Common Aerial Shell Burst Patterns and Associated Terms

Chrysanthemum – A common spherical "floral" pattern in which the stars leave a visible trail.

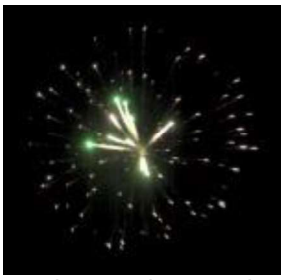
Peony – A spherical pattern in which the stars leave no visible trail (giving the appearance of points of light radiating outwards from a central burst). Two or three color changing peony effects are common in the larger sizes.

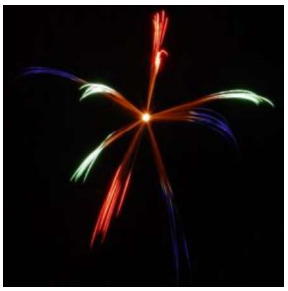
Willow – Long burning golden stars cascading downwards in a non-spherical '**weeping willow**' pattern. The effect may reach the ground. Often undesirable effect when fire danger is extremely high.

Brocade – Similar to a **Kamuro** effect, but with shorter burning stars.

Palm – Large, bright gold or silver stars that permeate outwards **–** giving the appearance of a palm tree. An **Octopus** shell is similar to a palm but has, specifically, eight thick tendrils (arms).

Crossette ("**Splitting Comets**") **–** Stars which split into several components, producing a 'criss-cross' effect in the sky.





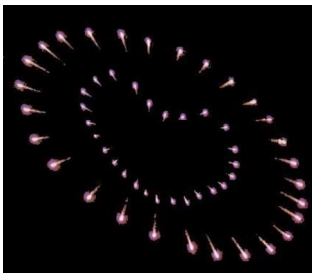
Strobe – An effect that 'pulsates' in the night sky. Similar to glitter but at a lower frequency **–** giving the appearance of numerous flash bulbs. In some cases, long duration strobes may also reach ground level

Diadem – Usually refers to a 'final effect' at the end of a willow or Kamuro style shell. Example: Gold Willow to Red Diadem.

Pistil – A central effect that is often incorporated into peony or chrysanthemum shells (not exclusively). Example: Red Peony with Blue Pistil.

Falling Leaves – A gentle effect where the 'stars' drift downwards in a small cluster. The 'leaves' are often slow burning fuse as opposed to rapidly burning pressed composition.

Horsetail (**Waterfall**) **–** An willow effect (usually gold or silver) in which the stars fall in a cluster **–** giving the appearance of a horses tail. This is achieved by ensuring that the shell has a 'soft break' so that stars are not propelled vigorously from a central point.



Pattern Shells (i.e. Heart, Saturn Ring, Snail, Star, Cube, Smiley Face, Butterfly) **–** Shells designed to break so that the stars emerge in a well-defined geometrical pattern. The effect is not always seen clearly as the burst may not eject the stars at the correct viewing angle.

Salute (**Maroon**) **–** A shell designed, in its simplest form, to give a single report. Salutes made with flash powder are more vibrant than those made with traditional black powder but also more volatile.

The range of shells now available is huge and the combinations of effects are almost endless. The above list of terms is by no means exhaustive.

Section 3: Aerial shell Malfunctions, Causes and Safety Considerations

Proper Functioning Vs. Malfunctions

See the flow chart (on next page) for the aerial shell firing sequence, showing proper functioning (center shaded column) and possible malfunctions (unshaded columns to either side).

A **malfunction** is defined as hazardous performance, other than intended.

Some malfunctions can be caused by mishandling the aerial shells, and some existing problems can be identified by careful inspection at the display site.

Fig. 3.01: Shell lift charge bags; photo Pyro Spectaculars. Fig. 3.02: Black powder lift charge broken. Photo: Skylighter.com

Format for malfunction discussions:

- Description (definition) of the particular malfunction – for the purpose of discussion.
- "Cause" of the malfunction – primary cause(s), emphasizing those things under the control of the display operator or that can possibly be detected by inspection by the display crew.
- "Prevention" of the malfunction – emphasizing those actions that can be taken by the display crew, rather than by the manufacturer.
- "If it happens" – what can be done to help minimize the consequences in the event of this malfunction.

