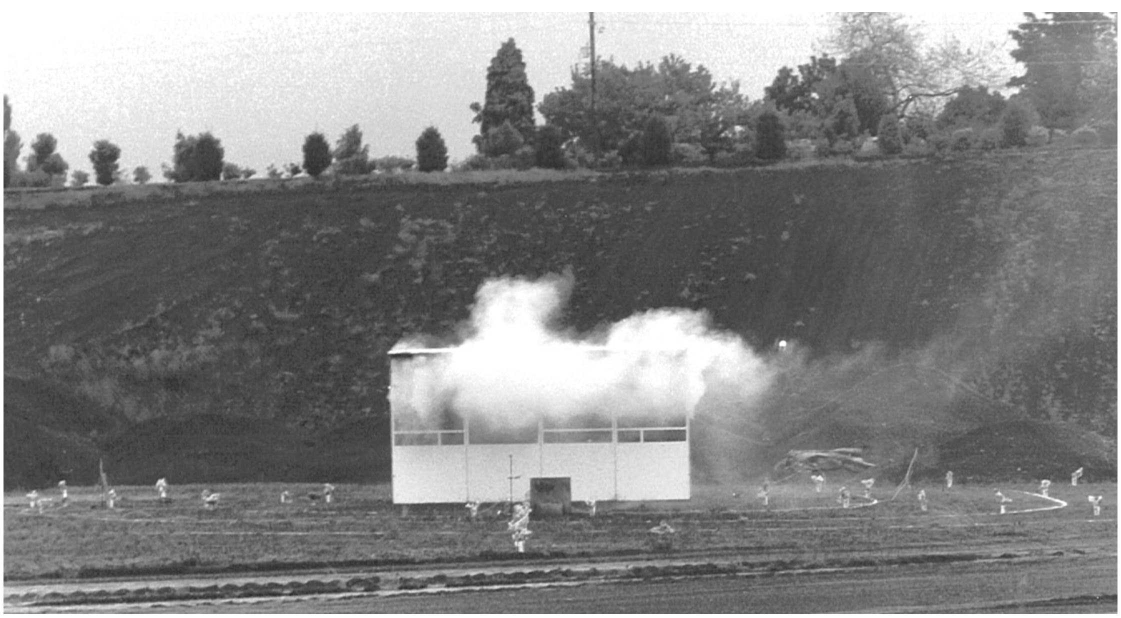

Figure 4. Confirmed fireworks ignition.

Figure 5. Seventeen seconds after confirmed firework ignition.

electric match in the ditch. The cardboard box was directly under a shelf containing firework devices set out for display and in-between cardboard-boxed cases of firework devices. The match was energized and ignited the stand contents.

Test Results

The test was documented with video and still photography. Video cameras recorded the burn continuously—from all sides—from the beginning of the ignition sequence through stand collapse. Still photographers recorded views of all four exterior sides in ten second intervals beginning with the first visible fireworks ignition. Once ignited no attempt was made to extinguish

Figure 6. Flashover.

the fire. At the conclusion of the burn the site was documented and the remains of fireworks or other debris that had exited the stand were identified and their locations recorded. The confirmed firework ignition time was established at the point when device discharge was audibly and visually noticeable.

Actual heat flux recordings graphed against time appear on Chart 1. Temperature recordings are graphed similarly on Chart 2. Chart 3 indicates calculated heat flux intensity at various distances in front of the stand at peak flux as well as the 150-second average intensities. Chart 4 similarly records heat flux intensity at the side of the stand. Chart 5 indicates the site configuration and the location of the identified remains of firework pieces that exited the stand to a distance of 130 feet (40 m).

Paper targets placed within 15 feet (4.6 m) of the front of the stand were ignited during the fire. Targets placed to the side and rear of the stand were not ignited regardless of their placement, however the wax melted out of the paper cups and the newspaper within the cups located within 10 feet (3 m) of the sides and rear of the stand darkened and became brittle. The remains of more than 150 individual fireworks pieces were identified outside the stand at the test's conclusion. The fireworks exiting the stand approximated a normal distribution with a mean of 27 feet (8.2 m) and a standard deviation of 23 feet (7 m) from the stand's partially open front. The number of fireworks that exited other than through the front open sales area was negligible. A number of larger aerial pieces thought to be mortars were observed exiting the stand and landing as far as 250 feet (75 m) from the stand's front during the test. Video recordings confirmed the visual observation however the remains of the larger devices could not be identified at the test's conclusion.

