

# Pyrotechnics in Stadia

Health and Safety issues relating  
to the use of pyrotechnics  
in football stadia

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November 2016

*We acknowledge and thank our colleagues and friends within the industry and enforcers who have graciously reviewed and contributed to this paper and in particular provided input regarding the use of pyrotechnics in stadia within their own countries and the issues arising from such use.*

*Pierre Thebault – Pyroconsultant – France*

*Ed de Jong – Regulator – Netherlands*

*Izuskan Astandoa – Manufacturer – Spain*

*Karsten Nielsen – EUFIAS (Industry Association) - Denmark*

*Simonetta Parente – Manufacturer – Italy*

*Others in Germany, the UK and outside the EU*



## EXECUTIVE SUMMARY

This study was undertaken in accordance with the terms of reference prepared by UEFA in partnership with Football Supporters Europe (FSE).

A key aim of the study was to provide an informed summary of the potential short and long term health and safety risks associated with the use of pyrotechnic devices in football stadia.

The report assesses the health risks posed by each type of device in a crowded environment such as a football stadium. It also highlights that whilst pyrotechnic devices used in stadia may be described as “fireworks”, they are all explosive devices sharing some common features which impact on the potential harm they may pose, not least in terms of mishandling or malfunction. For example they:-

- Consist of pyrotechnic compositions which include their own oxidants and will generally burn “to completion”
- Burn at high temperatures – typically 700-1700C (and for certain compositions up to 2500C)
- Produce toxic combustion products including oxides of sulphur (SO<sub>2</sub>), Nitrogen (NO<sub>2</sub>, NO<sub>x</sub>) and solid oxides of metals as well as more complex products.

The legality issue is explained in the study along with the significance of the European Directive on Pyrotechnic Articles (2013/29/EU) which fully comes into force in July 2017. The Directive will place extensive monitoring and controls on the manufacture and supply of pyrotechnic articles. Various European Standards have been developed to meet the requirements of the Directive. The report concludes that implementation of the Directive could result in an increased supply of non-compliant devices (through less reputable sources) or the manufacture and use of “home-made” items and this supply of “illegal” pyrotechnics raises the potential for malfunction and increases the level of risk.

All pyrotechnic articles complying with the Standards have a “safety distance” (or other performance related information) printed on the device itself which exceeds that available within a crowded stadium. The only conclusion to be drawn from this is that manufacturers do not consider it safe for pyrotechnics to be used in stands occupied by spectators.

The study highlights the potential harm posed by pyrotechnics from the “normal” functioning of all pyrotechnics and recognises that the devices are not immune from product failure – described as “abnormal” functioning.

In addition to evaluating the current risks associated with the specific devices used frequently or occasionally in European stadia, the study also sets out the categories of health and safety risk that pyrotechnics can inflict on users and, importantly, others in football stadia. These are:-

- **Burns to flesh** – Pyrotechnics burn at high temperatures (extremes are c. 700-2500C) and can easily cause burns either from direct contact with the pyrotechnic flame or in close proximity. Pyrotechnic stars (\*eg flares) can almost stick to the skin when burning, but even if the contact is only fleeting considerable damage can be done. Furthermore, direct contact can contaminate the wound with combustion by-products meaning healing is complicated.
- **Burns to clothing** - The high temperatures mean melting and/or burning of synthetic clothing is likely. This can lead to significant burns to large parts of the body if the clothing is not removed quickly and/or extinguished.
- **Burns to structures and other hazards** - The high temperatures mean that ignition of structures or other hazards (eg seating, waste bins, gas cylinders etc) is possible. This can cause a localised or extensive fire.

- **Explosive effects on persons** - Damage to the body (including fatality) can arise from close proximity to an explosion from, for instance, a maroon or rocket head. Ear/hearing damage is very likely to those within a few metres of such a device exploding.
- **Explosive effects on structures** - Explosive effects could compromise the structural integrity of even substantial structures.
- **Smoke – acute toxic effects** - Most pyrotechnics produce some smoke including non-metal and metallic oxides and metal salts. In most cases these are not unduly toxic but can exacerbate existing respiratory conditions. Coloured smokes can stain persons, clothing or structures and may be mild irritants. Smoke inhalation by the person firing the item or those adjacent is most likely to occur when the product is used in close proximity to others and where it is impossible to stand “upwind”. Furthermore, within a stadium it is unlikely that there will be the normal dispersion of the smoke as would be expected if the device was used outside.
- **Smoke – chronic effects** - Heavy metal oxides and salts may produce long term chronic effects (including potential carcinogenic effects) on repeated or high concentration exposure. Coloured smokes (especially those from less reputable sources) may contain highly bio-active dyes.
- **Impact on head, eyes etc** - Thrown or projected items can cause impact damage to persons or to structures especially in close proximity.
- **Impact on vision**- Impact damage to eyes, or chemical contamination can cause temporary or even long term loss of sight particularly if there is physical damage or burning.
- **Impact on Hearing** - Damage can result from close proximity of explosive effects such as those from bangers or the head of a rocket exploding. Such items are generally intended to be used at least 25m from persons (if they are categorised as fireworks).
- **Panic** - The effect of panic on an audience as a result of actual or perceived injury or structural damage as well as that resulting from actual injury or damage can be a significant factor. Emergency evacuation procedures should be considered where panic is caused by a pyrotechnic device functioning in a crowd of people – we believe the effects could be significantly different to other causes of panic especially in a heightened awareness to terrorist activities.