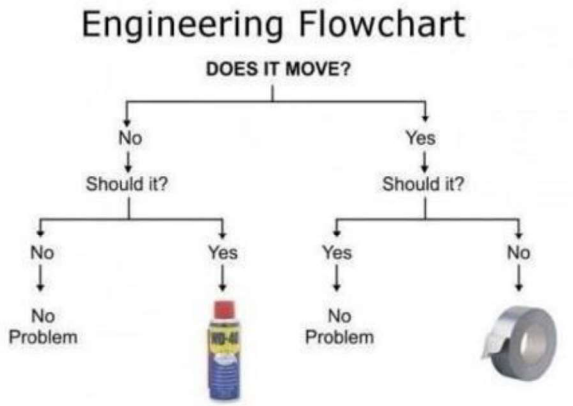


Fig. 3.03-3.04: The best and important problem solving items and flowchart for technicians include WD-40 and Duct Tape.

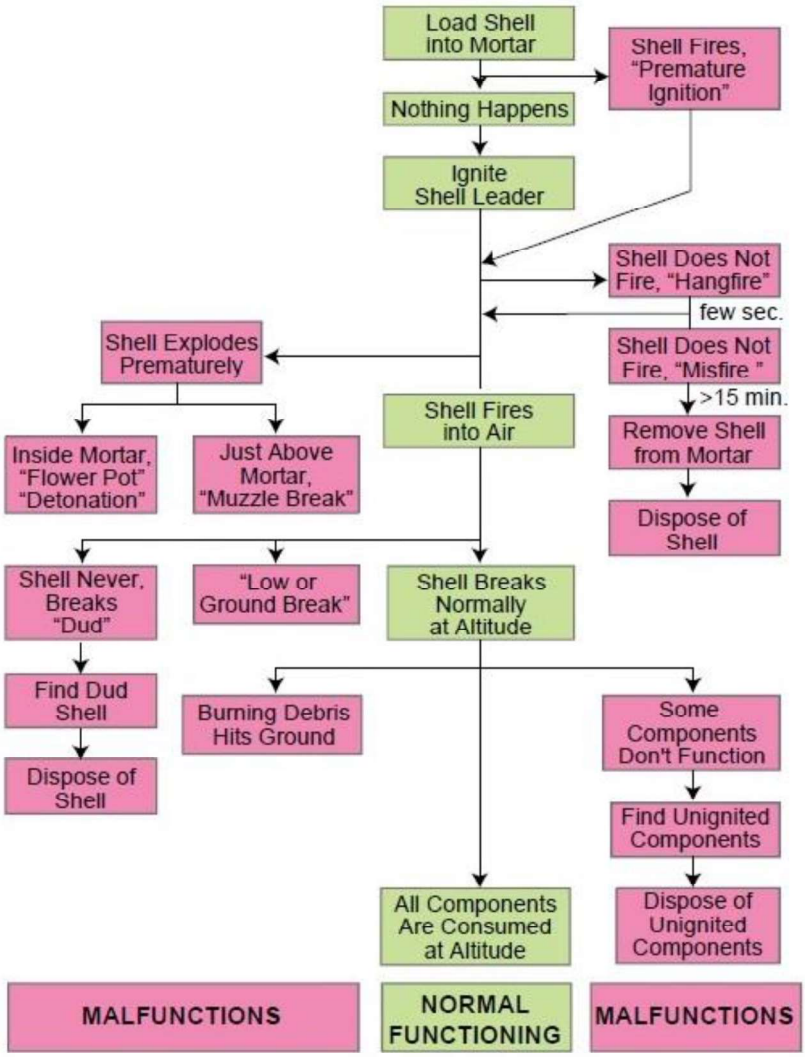


Fig. 3.05: Aerial Shell Failure Flowchart for Manual Firing. Illustration: Journal of Pyrotechnics

Aerial shell ignition problems:

a. "Premature ignition"
b. Delayed ignition – "Hangfire"
c. Ignition failure – "Misfire"

Premature Ignition

Definition

Premature ignition. An aerial shell fires from mortar before it is intentionally ignited.