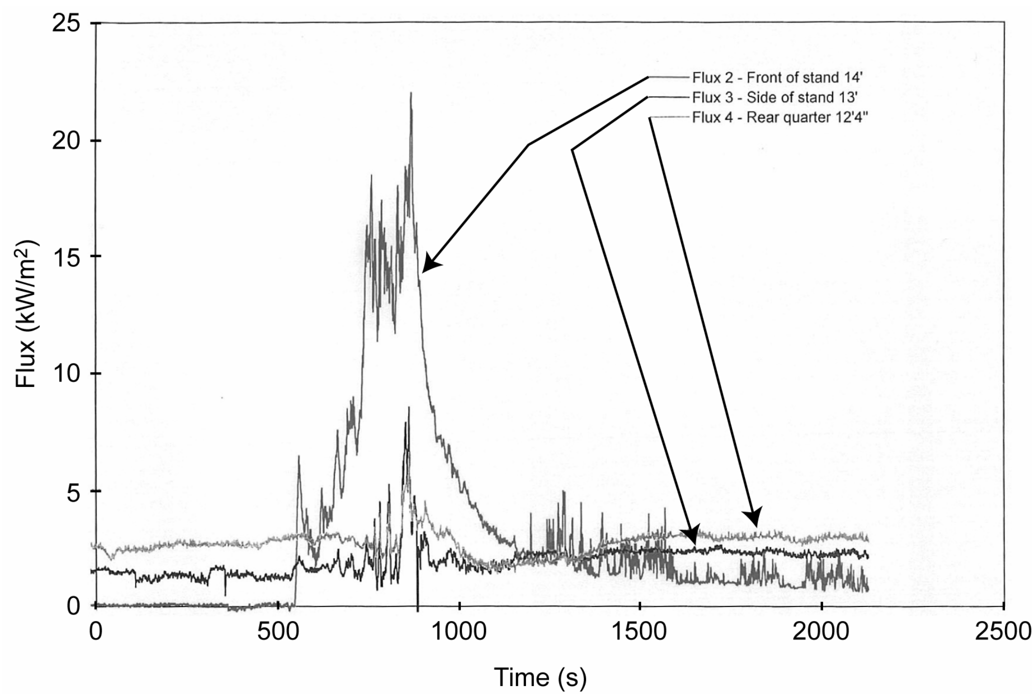

Chart 1. Fireworks stand fire heat flux at different locations.