**The report concludes that there are significant health and safety risks arising from their use in close proximity to other people and in contravention of the safety distances which are specified on the pyrotechnic articles themselves. All pyrotechnic devices have a “safety” distance for good reason and which will exceed the available space within a crowded stand or stadium. It is not safe, therefore, for any pyrotechnic device to be used in spectator areas within football stadia.**

The report also refers to other issues relating to the use of pyrotechnics in stadia including the Health and Safety of safety and security personnel.

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## Terms of Reference

In accordance with the terms of reference provided by the UEFA working group on pyrotechnics in partnership with Football Supporters Europe (FSE) this study and report examines the Health and Safety risks arising from the use of pyrotechnics in stadia.

## Introduction

This report reviews the types of pyrotechnic devices that are used by members of the public within stadia. It considers the effect of such pyrotechnic devices on human health and safety on a variety of persons who might be affected.

The report also briefly considers related issues and potential developments in areas like professional use, low impact pyrotechnics and the use of LED flares.

## Background

There have been a number of well publicised instances of pyrotechnics being used within stadiums by the public. Although in many cases there have been no injuries or damage, there are also many cases where such injuries or damage have occurred.

Furthermore, with the nature of pyrotechnics changing, and the availability of potentially more powerful items being available through internet sales (primarily within mainland Europe) there is the risk of more severe incidents occurring.

It is important to identify

- What pyrotechnic articles are commonly used in stadia?
- What incidents have occurred?
- The potential risk of incidents

## Explosives, Pyrotechnics and Fireworks

The public generally refer to any pyrotechnic device used within a stadium as a “firework”. This may not be technically correct and it is important to understand why.

It is important to understand that **all fireworks are pyrotechnic articles**, but not all pyrotechnic articles are fireworks.

Similarly, **all pyrotechnic articles are explosives**, but not all explosives are pyrotechnic articles.

The formal definitions are actually not that helpful – but the important things to appreciate is that different types of similar pyrotechnic devices may contain different quantities of pyrotechnic composition, be designed to burn for longer (or shorter) durations and may produce different combustion by-products.

**It follows that all of the items of interest to this study are explosives, and if modified, mishandled or used in a manner that they were not designed for they may behave in a way which even the general public would regard as being explosive – with the potential for extremely serious consequences including multiple deaths as a result.**

## European Standards and Directives on Pyrotechnic Articles

The European Directive (2013/29/EU) on Pyrotechnic Articles is now in force and the harmonised Standards derived from it fully come into force in July 2017. It categorises 8 types of pyrotechnic articles according to their generic types (eg Fireworks, theatrical pyrotechnics or “other” pyrotechnic articles) and their intended use by consumers or professionals.

**It is important to note that the Standards only relate to the quality of production of Pyrotechnic Articles, their performance under standard conditions and to issues concerning the suitability of supply to consumers or to professionals (ie “persons with specialist knowledge”). For instance, Category 1 fireworks are suitable for indoor use, Category 2 for use in a domestic garden (with a minimum safety distance of 8m), Category 3 fireworks for consumer “display” use (with a minimum safety distance of 20m) and Category 4 “professional” fireworks.**

**The Directive and Standards do not apply to how they are actually used once they have been supplied. For instance, the specified safety distances for the commonly used types described within this report can never be met by members of the general public within a stadium.**

There are some relevant pyrotechnic devices which are not included within the Directive such as:

- Items designed for life saving (SOLAS) – for example distress flares
- Items designed for military or police use – for example distraction devices

**However, all of these pyrotechnic articles, covered by Directive 2013/29/EU or not, pose similar Health and Safety issues.**

## Historical information

There have been many incidents involving the use of pyrotechnics in stadia, but many of course are not well documented or are supported by images or video. The following images, obtained from extensive internet searches, are used to illustrate the types of effects and likely problems. Not all relate directly to use in stadia but are illustrative of the types of effects and potential for harm that could be found within stadia.



*Figure 1- flare and smoke device*

In this image it is possible to see not only the high intensity of the flame produced by the flare, but the smoke produced from the combustion by-products (in this case it is likely to be aluminium oxide) from the burning of metal fuels in the composition. The smoke is in fact not deliberate in this case but a normal incidental effect.



*Figure 2- flares in spectator areas*

This image shows a flare ignited in close proximity to people. Given the burning temperature of the flare is approximately 1700C it can be seen that significant burns to bystanders could result from careless movement of the device to nearby persons, or to the user as the device burns to completion.



*Figure 3- Flares in spectator areas*

This image shows multiple flare-like devices within a spectator area. The number and close proximity of such items poses significant risks of personal injury or ignition of clothing or the structure of the stand.





*Figure 4- shell or other busting effect on road*

This image, although not within a stadium, shows the explosive and projectile effect of a device with a bursting charge (eg a shell or rocket head or Roman candle bombette). The intensity of the burst is obvious from the trajectory of the stars (straight lines) and could cause significant injury to nearby persons from the projectile effect alone. In addition, of course, the projectile elements are burning at high temperatures and could cause burning or ignition of clothing or structures.



*Figure 5- Multiple flares*

In this image multiple long burning stars are on the playing surface. These could be individual flares, or long burning stars from a device intended to project several subunits simultaneously (eg a mine)



*Figure 6- official dealing with flare*

In this image an official is attempting to deal with a pyrotechnic device by placing in a metal container to remove it from the playing surface. Although we appreciate the logic behind this approach we are concerned that if the device was of an exploding type (eg a large banger with a delay) the metal vessel itself could fragment once the device burst – thus increasing the hazard.

**The advice given to safety and security personnel, players or others who might attempt to deal with pyrotechnic devices on the field should be examined to ensure that they are not inadvertently increasing the hazard to themselves or others.**



*Figure 7- flares falling onto the playing surface*

In this image it is again difficult to tell if the device has been thrown (eg hand-held flare) or is a projected effect (distress rocket). What is obvious in either case is that the burning pyrotechnic is of

a long duration. Long duration items pose particular risks as they will continue to burn (at high temperature) wherever they happen to land.