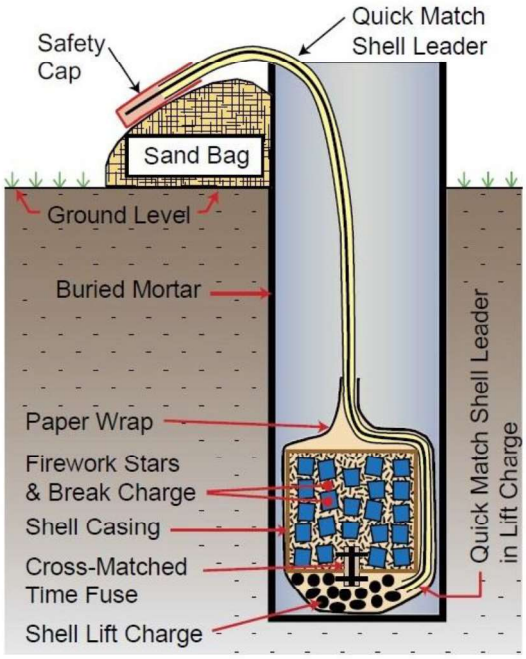
Cause

Burning debris in the mortar or on the ground near the shell leader, or sparks otherwise contacting exposed pyrotechnic composition.

Prevention

Eliminate burning debris and any exposed pyrotechnic composition.

If It Happens
NEVER have any body parts over a loaded mortar!



Handfire & Misfire

Hangfire

An unusual long delay (more than a few seconds) between lighting the shell leader and the aerial shell firing from the mortar.

Cause
Shell leader (fuse) damaged or damp.

Prevention
Careful inspection of aerial shells (especially the fuse) before the display and protection of the shells from moisture may reduce the probability.

If it happens
Wait several seconds before approaching to properly mark the mortar; be aware that the aerial shell may fire at any time. Also verbally warn the crew not to reload the mortar.

Misfire

The shell leader is ignited, but the aerial shell never fires from the mortar.

Cause
Shell leader (fuse) damaged or damp.

Prevention
Careful inspection of aerial shells (especially the fuse) before the display and protection of the shells from moisture may reduce the probability.

If It Happens
Wait several seconds before approaching to properly mark the mortar; be aware that the aerial shell may fire at any time. Also verbally warn the crew not to reload the mortar. After the display, clear the shell from the mortar.

Shell Flowerpot

Flowerpot happens when an aerial shell explodes relatively weakly while inside the mortar, which usually remains intact.

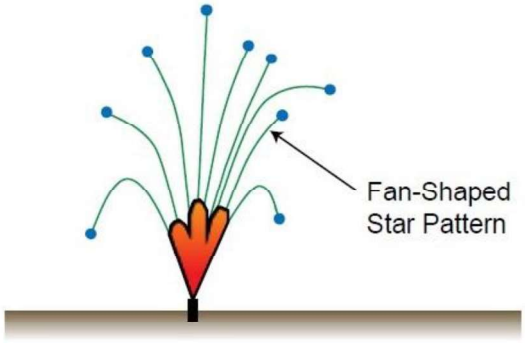


Fig. 3.07: This illustration shows the appearance of shell flowerpot. Illustrations: Journal of Pyrotechnics

Cause
A major fire leak into the aerial shell. Possibly because of a substantial failure of the shell casing.

Prevention
In extreme cases, inspection may reveal damage to the shell casing.

If It Happens
Protect aerial shells in ready boxes and shells being loaded from sparks and burning debris (thus avoiding larger problems), wear proper clothing and personal protection equipment (PPE).

Note that some muzzle breaks may present much the same visual appearance as do flowerpots and mines.

Shell "Detonation"

Shell "Detonation" occurs when an aerial star shell explodes violently while still inside the mortar, which is often destroyed. (Note, this is almost certainly not a true high explosive detonation, but all or most of the shell's contents are consumed almost instantly). Shell Detonation is also known as **VIME** = Violent In-Mortar Explosion.