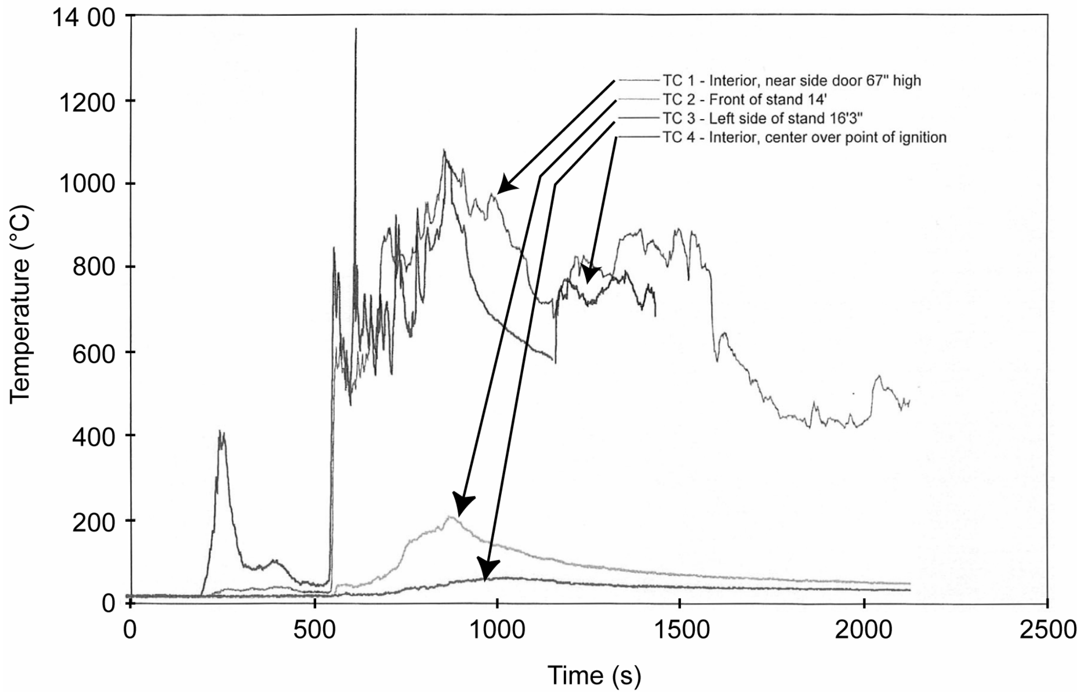

Chart 2. Fireworks stand fire temperatures.

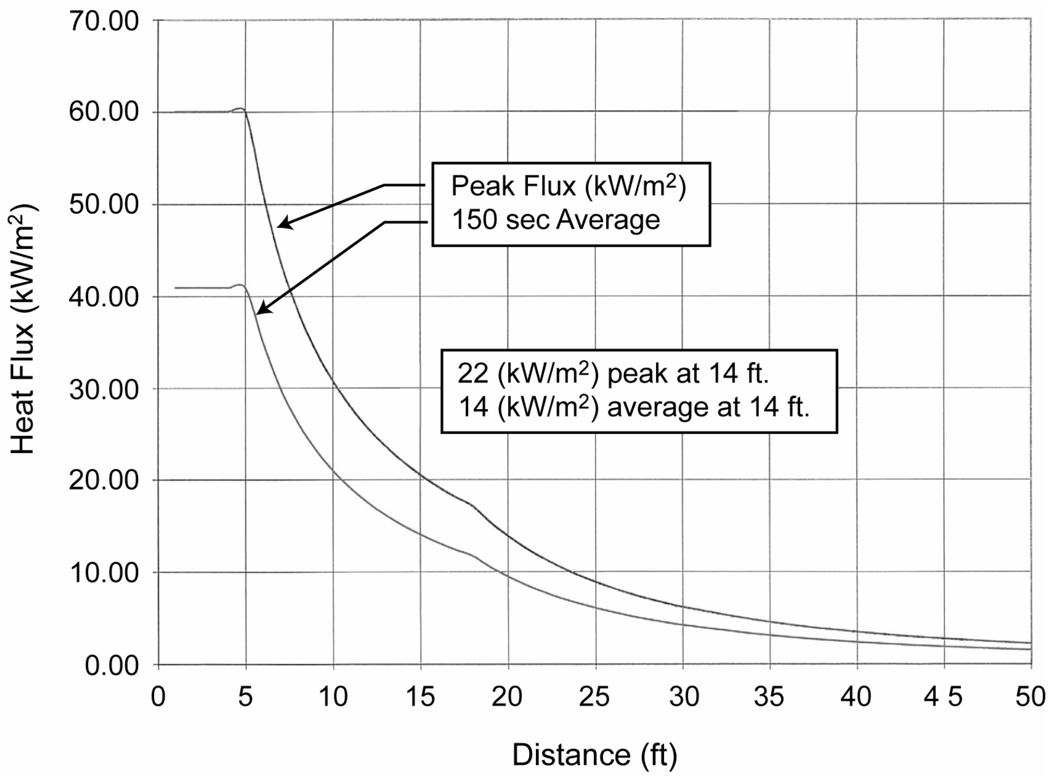

Chart 3. Heat flux at exterior front of stand.