#### “Legal” and “Illegal” pyrotechnics

Even in circumstances where the product itself is “legal” (in so much that it complies with the requirements of the relevant Directives and Standards) its use may be regarded as “illegal” in so much as

- It has been illegally supplied
- It is being used in a situation where its use is prohibited
- It is being used in a situation where it poses significant Health and Safety risks to the user or those in proximity to them

## Pyrotechnics Types and Effects

### General issues

All pyrotechnic devices share some common features which are important in the consideration of the potential harm they might create.

*Table 1- General pyrotechnic issues*

Feature	Comments
They are formed from pyrotechnic compositions which include their own oxidants	<p>This means that once ignited they will generally burn “to completion” and cannot be extinguished by conventional means (eg by excluding oxygen).</p> <p>Some pyrotechnic devices will burn under water – and hence cannot be extinguished by water (or other) fire extinguishers</p> <p>For instance, a typical Roman candle will burn for 45 seconds ejecting 8 shots sequentially – and cannot be stopped part way through</p>
They burn at high temperatures	<p>Typically, 700-1700C (and for certain compositions up to 2500C for short periods). Some effects will burn for many seconds and if in contact with skin can cause extensive burns, or ignite clothing or structures.</p> <p>Short duration items may still cause significant burning</p>
They produce toxic combustion by products	<p>These include gaseous oxides of sulphur (SO<sub>2</sub>), Nitrogen (NO<sub>2</sub>, NO<sub>x</sub>) and carbon (CO<sub>2</sub>) and solid oxides of metals as well as more complex products. In normal use, even within theatres, these products are dispersed easily and the concentrations are low. However, with uncontrolled use within stadia, especially in close proximity to users and adjacent persons the effects could be significant.</p> <p>In combination with burning, the burn may be contaminated with chemical combustion by products which may increase the severity of the injury and lead to poor healing.</p> <p>See later for more information</p>
They potentially can perform “abnormally”	<p>Most pyrotechnic articles are cheap hand-made items and there is a potential for them to perform abnormally if they have been poorly handled, or modified by the user. For instance, normally well controlled fountains have the potential to explode if the composition has been cracked.</p>
They are explosives	<p>Some pyrotechnic articles are designed to explode causing both blast damage (which may be local) or fragment throw (or both).</p> <p>Even those items not designed to explode may malfunction (see above) if modified or if they have deteriorated in storage.</p>

Pyrotechnic devices are now available in a wide variety of coloured effects as well as “standard” colours used for other purposes. Distress flares are usually white or red, and distress smokes are usually orange. We suspect that the growing range of specialist devices reflect particular colours wanted by supporters of particular teams, or perhaps to mark particular events.

## Types of pyrotechnics and fireworks used in stadia

**NOTE: the inclusion of any image is not indicative that the particular device has been used within a stadium, nor that the manufacturer of that device condones or encourages the use of that device within stadia.**

The major types of effects that have historically been used in stadia are:-

- Hand held flares
- Distress flares
- Smoke devices
- Strobes
- Bangers
- Fountains
- Sparklers

Other types that have been used rarely, or may, in our opinion, be used in the future include:-

- Rockets
- Roman Candles
- Single shot devices
- “Cakes”
- Mines
- Whistles

Details of these types, and their effects and potential for harm are given in Annexes 1 and 2, but illustrations of their effects and use is given below. It is often difficult to distinguish different types of pyrotechnic devices as many share very similar exterior appearance. Obviously those labelled properly in accordance with appropriate Standards can be distinguished explicitly as the mandatory labelling will include the type of device, but non-compliant articles may provide very little information (including safety information) to the user.

### Hand held flare

This device produces a bright light (white or coloured – often red) at the mouth of the tube along with considerable amounts of smoke.

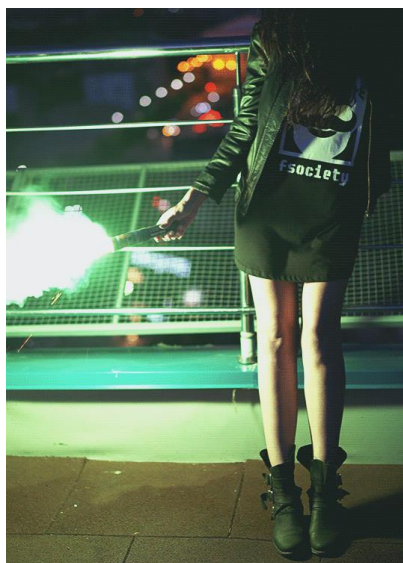


Figure 8- Hand held flare



These devices may be designed for distress use (often red or white) or may be small hand-held devices explicitly manufactured or marketed for use in stadia (in a multitude of colours).

They may be marketed as “Bengal lights” in a variety of colours as fireworks or “Flares” for more general use.



Figure 9- hand held flares



Figure 10- hand held flares

In these images the bright light of the hand held flare can be seen, together with the smoke produced from combustion of the pyrotechnic composition. It is also possible to see sparks thrown from the flare burning surface which fall to ground alight and could cause injury as well.



Figure 11- hand held flares (note reference to Bengals)



*Figure 12- Hand held flare*

These images show devices designed to be held in the hand and tested to ensure that the part where the hand should be remains cool.



*Figure 13- Firework Bengal Illuminations (Flares)*

This image shows devices intended for firework use but which may be used in exactly the same way as hand-held flares. They are not designed to be held in the hand however and the card tube will burn away as they function either leading to burns to the users, or to others in the vicinity as the user drops it as it gets near the end of burning.