Appearance
Loud report and flame, few if any stars will be visible.

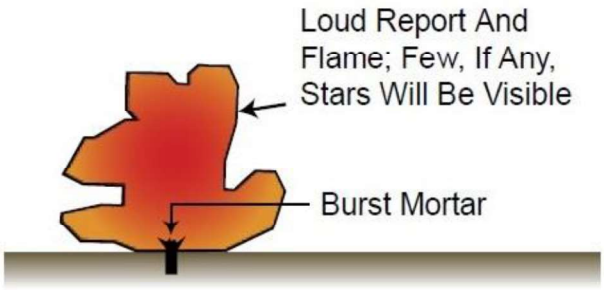


Fig. 3.08: Low break-dud. Photo: GFA Pyro. Fig.3.09: Illustration of shell detonation. Journal of Pyrotechnics

Cause
A major fire leak into a star shell. Possibly because of a substantial failure in the shell casing or upside down. (Why does this not result in just being a flowerpot? This is not well established; perhaps the stars are unusually pressure sensitive.)

Prevention
In extreme cases, aerial shell inspection may reveal damage to the shell casing.

If It Happens
There is no time to react. Have well buried or barricaded mortars, have personnel in a "protective position" (crouched down and facing away from the mortar) and have personal protection equipment being worn. Inspect for damage to other equipment and fireworks before continuing.

Shell "Detonation"


Fig. 3.10: A hole blown in the ground from a 3-inch shell. Photo: IPM. (left) Fig. 3.11: Blown 3-inch mortar. Photo: user Raini at Feuerwerk.net Wiki

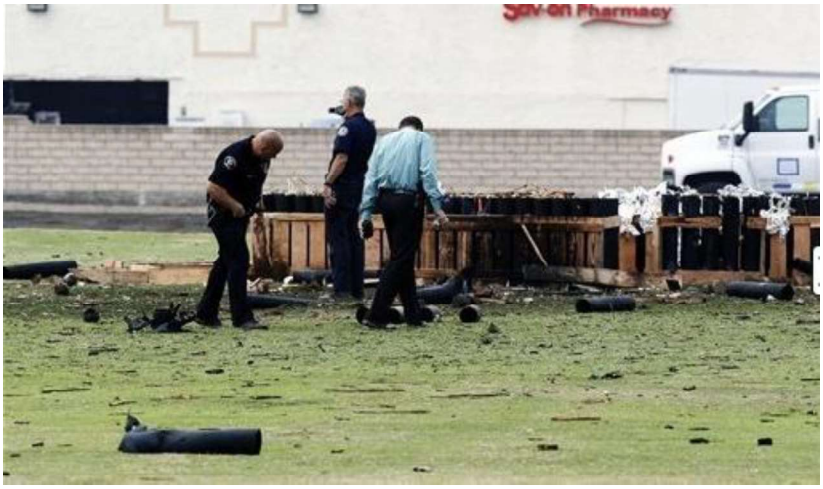



Fig. 3.12: Large mortar shredded by a shell "detonation". Photo: IPM. Fig. 3.13: Simi Valley explosion site where HDPE mortars are displaced due to double-break shell malfunction "detonation". Photo: Nick Ut, AP

Muzzle Break

Muzzle Break

An aerial shell explodes just after leaving the mortar.

Appearance

Perhaps a somewhat spherical star pattern.