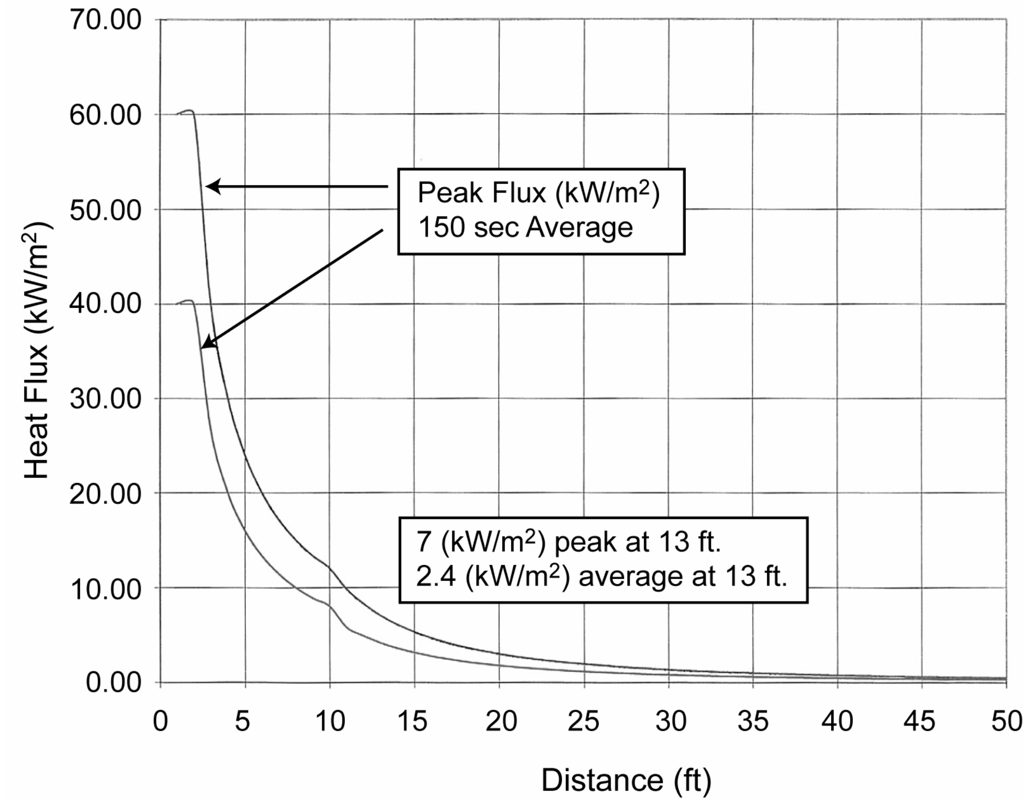

Chart 4. Heat flux at exterior side of stand.

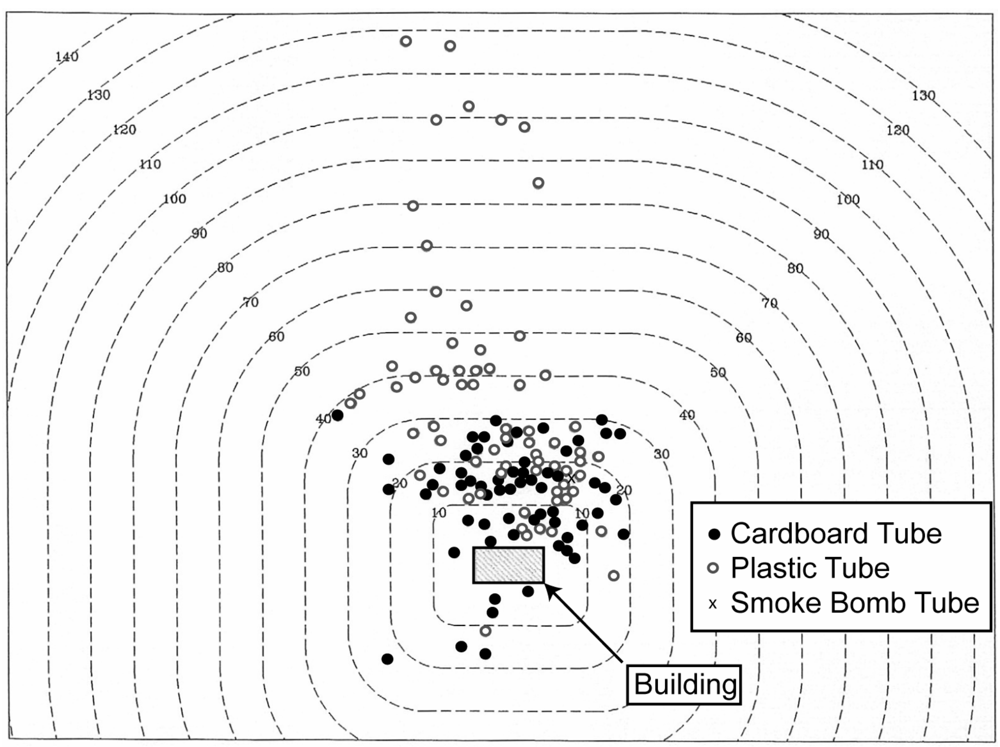

Chart 5. Site configuration and the location of the identified remains of firework pieces that exited the stand to a distance of 130 feet (40m).