*Figure 14- Firework portfires (in effect hand held flares)*

Portfires are intended to be used to ignite other fireworks – but they produce a flare like effect and are designed to be held in the hand or attached to a stick. They are easily obtained and are rarely controlled in supply.

#### Distress flares

This device ejects a star (sometimes with a parachute to slow its descent) which burns for an extended duration. It is sometimes difficult to determine in a photograph whether a device has a projectile effect or has been thrown.

The significant additional issue with such distress devices is the burn duration – this is often greatly extended (as they were designed to burn for a long time to attract attention as a distress device) and hence will continue to burn once discharged and maybe within the audience area or on the playing surface.



*Figure 15- distress flare (or similar device thrown from spectator area)*



*Figure 16- as previous figure showing trajectory of thrown or projected device*



*Figure 17- projected or thrown flare*

These images illustrate the long burning nature of these types of effects. Even when the device has reached the ground it will continue to burn for many tens of seconds. SOLAS type flares are obviously designed for use at sea, and hence are not extinguished by water.





*Figure 18- Parachute flares*



*Figure 19- hand held parachute flare (labelled parachute rocket)*

These images show the external appearance of parachute distress flares. It is often difficult to distinguish these from hand held flares, but their operation is normally such that the base of the item is struck to ignite and eject the star (sometimes with its associated parachute).

Spain reports that the use of SOLAS approved distress flares appears to be common. A few years ago one person was killed by such a device believing that he had bought a hand held flare instead.

#### Smoke devices

This device produces dense pyrotechnic smoke (usually orange coloured – distress, or other colours for stage or other use) as a deliberate effect (Note all pyrotechnic devices produce some smoke<sup>1</sup>)

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<sup>1</sup> The pyrotechnic industry is developing a range of low smoke and “cool burn” pyrotechnics based on, in general, nitrocellulose chemistry (rather than the traditional inorganic oxidants and fuels). However, such articles do not remove many of the hazards associated with the use of traditional pyrotechnics in close proximity to others.



Figure 20- Blue smoke device



Figure 21- Yellow smoke device

These images show the deliberate production of smoke as the primary effect.



Figure 22- Red smoke device (note ring-pull ignition)



*Figure 23- Smoke device*

### Strobes

These devices produce flashes of light (usually white but may also be coloured) of approximately equal intensity and of approximately equal duration and frequency.

They can induce epileptic effects in vulnerable people and are disturbing for even those who are not. Indeed, they are used as distraction devices in police or military raids for this very reason.

### Bangers

These devices produce a large flash and a bang and usually rupture the case which can cause fragment effects



*Figure 24- official runs after explosion of pyrotechnic device*

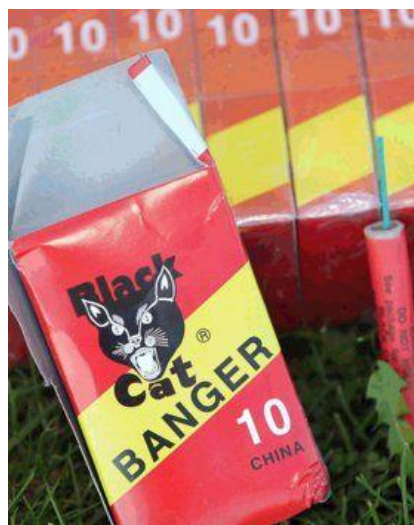
In this image (a still from video) the explosion of a device on the ground is noted – with almost no debris remaining. There is a blast effect, and associated loud bang which can cause deafness and significant distress, together with local blast effects and fragments from the device itself as it bursts.

These items are potentially fatal or could cause significant and permanent injuries. If they function in an enclosed space (eg a collection vessel) or against a structure, then disruption of the container or structure could result.



*Figure 25- small "firecracker"*

This image is of a small fire cracker – a simple device containing flash powder within a card tube. Once the fuse burns into the device it will explode violently.



*Figure 26- pack of bangers. Note green fuse on individual item*

This image shows a pack of firework bangers which are widely available across Europe although they are manufactured in China. It is not clear whether they are suitably labelled for the country of sale – but we suspect not.





*Figure 27- Bird scaring rope - from which individual bangers can easily be extracted*

This image shows a typical “bird scaring” rope. In normal use the rope burns slowly, igniting each banger in turn. However, it is very easy to remove each banger from the rope and light them in turn, using the short length of green fuse to give time to allow the device to be lit and thrown.



*Figure 28- consumer pack of "Salutes" - bangers*

## Fountains

These devices produce a shower of sparks and may burn from <1sec (“Jets”) up to 45 seconds or more



*Figure 29- Silver fountain (c. 2m effect)*

This image shows the functioning of a firework fountain – producing a shower of sparks over the duration of 0.5 to 45seconds – depending on type.

The incandescent sparks are directional, but could cause significant injury if directed at a person. In addition, of course, once ignited the device will continue to burn for its design duration.



*Figure 30- pyrotechnic "fountain" for ordnance disposal*

Fountains have been adapted for use in ordnance disposal and also as ignition devices (eg for remote ignition of bonfires) and this provides a potential alternative route of supply where fireworks themselves are prohibited.



*Figure 31- Firework conical fountain*

This is a typical conical fountain – designed to increase burning intensity as it functions. The thin walled tube burns away as the device functions.



*Figure 32- Ice fountains*

Ice fountains are popular indoor devices for putting on birthday cakes, and may also be used indoors in theatres and for stage effects.