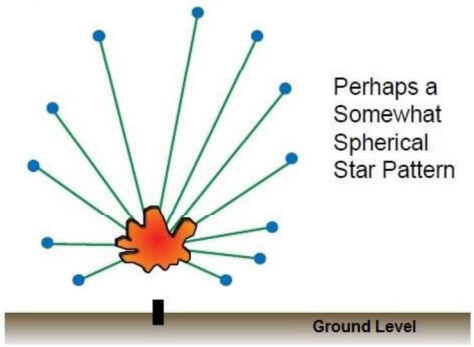


Fig. 3.14: Illustration of muzzle break, Journal of Pyrotechnics

Cause

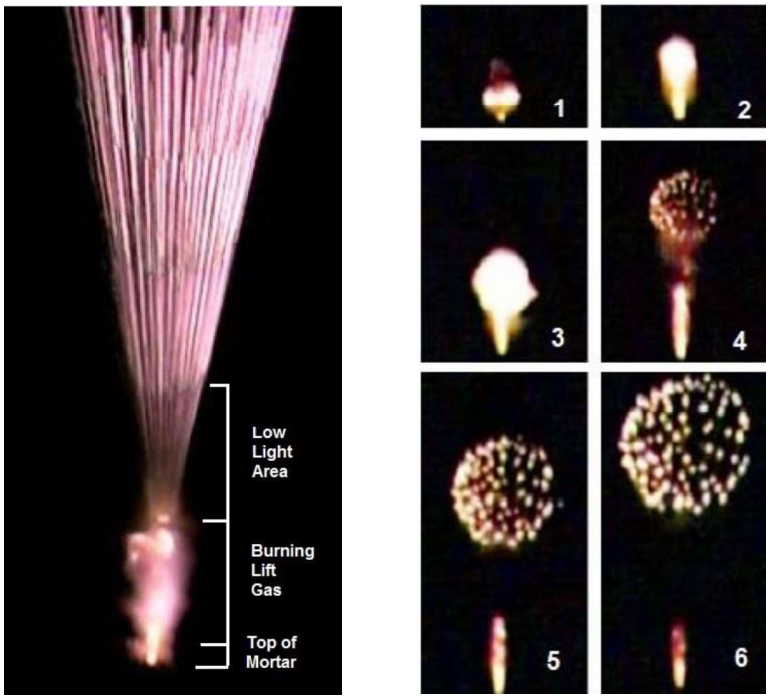
A relatively minor fire leak into the aerial shell or an internal ignition due to friction because of the movement of stars inside the shell. This seems to be more common with shells larger than 6-inch (150 mm).

Prevention

None known. The point where the minor fire leak most likely occurs (around the time fuses) is not exposed to view.

If It Happens
There is no time to react. Have any unloaded fireworks well protected, have personnel in a "protective position" (crouched down and facing away from the mortar) and have personal protection equipment being worn.

When a muzzle breaking shell is traveling upward at a high speed, compared with the radial spread of the stars, it creates the visual appearance of a flower pot.



Two views of the same event. Left, as it would be "seen" by an observer. Right, a rapid series of images taken with a fast shutter speed. The aerial shell burst can be seen to occur in the third photo; then the stars from a normal spherical pattern.

Low (or Ground) Break

Low or **Ground Break** occurs when the aerial shell fires normally, but bursts near or on the ground.

