Section 1: Hazard Management for Firework Displays

Accidents, law suits and regulation

Fireworks are not unreasonably dangerous when they are properly used.

A recent study found that people are at least 3 to 5 times more likely to be killed or seriously injured driving round trip to view a fireworks display than they are to be killed or seriously injured from the fireworks at the display.

Most fireworks accidents are the result of carelessness, misuse or failure to follow regulations.
Each year people (spectators and crew members) are needlessly injured (or possibly killed) because of failures to recognize and take seriously the potential danger of fireworks.

Lawsuits and regulation are the natural result of accidents that produce injuries. This is a chain of events.

Accident > Injury > Litigation > Legislation

The only practical point to break this chain is to limit accidents, especially those involving injuries.

Definitions:

1. **Hazard**
2. **Risk**
3. **Safe**

Hazard and Risk Defined

These two terms are often confused with each other.

The **hazard** of an event is the potential consequences of an event – however infrequently that event may occur. The consequence of an event is its intrinsic potential for harm to persons or property.

Synonyms for hazard include:

- Consequence
- Danger (a poor term and one with overly negative connotations)

The **risk** arising from an event considers both the intrinsic hazard of the identified event and the frequency with which that event tends to occur.

Synonyms for frequency include:

- Likelihood
- Probability

"Safe" Defined

A typical dictionary definition of "safe": …"Anything involving no risk of mishap, error, etc."
By this (poor) definition of safe, nothing mankind does is safe because there is always some "risk of mishap" in literary every possible activity.

- Crossing the street. -> Being hit by a car.
- Eating food. -> Choking or food poisoning.
- Reading a book. -> Getting a paper cut.

The definition of "safe" from hazard management:

- "Something is safe when the attendant risks are below an acceptable level."[W.W. Lawrence]
- This definition recognizes the fact that nothing one does is completely free of the possibility of injury and that something is considered safe when the risk (probability and/or consequence) is sufficiently small.
- This is the definition used in these notes.

Fireworks Hazard Management

The three basic elements of all **hazard management** programs are:

1. **Recognition of hazards**
2. **Evaluation of risks**
3. **Control of risks**

1. Recognition of Potential Hazards

Understanding how fireworks function and occasionally malfunction. Fireworks present a level of hazard greater than many workers in the trade realize. For example:

- Fireworks **salutes** often have an air blast equivalency in excess of 50% of their weight in TNT.
- Large **aerial shells** often leave the mortar traveling more than 200 mph (320 km/h); this is nearly the energy produced by a small automobile traveling at 20 mph (32 km/h).
- Firework **stars** may burn at temperatures greater than 3600 ºF (2000 ºC).
- **Dud** shells can fall to the earth traveling about 125 mph (200 km/h). This is sufficient that even a relatively small aerial shell can cause death if a person is struck.

- Large aerial shells can explode with an air blast pressure significantly greater than that produced by a military hand grenade; they can produce an intense fire ball and may generate potentially life threatening fragments.

2. Evaluation of the Risks

Combining estimates of the probability of a problem occurring and the severity of the resulting consequences for various possible fireworks malfunctions, equipment failures, crew errors, and spectator problems.

Risk assessment has two components that involve determining of estimating:

- The probability of a mishap occurring.
- The severity of the consequences if the mishap does occur.

A minor risk has a low probability or a minimal consequence. For example, consider the following potential activities:

Activity	Consequence	Probability	Risk
Jumping off tall buildings to see if you can fly	Crash landing (severe)	Very High (~100%)	Unacceptable
Swimming in the sea	Being eaten by sharks (severe)	Very Low (~0%)	Acceptable
Flipping a coin to decide what TV program to watch	The other program is better. (inconsequential)	High (50%)	Acceptable

Table 1.1 Table of consequences, risks and probabilities

Risks are least when both the consequences are minor and the probability of occurrence is low.

3. Control and Minimization of the Risks

The actions undertaken to reduce the risk by reducing the probability of an accident occurring, the consequences of a fireworks accident or both.

Fig. 1.03: Danger sign at Macy's display. Photo: Fireworks by Souza. Fig. 1.04: Sign located at Walt Disney, Anaheim CA. in the fallout area of Disneyland. Photo: WNYC.org, Erica Getto and Disneyland (right)

Examples of Fireworks Risk Control

To reduce the probability of an accident occurring:

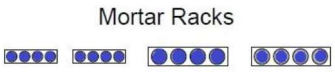
- Inspect all aerial shells for damage and do not use any suspect shells.
- Keep electric matches shunted when possible and their safety shrouds in place.
- Protect aerial shells and other fireworks from damage due to moisture.