Discussion / Analysis

The following tables are provided as an aid in evaluating and interpreting the information in this report and are intended to be general in nature for illustrative purposes.

Effects of Heat Flux[5]

Heat Flux (kW/m^2)	Effect
1.0	Noonday sun on the beach in Florida.
6.0	Cardboard will propagate flame.
7–8.0	Solid wood will propagate flame.
10.0	Exposure to skin will cause unbearable pain within five seconds.
10–11.0	Critical flux to self-ignite cardboard.
20.0	Exposure to floor of room at flashover.
20.0	Solid pine will ignite in 70 seconds.
40.0	Exposure to wall (mid-height) of room at flashover.
50.0	Solid Douglas Fir will self-ignite in 6–10 seconds.
60.0	Exposure near ceiling of room at flashover.
120–140	Exposure from E199 furnace at one hour.

Effects of Temperature on Wood

Temp. (°C)	Effect[6a,7]
180	Piloted ignition in 14–40 minutes
200	Piloted ignition in 12–25 minutes
225	Piloted ignition in 7–17 minutes
250	Piloted ignition in 4–9 minutes
300	Piloted ignition in 1.6–3.5 minutes
400	Piloted ignition in 20–30 seconds
600	Spontaneous ignition of solid wood

Firework devices in the stand discharged for approximately three minutes after confirmed fireworks ignition. Although actively burning, the stand remained intact during this three-minute period. Collapse of the stand began about five minutes after confirmed firework ignition. By the time the stand began to collapse firework ignition and discharge had virtually ceased. Prior to its collapse the ¼-inch (6-mm) plywood construction generally contained aerial and other devices within the stand and provided thermal protection to exposures on the sides and rear. Once collapse began and the stand materials were heavily involved in fire, the thermal effects emitted from the sides and rear increased.

Calculated at 20 feet (6 m) from the sides and rear of the stand, radiant heat flux was insufficient throughout the test to propagate flame across cardboard. Few devices capable of providing a piloted ignition source exited or landed to the sides or rear of the stand. After the stand became involved in fire, the conditions within 20 feet (6 m) were sufficient to ignite common combustible materials. The wax paper cups and newspaper located within 10 feet (3 m) of the sides and rear of the stand turned brown and became brittle during the fire. The conditions surrounding these materials were probably capable of propagating combustion had an ignition source been introduced. At 20 feet (6 m) from either the back or the sides of the stand, peak and 150 second average flux rates were insufficient to propagate flame across cardboard.

Conditions extending from the stands partially open front side were markedly different than those experienced to the sides and the rear. Almost immediately after confirmed firework ignition, devices began exiting through the open front sales area. As the contents of the stand became more involved during the initial minutes, the number of devices exiting the stand increased. Fireworks exiting from the front were generally finished three minutes after confirmed ignition. During this three-minute period measured flux at 14 feet (4.3 m) in front of the stand exceeded 18 kW/m^2 approaching that experienced at the floor level in rooms during flashover (20 kW/m^2). Ignited fireworks fell within 14 feet (4.3 m) of the front of the stand while these conditions persisted. The maximum radiant energy recording, 22 kW/m^2 occurred 14 feet (4.3 m) in front of the stand at approximately five minutes after confirmed firework ignition after firework discharge was substantially complete.

The calculated radiant energy conditions within 5 feet (1.5 m) of the front of the stand were consistent with those obtained at the ceiling level of rooms at flashover. At 20 feet (6 m) in front of the stand calculated radiant energy was sufficient to self-ignite cardboard and propagate fire across solid wood. At a distance of

40 feet (12 m) in front of the stand both the peak and 150 second average flux rates were below that required to propagate flame across cardboard. The heat flux emitted from the back or the sides of the stand was approximately one half that observed at the front at similar distances. Except for the fireworks exiting the stand, conditions 40 feet (12 m) in front of the stand were similar to those experienced 20 feet (6 m) to the sides or rear of the stand.