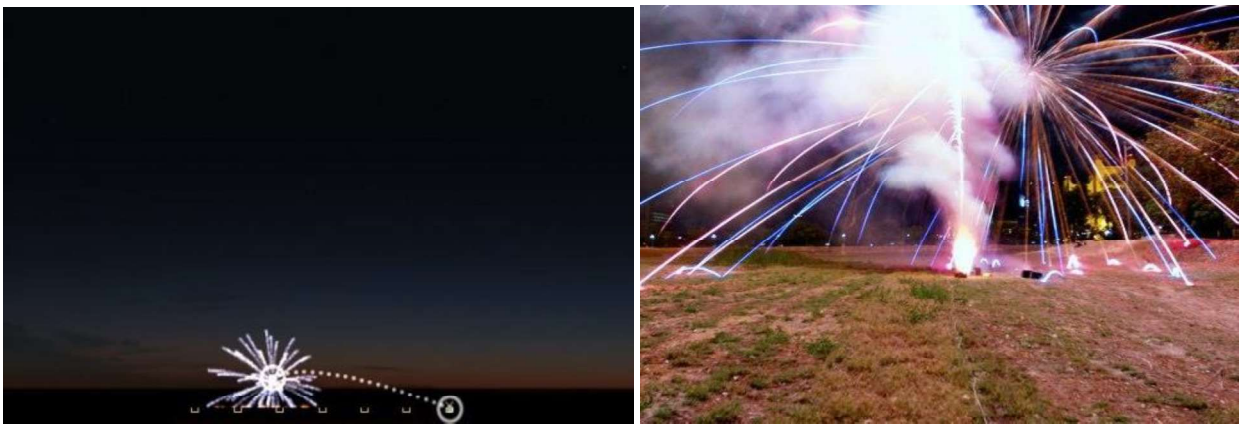


Fig. 3.16-3.17: Low break shell trajectory and example. Photo: Finale Fireworks (left) KyPyro, FB (right)

Causes

- The shell was fired from an over-sized mortar;

- Lift powder (charge) was lost or was quite damp;
- A mortar with a leaking or blown-out plug was used, or
- The shell was not fully lowered into the mortar.

Prevention
- Take care in loading (or if reloading) aerial shells;
- Inspect aerial shell for leaking lift powder and signs of dampness;
- Inspect mortar for a solidly attached plug, and
- Clean mortar (but only when necessary).

If It Happens
When possible, have mortars angled away from the crew and spectators, use a display site that is sufficiently large, have no combustibles in the fallout area, and keep unfired fireworks protected from sparks and burning debris.

Dud Shell

Dud. The aerial shell fires normally, but never bursts and falls to ground as a "live" (unexploded) shell.

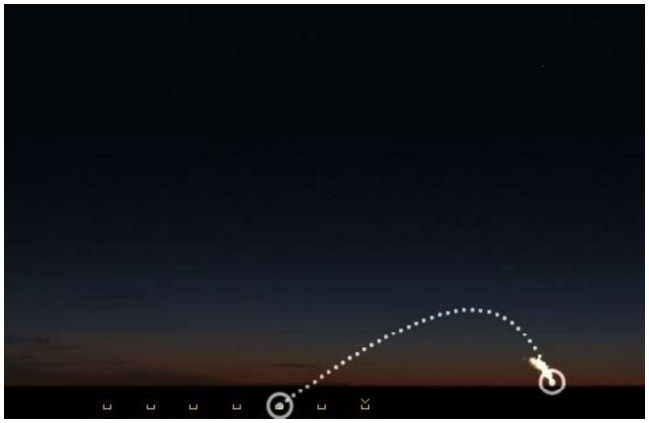



Fig. 3.18-3.19: Dud shell trajectory. Photos: Finale Fireworks and IPM (right) shell fired but un-exploded

Causes
Damp time fuse, damaged time fuse or insufficient prime on fuse.

Prevention
Careful aerial shell inspection may indicate current dampness or past water damage.

If It Happens
When possible, have mortars angled away from the crew and spectators; use a display site that is sufficiently large. Locate and remove the dud shell after the display, and properly dispose of the dud shell.

Note that the dud shells (especially large caliber aerial shells) may ignite when they impact the ground. However, they will generally have been sufficiently damaged by the impact that they will mostly produce a fire ball effect, rather than a powerful explosion that disperses the stars to a great distance.

Burning Fallout & Dud Components

Burning Fallout occurs when the aerial shell breaks at altitude, but some burning materials fall to the ground.

Cause
Stars or components are damp or oversize; non-pyrotechnic materials in the aerial shell are ignited when the shell bursts.

Prevention
Careful aerial shell inspection for current dampness or past water damage may reveal a problem.

If It Happens
When possible, have mortars angled away from the crew and spectators, use a display site that is sufficiently large, have no combustibles in the fallout area.

Dud Components

Some shell components fail to ignite or burn and fall to the ground as "live" items.

Cause
Stars or components are damp, are poorly primed, or the aerial shell break is too powerful for the stars or components to remain ignited.

Prevention
Careful aerial shell inspection for dampness or water damage may reveal a problem.

If It Happens
When possible, have mortars angled away from the crew and spectators, use a display site that is sufficiently large. Retrieve unignited components after the display and properly dispose of them.