To reduce the consequence of an accident:

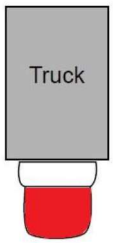
- Keep unnecessary personnel out of the fireworks discharge area.
- Sandbag or barricade the fireworks mortars when manually firing aerial shells.
- Separate the storage areas for fireworks from areas where fireworks are being prepared.

Fig. 1.05: Unloading rental truck while using ramp. Photo: IPM and Northern Lights Pyrotechnics

Often risks can be minimized using methods that require little or no additional effort or expense.



When transferring fireworks between two trucks, for safety reasons, the trucks should be separated by some distance and a ramp used between them. This will allow a much better chance of escape in the event of an accidental ignition of the fireworks.



Sometimes a little thought will provide a safety improvement with no added work.

It is common to position the truck carrying the fireworks as shown (to the left). If there is an accidental ignition of an aerial shell in the mortar area when the back of the truck is open, there is a good chance that the contents of the truck will be ignited producing a much greater accident.

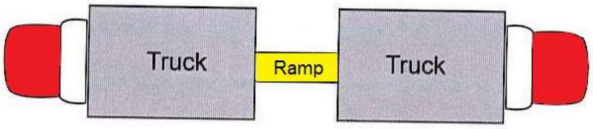


Fig. 1.06: Using ramp to unload product and equipment from truck. Fig. 1.07: Illustration of using a ramp for transfer of product from truck to truck. Photos: Hellopro UK (right) and Journal of Pyrotechnics (left)

With the following orientation of the truck, that type of accidental ignition of the contents of the truck is effectively eliminated, without having to carry the aerial shells farther on average.

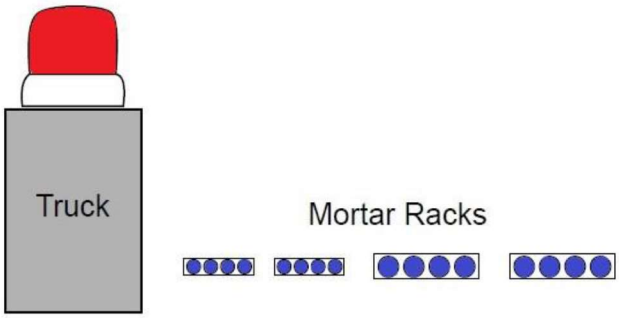


Fig. 1.08: Illustration of proper position of truck during loading of mortars. Illustration: Journal of Pyrotechnics

Display operator definition and responsibilities

Operator: The person with overall responsibility for safety, and the setting up, discharge and tear down of an outdoor fireworks display.

The operator's responsibility:
With regard to the Public:

- No single failure of fireworks or equipment can be allowed to injure a member of the public.

With regard to the crew:

- **Training**: Tell them the correct way and WHY.
- **Crew Size**: Do not have too many or too few.

With regard to the Display Company and Sponsor:

- First and Foremost: A safe show.
- Second: A Great Performance.

Fig. 1.09: Entertainment Fireworks, Inc., site of accident on June 2014 during loading operations. Photo: Komo News, Tonino, Washington

Operator Participation:
Before and after the display – Oversee and check on the proper completion of all work.
During the display – Monitor safety and crew performance and take all needed corrective measures.

Section 2: Basic Aerial Shell Components and Functioning

Firework aerial shell shapes and sizes

a. **Spherical**
b. **Cylindrical**

Aerial shells are 2 basic styles of aerial shell construction:

- **Spherical Aerial Shells** (often referred to as Japanese or oriental-style shells). Spherical shells typically produce star patters that are spherically symmetric.
- **Cylindrical Aerial Shells** (often referred to as canister, Italian or American-style shells). Cylindrical shells typically produce less symmetric star patterns.

Fig. 2.02: Aerial shells comparison. Photo: courtesy of FireworkFX.com. Fig. 2.03: Various ball (round) shells with leaders, including finale chain (right). Photo: IPM Universal

Examples (photo above) of various weights of shells of the same 3-inch caliber. Italian shell weight of (1012g), Spanish (660g) and Chinese (312g).

Aerial shells range in size from less than 2 inches (50 mm) to more than 12 inches (300mm). However, most shells used in displays are between 2.5 and 6 inches (65 and 150mm).

Aerial shells are measured in terms of the internal diameter of the tube (fireworks mortar) from which they are designed to be fired.

Because of the need for clearance between the aerial shell and mortar, actual shell diameters are less than their nominally stated size. For example, most 3-inch (75mm) shells are about 2.7 inches (66mm) in diameter.

Aerial shells must be constructed to fit properly in the mortar such that they will be propelled to the proper height before functioning.