Most of the pyrotechnic materials were consumed within three minutes of confirmed fireworks ignition. Heat flux rates and temperature readings peaked at approximately five minutes after fireworks ignition indicating the greatest heat release rate due to the combustion of the structure and the combustible remains of firework devices rather than the pyrotechnic material itself. Identifiable firework devices propelled from the stand during the test were almost exclusively aerial devices that fell approximately in a 45° arc beginning at the stand's front and extending out 250+ feet (75+ m). Half of the device remains landed within 27 feet (8.2 m) of the stand's open front, two-thirds within 60 feet (18 m). The devices continued to burn in varying degrees upon hitting the ground providing ignition sources in areas where the heat flux was sufficient to either ignite or propagate flame across light combustibles and wood. The hazards created by aerial devices exiting the stand were unquantified, however their effect on nearby pedestrian or vehicles access points and routes could be significant.

The fireworks in the stand did not ignite immediately upon energizing the "electric match" ignition device. The cardboard and paper initially surrounding the electric match did however ignite and were at least partially consumed prior to igniting fireworks or stand materials. Personnel were prohibited from entering the structure after the ignition sequence began, preventing adjustment of the materials to aid ignition. The extremely wet conditions at the site undoubtedly had an overall mitigating effect on the fire conditions, slowed the ignition of the cardboard and paper within the stand and delayed fireworks ignition. Once fireworks were ignited the fire built rapidly. The atmosphere within the stand became lethal (thermally toxic[6b]—exceeding 140 °C) within seconds after confirmed fireworks ignition. Within one minute after confirmed fireworks ignition upper gas layer temperatures exceeded 1,100 °C consistent with flashover conditions.[6c] Had the ignition device been situated to achieve immediate fireworks ignition upon being energized neither the pyrotechnic nor the thermal effects would have varied.

Environmental conditions have an effect on the rates of combustion of common combustibles. Ambient temperature, humidity, preheating and moisture content are generally accepted as factors having an effect on the ignitability, burning characteristics and the rates of combustion of commonly combustible materials. These factors can affect pyrotechnic materials similarly.[8] Lower ambient temperatures, high humidity and high moisture content generally slows the rate of burning of pyrotechnic material while the phenomenon of "heat cycling" where materials are subjected to alternating high and low temperatures can increase pyrotechnic burn rates. The fireworks used for the test came from multiple manufacturers with unknown manufacture dates, had not been stored in environmentally controlled conditions prior to their use and were subject to the damp, cool environmental conditions present at the site the day of the test. The environmental effects on the burning rates of the fireworks used were not quantified. However, it is reasonable to speculate that fireworks sold at retail may be subjected to similar conditions.

The environmental conditions and their effect on the burn rate of the test structure were not quantified. The wooden stand and the ground underneath the structure were thoroughly soaked with water by the time the test was initiated. Neither the amount of heat absorbed drying the ground under the stand nor the amount absorbed by the structure prior to reaching its ignition temperature is known. Visual observations captured on video and still photography show that the walls and roof of the structure produced clouds of steam prior to their ignition. Although environmental conditions similar to those experienced on the day of the test could occur at other times, the cool temperatures, heavy rain and high humidity are thought to be atypical of the weather during a fourth of July selling period. For this reason it is believed that the environmental conditions had an unquantified mitigating effect on the test fire conditions and the subsequent thermal effects recorded.

Conclusions

This test documented and recorded the effects of a fire in a structure typical of the type often used for the temporary retail sale of fireworks. To evaluate the adequacy of fire protection for this or any other type of fire hazard requires an examination of multiple factors including: type and materials of construction; the type and configuration of the fire load; physical location and setbacks from combustibles, buildings, property lines, roads and pedestrian access points and hazards; nearby hazards and exposures; environmental conditions, and the availability of fire suppression forces. Any modification of a single factor without consideration of its affect on the others can render the complete fire protection "package" inadequate. State and local laws differ as to the types of firework devices that are legal for sale and discharge. Different mixes of fireworks, particularly the presence of firecrackers or similar devices or display fireworks could create fire conditions much different than those encountered during this test. The information provided in this report, although specific to a given set of criteria, has general implications useful for similar applications.