These devices rely on different chemistry to most pyrotechnic devices – they are often based on Nitrocellulose rather than traditional inorganic fuels and oxidisers. One consequence of this difference in chemistry is that they burn “cool” and with little smoke – but the devices are relatively limited in comparison with other, more traditional, pyrotechnic articles.



*Figure 33- Hand held ice "Candles" - almost certainly fountains*

### Sparklers

A pyrotechnic coated wire which is designed to burn from the tip in a controlled manner emitting sparks



*Figure 34- Sparkler burning*

Sparklers are widely available, but are one of the firework types that is responsible for the most injuries in "normal" use. Primarily this is because the wire running through the item remains extremely hot (1200C +) for a while once the sparkler is extinguished. As such any contact with flesh can cause deep burns which will be contaminated with combustion by products.

The sparks from a sparkler rarely cause significant injury as the individual sparks are of low thermal mass.

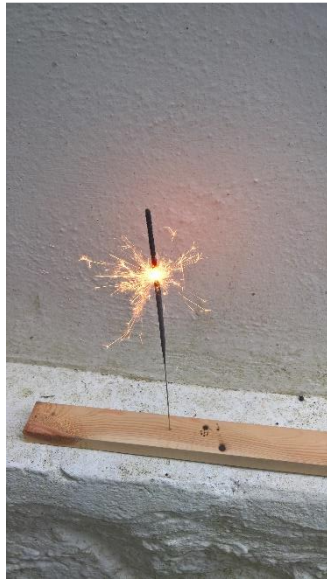
If several sparklers are held in close proximity it is possible to cause a rapid acceleration of the burning rate and many accidents in "normal" use have been attributed to this in the past.

Germany reports that sparklers are used extensively within stadia.

Another significant issue with sparklers arises if they are held together and lit, or if they are lit when confined within, for instance, a plastic tube. In this case the rate of burning can increase



significantly. If held when lit this can cause severe burns, and if confined could case the rupture of the enclosing tube -in effect leading to a “pipe bomb”.



*Figure 35- Single sparkler burning*



*Figure 36- Multiple sparklers burning*

## Rockets

These devices are designed to fly through the air and (optionally) burst at the apex of their flight to produce a spread of stars.



*Figure 37- selection of pyrotechnic rockets with sticks*

These rockets are equipped with sticks to stabilise their flight. Obviously once the rocket has completed its effect (which may involve bursting of the firework head to give a spread of stars) the stick will fall to ground – often at high speed. Injury can therefore result from the structural components of the rocket.



*Figure 38 - firework rockets with stabilising fins*

These rockets are not equipped with sticks, although there will also be debris problems associated with their use.



*Figure 39- small firework rockets fired as part of Taiwanese celebration. Note projectile effect*

This image shows the firing of many rockets from the ground as part of traditional Taiwan celebrations. The image shows the trails left by the burning rocket motors as they fly – although the individual rockets are small, they travel at high speeds with significant energies.



*Figure 40- burst of firework rocket*

This image shows the typical burst of a rocket head at the apex of its flight when operating “normally”. The bursting of the case and the rapid spread of stars could cause significant injuries if it functioned in close proximity to people.

## Roman Candles

These devices produce stars, mini star bursts or reports over an extended period from a single tube.



*Figure 41- Roman candles*

This image shows a variety of Roman candles available to the consumer. The devices are recognisable from the long length compared to diameter – as each tube contains multiple effects ejected sequentially over a period of 20-45 seconds.



*Figure 42- Roman candles*

It is difficult to illustrate the effect of Roman candles in a still image – but this image shows multiple effects originating from the same tube fired over an extended period. As with other devices, once lit the Roman candle will normally burn to completion and cannot be extinguished. If oriented towards a person this could cause both a projectile injury and repeated burn/projectile injuries



### Single shot devices

These single tubed devices produce stars, mini star burst or a report in the same way as does a Roman Candle. The effects are exactly the same but obviously only a single “shot” is fired. However, the effect is normally projectile and may contain multiple stars, projected bombettes, or bangers

### “Cakes”

These devices, which comprise several single shot tubes, linked together and fired sequentially produce stars, mini star bursts or reports over an extended period

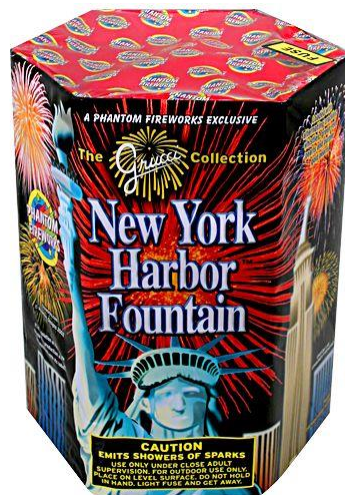


Figure 43- medium sized Multishot "cake"



Figure 44- large sized multishot "cake"



*Figure 45- design functioning of cake - multiple shots of different types*

It would be difficult, we believe, to “smuggle” such devices into a stadium (whereas all the other items are relatively small and could be hidden more easily from inspection). However, it is also possible that people will attempt to break down these multishot cakes to extract single individual tubes if routes of supply of individual items is restricted.

### Mines

These devices eject a single conical display of stars or other units in a single “shot”. They are extensively used for punctuation of pyromusical events as the effect is immediate on electric ignition.



*Figure 46- Stage mines*

These mines are equipped for electric ignition – but this is not always the case. They are another projectile effect and as such the tube need to be supported (in normal use) sufficiently that that the item does not fall over.



Figure 47- firework mines in use

### Whistles

Whistles produce a high intensity screeching or whistling sound over several seconds



Figure 48- Pyrotechnic whistles

This image shows a box of pyrotechnic whistles intended for firing from a gun, often for bird control at airfields etc. The whistle lasts for several seconds and is of very high intensity.