Dud Shell and Components

Fig. 3.20: Dud 3-inch ball shaped aerial shells. Photo: courtesy of Twin Falls Police Bomb Squad. Fig. 3.21: Dud shells that have been water damaged and without lift charge. Photos: IPM

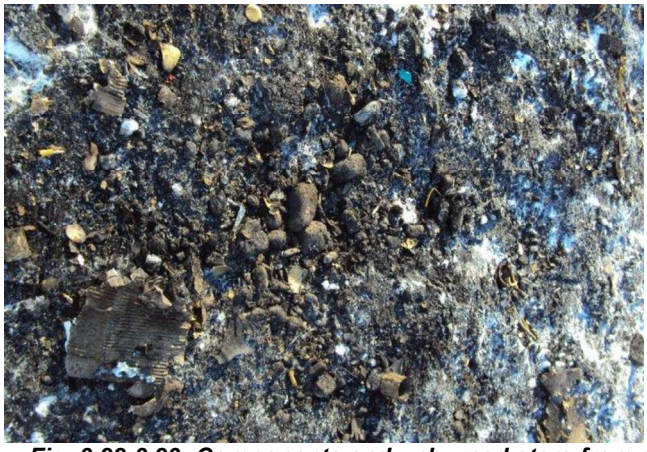


Fig. 3.22-3.23: Components and unburned stars from cake. Burn pit for disposal of pyrotechnics. Photos: IPM

Aerial shell functioning problems:

a. Explosion within the mortar
   1. Mild explosion – "**Flowerpot**"
   2. Powerful explosion – "**Shell Detonation**"
b. Explosion just above the mortar – "**Muzzle Break**"
c. Delayed explosion – "**Low or Ground Break**"
d. Failure to explode – "**Dud Shell**"
e. Burning debris reaches ground
f. Shell components fall to ground unignited

Fig. 3.25-3.26: Beautifully captured are some examples of some low break shells. Photo credits: Jessica Claire (left) TheMindofJustin.com (right). Fig. 3.24: (Above left) illustration of low break shell. IPM

Measures to protect the public and crew in case of aerial shell malfunctions

Prioritized list:

- Provide adequate spectator separation distance (during the display).
- Locate and remove duds (after the display).
- Inspect the aerial shells at the display site well before the display.
- Provide the crew with proper training and personal protective equipment (PPE).
- Use strong mortar racks, such that mortars will not be repositioned by a malfunction.
- Use proper mortar burial and/or barricading.
- Maintain crowd control. (Generally not responsibility of the display crew).
- Protect fireworks from adverse weather and sparks.

Fig. 3.27: Mortar rack test after shell detonation. Photo: Fireworks FX, Inc. Canada

Taking the first two steps will eliminate the vast majority of injuries to the public.

Over the past 25 years there have been great improvements in the performance of aerial fireworks. However, the display crew must never assume that malfunctions will not occur.

Aerial shell inspection items

No leaking **lift powder**. (Loose powder in a box of aerial shells may indicate that a shell(s) is losing its lift powder).


Fig. 3.28: Lift powder seen on bottom of shell box. Fig. 3.29: Tear in the bottom of lift powder. Photos: IPM

Feel the presence of lift powder on all shells.

Fig. 3.30: Powder lift on bottom of aerial shells. Photo: Northern Lights Pyrotechnics

The proper fit of shells in mortars (close but freely sliding).


Fig. 3.31: Loading shells into mortars (left). Fig. 3.32: Loading shells by leaders (right). Photo: C&EN

Leader fuse must be secured to the top of the shell. If fuse loop is broken then it shall be set aside and repaired. (See next page)