Once the pyrotechnic materials in the fireworks are consumed—in this case within about three minutes after ignition—the fire involves essentially a room and contents. The presence of the pyrotechnic materials accelerates the fire leaving little time for occupants to react once fireworks are ignited. In this test even light construction materials such as ¼-inch (6-mm) plywood were sufficient to contain the fireworks within the structure and provide a degree of thermal protection while the fireworks discharged. Where openings are present, typically along the front side to facilitate sales, thermal protection and firework device containment is compromised creating exposure hazards remote from the stand itself.

The radiant heat flux data supports the adequacy of a 20-foot (6-m) setback to combustibles from temporary stands constructed and loaded with fireworks similar to that described in this report—except where openings are present. Where openings are present, particularly a large front sales opening, a 40-foot (12-m) setback is required to provide a level of thermal exposure protection similar to that provided on sides without openings. A 20-foot (6-m) setback may also be appropriate where openings are provided with automatic closing mechanisms.

Fireworks exiting the structure create a different and perhaps compounding set of hazards. While the fire is actively burning, fireworks exiting through openings place ignition sources in high heat flux areas close to the stand. Ignited devices were also observed traveling more than 250 feet (75 m) from the stand, spreading ignition sources a considerable distance. Where a setback may be sufficient to provide thermal protection, it may be insufficient to provide protection from firework ignition sources. The absence of aerial devices or the presence of automatic closing devices on openings could mitigate this hazard such that setback requirements established for thermal exposure protection may be appropriate.

Test data indicates that lightweight temporary construction of at least ¼-inch (6-mm) plywood over light wood framing can contain certain common fireworks within a structure upon ignition and provide limited thermal protection for exposures. Other construction techniques and materials that provide at least an equivalent level of protection should be similarly adequate. A different or more concentrated mix of fireworks may require more substantial construction methods and different setback requirements to provide similar levels of protection.

The presence of openings in the construction has a dramatic effect on a structure's ability to protect exposures and contain ignited fireworks. Test data documented a much higher level of thermal and pyrotechnic device exposure to surrounding materials on the side of the stand with the large sales opening. Had the number or dimensions of openings from the stand been greater or had construction materials been less substantial or had they failed sooner, the thermal and pyrotechnic exposures would have been greater around the stand's perimeter.

This test was conducted outside of a controlled environment yet similar to conditions that may be encountered in real life applications. No attempt was made to evaluate the ignitability of the devices or the ease at which they may have been extinguished if ignited. Similarly, the test made no attempt to evaluate the configuration of the fireworks but again, the arrangement was intended to reflect those conditions actually encountered in the field. There is little publicly available literature documenting similar large or small-scale tests. The fire service and the pyrotechnic industry would both benefit from additional testing designed to evaluate protection needs under different fuel loads and configurations where consumer fireworks are sold and stored.

References

1) D. Lynam, "Fireworks Stand Test Burn", *Fire Technology*, Vol. 37 (2001) pp 153–166.
2) The Western Fire Center, a fire testing, research and consulting agency is located in Kelso, Washington.
3) Western Fireworks, a fireworks wholesaler, is located in Canby, Oregon.
4) Washington Administrative Code Section 212-17 limits consumer fireworks to:
   (1) Ground and hand-held sparkling devices that include dipped stick sparklers, cylindrical fountains, cone fountains, illuminating torches, spinning wheels, ground spinners, and flitter sparklers;
   (2) Aerial devices including helicopters and aerial spinners, roman candles, mines and shells (mortars);
   (3) Combination items containing two or more of the listed devices; and,
   (4) Smoke devices. Those items specifically prohibited and excluded from the product mix used in this test include firecrackers, salutes, chasers, skyrockets, or missile-type rockets.
5) Western Fire Center, Report #97069, Kelso, WA (1997).
6) National Fire Protection Association, *Fire Protection Handbook*, 17th ed., NFPA, Quincy, MA. (1991) [a] pp 3–25, 26; [b] p 3–9; [c] p 6–75
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