Other whistling devices are available with conventional fuses.

### The effects of confinement on pyrotechnic risks

As noted above the “confinement” of pyrotechnic devices in bulk in packages, or of individual devices in strong walled containers can significantly increase the risk to those persons around the device as it functions or to structures.

The major effect is likely to be fragmentation of the container and the subsequent impact of such fragments on persons. Lesser effects include “enhanced” direct blast effects (which can cause direct tissue and even organ damage, as well as ear drum rupture etc) and enhanced thermal effects.

High energy (and usually sharp) fragments projected from the device and its container can cause injuries as discussed elsewhere but at extended distances.



## Health and Safety Issues arising from the use of pyrotechnics in stadia

The vast majority of pyrotechnic devices are not intended to be fired from the hand. However, we appreciate that in most cases this is exactly the method of firing of choice by persons within stadia for practical reasons if nothing else.

*Table 2- use of pyrotechnics in stadia - general issues*

<b>Method of firing</b>	<b>Effects and risks</b>
Hand held firing of items designed to be hand held	<p>Minimal risk to user from normal functioning. Persons nearby would be affected by heat and smoke and could suffer significant injuries if within the manufacturer's specified safety distances.</p> <p>Minor risk from malfunctioning item as power of item is deliberately restricted</p>
Hand held firing of items designed NOT to be hand held	<p>Significant risk to user as item has not been designed or tested to be used in this way.</p> <p>Likely effect on persons nearby as extent of effect (sparks etc) are greater than for those designed to be hand held.</p> <p>Significant risk from malfunctioning items</p>
Local effects	<p>These will predominantly be those associated with heat and smoke generation. Significant burns from the high temperature of burning may result, together with possible chemical contamination of wounds by combustion by-products.</p> <p>There is also potential for normal "dross" that falls from the burning surface to ignite combustible material around where the item is functioned, or, if falling on the hand, to cause the item to be dropped.</p>
Remote effects – thrown items	<p>Most pyrotechnic articles are not designed to be thrown – they are designed to be erected in such a way that they cannot fall over and produce effects in the desired direction. Throwing of such items can cause several potential issues:-</p> <ul style="list-style-type: none"> <li>• Transfer of burning and smoke to the remote location – where it is likely the effect will continue for an extended period</li> <li>• Physical damage to the device causing it to function abnormally – up to exploding</li> </ul>
Ranges of effects – projectile elements	<p>Effects designed to produce projectiles – either burning stars, or other payloads such as mini-bombettes or whistles, are designed to be fired at or near vertical in normal use.</p> <p>If they are oriented at low trajectories when functioned the payloads may travel significant distances (see Appendix 1) and may land on the ground or in other parts of the spectator areas still functioning.</p> <p>This may cause local heat/smoke effects – or the device may explode "normally" at the design time producing blast and fragment effects at the point where the burst occurs</p>



*Figure 49- smoke device thrown from spectator area*

This image shows a hand held smoke being deliberately thrown over the heads of the audience. If it were to land within the spectator area burns and the effects of smoke could affect a significant number of people.

### The “normal” functioning of pyrotechnics

There are a large number of pyrotechnic and firework types identified within the European Standards, a subset of which have been, or may be, used by an unauthorised person within a stadium. We have attempted to address the types that have already been used, but identify other types which may be used in the future – particularly if controls on existing types are tightened.

The investigation of the potential for harm from the “normal” functioning of items albeit potentially in contravention of the instructions that are supplied with them is important. This includes aspects such as the construction, functioning and effects and especially:-

- Projectile effects
- Local effects
- Lift charges
- Burst charges
- Heat
- Smoke
- Debris
- Dross

These have been identified within Annex 1 and in the body of the report.

## Potential for malfunctions

Pyrotechnics are basically quite cheap, mass produced items. Items that conform to the European Standards are not immune from product failure – it is not physically possible to test every item for functioning before supply.

It is important to understand how the high consequence/low frequency risks arising from malfunctioning items relate to the high frequency/low consequence risks from “normal” functioning.

Although catastrophic malfunctions are rare, they do occur. As noted above all pyrotechnics are explosives and during malfunctioning may perform as violently as an equivalent quantity of explosive substances.

Such malfunctions could occur because: -

- Incorrect chemicals used (eg use of Potassium Chlorate in place of Potassium Perchlorate) meaning that the resulting device is sensitive to accidental ignition and greater explosive power than the item as designed. This is more likely to happen with illegal (ie deliberately containing prohibited mixtures) or low quality product
- Incorrect processing including casings or casing materials, closures and fuses
- Poor quality control at the point of manufacture
- Adverse chemical reactions during storage or transport especially those derived from temperature or humidity cycling (eg on trip from China to Europe). Again this is only likely to occur in extreme conditions and where the product is of low quality.
- Physical damage to items during storage, transport or prior to use especially those that crack consolidated compositions or cause leakage of composition
- Incorrect method of ignition – for instance people trying to light hand-held flares with a lighter or matches.

## Potential and extent of harm

This section considers how “normal” or “abnormal” functioning of items and the consequent potential for harm. Recall that “normal” means as expected and designed – even if not in the design orientation or the design location. “Abnormal” means if the device does not function as designed.