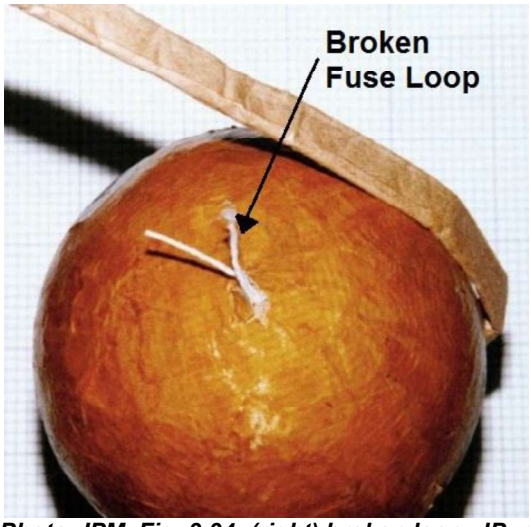


Fig. 3.33: Leader attached by a fuse loop which is intact (left) Photo: IPM. Fig. 3.34: (right) broken loop, JPyro

No tears or other damage in shell leader (fuse). If damage found, the leader should be repaired.

Fig. 3.35: Tear in quick fuse match. Photo: IPM

Leader is long enough (mortar length + approximately 6 inches) (15cm). These requirements are for manual firing.

Fig.3.36-3.37: Quick match leaders with safety cap protruding out of a mortar. Photos: IPM Universal

The **black match delay element** is long enough (usually 3 to 4 inches or 75 to 100 mm), and the safety cap is present and in place. These requirements are for manual firing.

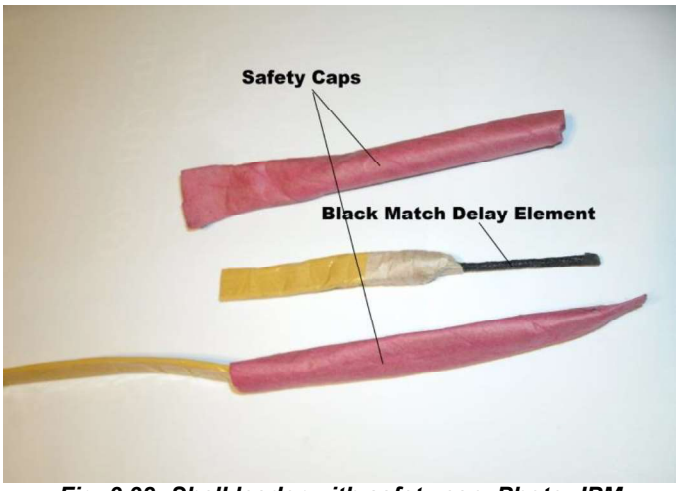


Fig. 3.38: Shell leader with safety cap. Photo: IPM

Fig. 3.39: Black match leaders with red safety caps. Fig 3.40: (right) Example of various colored safety caps. Photos: IPM

A strong **lowering cord** is present on large aerial shells above 8 inch (> 200mm).

Fig. 3.41-3.42: Lowering cord on larger aerial shell. Green lowering rope on large shells. Northern Lights Pyro

No evidence of water damage or of aerial shell having been wet. No dented, broken or cracked aerial shell casings.

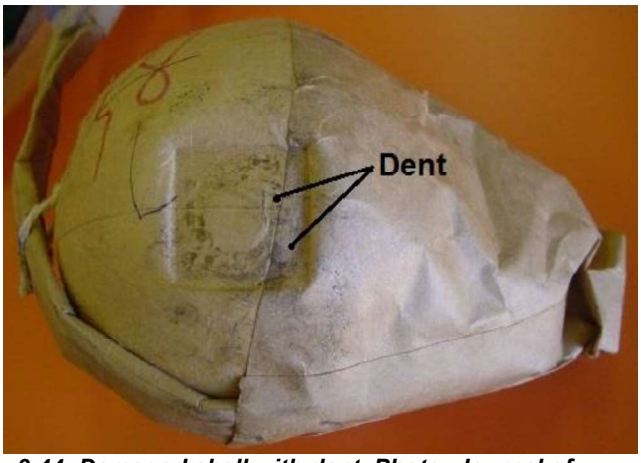


Fig. 3.43: Water damaged shell. Photo: IPM. Fig. 3.44: Damaged shell with dent. Photo: Journal of Pyrotechnics

Fig. 3.45-3.47: Technicians Rainey, Kevin Josephson and T.J Williams carefully loading 8" shells with the help of lowering cord. Photo credits: Northern Lights Pyrotechnics & IPM Universal