*Table 3- potential harm effects*

Harm effect	“Normal” functioning	“Abnormal” functioning
Burns – flesh	<p>Pyrotechnics burn at high temperatures (extremes are c. 700-2500C) and can easily cause burns either from direct contact with the pyrotechnic flame or in close proximity.</p> <p>Pyrotechnic stars (*eg flares) can almost stick to the skin when burning, but even if the contact is only fleeting considerable damage can be done.</p> <p>Furthermore, direct contact can contaminate the wound with combustion by-products meaning healing is complicated.</p> <p>If dross from the item falls onto the hand it can cause burns and potentially lead to the item being dropped</p>	<p>When a device explodes hot burning composition can be thrown significant distances.</p> <p>There may also be burns from burning parts of the device casing.</p>
Burns – clothing	<p>The high temperatures mean melting and/or burning of synthetic clothing is likely.</p> <p>This can lead to significant burns to large parts of the body if the clothing is not removed quickly and/or extinguished.</p>	<p>When a device explodes hot burning composition can be thrown significant distances.</p> <p>There may also be burns from burning parts of the device casing.</p>
Burns – structures and other hazards	<p>The high temperatures mean that ignition of structures or other hazards (eg seating, waste bins, gas cylinders etc) is possible. This can cause a localised or extensive fire.</p> <p>If dross from the burning item falls on the ground it could cause an ignition</p>	<p>Explosive effects could compromise the structural integrity of even substantial structures</p>
Explosive effects – persons	<p>Damage to the body (including fatality) can arise from close proximity to an explosion from, for instance, a maroon or rocket head.</p> <p>Ear/hearing damage is very likely to those within a few metres of such a device exploding</p>	<p>Explosive effects could be enhanced in malfunctioning items, or where items explode rather than functioning “normally” – for instance the explosion of a firework fountain because of damage to the internal composition</p>
Explosive effects - structures	<p>Explosive effects could compromise the structural integrity of even substantial structures</p>	<p>Explosive effects could be enhanced in malfunctioning items</p>

Harm effect	“Normal” functioning	“Abnormal” functioning
Smoke – acute toxic effects	<p>Most pyrotechnics produce some smoke including non-metal and metallic oxides and metal salts. In most cases these are not unduly toxic but can exacerbate existing respiratory conditions.</p> <p>Coloured smokes can stain persons, clothing or structures and may be mild irritants</p> <p>Smoke inhalation by the person firing the item or those adjacent is most likely to occur when the product is used in close proximity to others and where it is impossible to stand “upwind”. Furthermore, within a stadium it is unlikely that there will be the normal dispersion of the smoke as would be expected if the device was used outside.</p>	
Smoke – chronic effects	<p>Heavy metal oxides and salts may produce long term chronic effects (including potential carcinogenic effects) on repeated or high concentration exposure.</p> <p>Coloured smokes (especially those from less reputable sources) may contain highly bio-active dyes</p> <p>Smoke inhalation by the person firing the item or those adjacent is most likely to occur when the product is used in close proximity to others and where it is impossible to stand “upwind”. Furthermore, within a stadium it is unlikely that there will be the normal dispersion of the smoke as would be expected if the device was used outside.</p>	
Impact – head, eyes etc	Thrown or projected items can cause impact damage to persons or to structures especially in close proximity	Explosive effects could be enhanced in malfunctioning items especially where the wrong casing (or casing material) was used
Vision	Impact damage to eyes, or chemical contamination can cause temporary or even long term loss of sight particularly if there is physical damage or burning.	
Hearing	Hearing damage can result from close proximity of explosive effects such as those from bangers or the head of a rocket exploding. Such items are generally intended to be used at least 25m from persons (as fireworks <sup>2</sup> )	Explosive effects could be enhanced in malfunctioning items

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<sup>2</sup> 25m for Category 3 fireworks

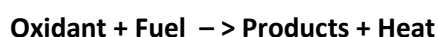
Harm effect	“Normal” functioning	“Abnormal” functioning
Panic	<p>The effect of panic on an audience as a result of actual or perceived injury or structural damage as well as that resulting from actual injury or damage can be a significant factor.</p> <p>Emergency evacuation procedures should be considered where panic is caused by a pyrotechnic device functioning in a crowd of people – we believe the effects could be significantly different to other causes of panic especially in a heightened awareness to terrorist activities</p>	Explosive effects could be enhanced in malfunctioning items

The negative environmental effect of fireworks is an area which has attracted much interest in recent years. This negative interest is probably predicated on a general anti-firework lobby as much as it is on any measurable effect, but of course, that is not to say that such concerns should be dismissed, nor that manufacturers, in particular, should not seek to minimise the potential negative environmental effects from their products. However, such a move should not compromise human safety at any stage of the manufacturing, storage, transport, use and disposal cycle.

It should also not be overlooked that improvised explosive devices could be, in effect, manufactured from simple pyrotechnics on site by those intending to cause harm. Packing existing pyrotechnics (especially those containing flash powder, or even, in some circumstances broken down sparklers, into a closed metal tube could lead to an improvised “pipe bomb”).

## Raw materials

The raw materials used in firework and other pyrotechnic compositions are diverse. In the most general terms a pyrochemical reaction can be described as



And to this generalised reaction may be added a large variety of additional components to produce additional effects. Examples of the constituents of pyrochemical reactions are given in the table below. Much more detailed pyrochemistry texts are available.

Table 4- Basic pyrochemical components

Component	Used for	Examples	Comments
Oxidant	Providing a non – atmospheric source of oxygen	Potassium nitrate Potassium perchlorate Barium nitrate	
Fuels	To burn in the presence of oxidant to produce heat – either for propulsion (hot gas production), for light emission (e.g. coloured flames) or transmission of fire (fuses)	Sulphur Charcoal Metals (e.g. Aluminium, Titanium) Resins (used as binders and as fuels) Lactose (for cool flames)	
Colour agents	Usually metal salts (not metals) which produce colour by atomic or molecular emission spectra	Cryolite (yellow) Strontium Carbonate (red) Copper Oxide (blue) Barium Nitrate (green) Calcium carbonate (orange)	The colour species in the flame is often MX (M=metal, X=Halogen or Oxygen) – it is not, for instance, copper(II) chloride (CuCl <sub>2</sub> )
Colour enhancing agents	Usually a source of chlorine in the flame	PVC Saran	
Metals	To produce sparks in the flame		Metals that react with atmospheric oxygen at high temperatures give better sparks
Binding agents	To produce stars	Dextrin Resins	
Glitter “delay” agents	To maximise the delay before the glitter “flash” reaction occurs	Barium carbonate	The “glitter” mechanism and related effects are not well understood. There are many texts available for advanced reading.
Whistle components	Produce a high frequency “whistle” when burned in the presence of an oxidant	Potassium salicylate Potassium benzoate	There are several texts available for advanced reading.
Manufacturing agents	To assist in manufacture – e.g. flow agents		

However, it is inevitable that some of the raw materials used will pose toxic or environmental concerns (although in general this is an issue related to manufacture as the raw materials are never

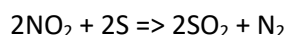
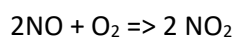
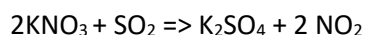
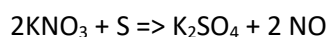
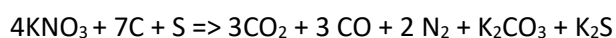
released on functioning), but to try and classify fireworks and other explosives on the basis of these components is to ignore the fact that the explosive effects are probably of the greatest concern, and that those explosive effects are intimately linked to the way that the explosives are packaged.

### Combustion chemistry

When fireworks burn a number of gaseous and solid products are formed. There is a considerable amount of data available on the normal combustion products from burning fireworks in the open, and the following equations are merely indicative of the typical combustion products from fireworks and pyrotechnics.

#### Blackpowder

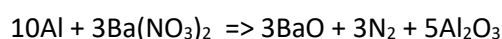
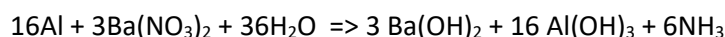
There has been extensive research on the burning of blackpowder and the following simplified chemical equations are not intended to be more than indicative of the type of reactions that are occurring.



What is important is the realisation that a wide range of solid and gaseous products is produced and that each of these, potentially, has environmental and health effects.

Similar, simplified, equations can be written for a range of pyrochemical reactions. Note that these equations are not complete – and, in general, are not balanced – they are indicative only.

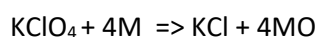
#### Nitrate based flash



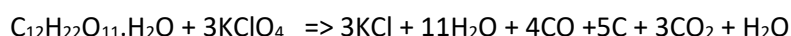
#### Coloured compositions (normally organic fuels)



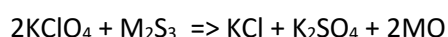
#### Metal Sparks (M = general metal)



#### Smokes (and other organic fuels)



#### Metal Salts (e.g. Antimony sulphide) (M = general metal)





## Heavy metals

The Disney Corporation published a paper in the proceedings of the International Pyrotechnics Symposium investigating the deposition of heavy metal salts into the Buena Vista lake over a period of many years from the nightly firework displays held there for over 25 years.

In essence the conclusions were as follows: –

- There has been very significant deposition of heavy metal salts in the lake
- The metal salts tend to sink to the bottom and are adsorbed onto the muddy substrate
- There is almost no variation of identified flora or fauna in the lake from when the research began.

A recent study in Austria describes “exorbitant” concentrations of barium and other metal salts in the snow following a New Year’s Eve celebration, however the base levels of heavy metals in snow are, unsurprisingly, rather low and hence the conclusions and flowery language must be treated with a degree of caution. No information was provided on any effects post – melt.

## Perchlorates

The perchlorate ion mimics the iodide ion and has a potential effect therefore on the thyroid gland in humans. The use of metal perchlorates (usually potassium perchlorate) as a substitute for chlorates is quite widespread and for good safety reasons. Compositions or perchlorate and metals are significantly less sensitive to many stimuli (friction, impact, spark) than their chlorate equivalents. There have been published a number of papers highlighting the concerns of perchlorates leaching into ground water, and the subsequent toxicological effects on wildlife, including humans. In the main this is a concern only for manufacturers of pyrotechnic compositions where bulk perchlorates may be handled and precautions must be taken to prevent groundwater contamination. Users of fireworks should not be threatened with the same potential controls for a variety of reasons: –

- The quantities are low
- Fireworks are designed not to release their compositions – instead it is the combustion by – products which are released on functioning
- Residual perchlorate is not a significant by – product of combustion – instead the oxidant essentially decomposes fully on functioning
- Natural attenuation is an important factor in lowering any perchlorate contamination.

## Toxic and health effects of functioning pyrotechnics

All pyrotechnics and explosives function by converting the chemicals they contain into combustion by – products, and in so doing generate gas, heat, light, sound or a combination of these, which ultimately lead to the observed effect.

The following table illustrates the potential toxic and health effects from the identified **combustion products** from burning fireworks and pyrotechnics. Obviously within a stadium it is likely that exposure times will be significantly less than 8 hours but 15 minute exposure could well be experienced– however this table illustrates the published data on toxicities from a variety of sources. It is also obvious from images and video of historic use of pyrotechnics by supported that potentially very high concentrations of these combustion by products may affect persons adjacent to where the devices are fired.

Note that “oxygen depletion” is not a significant effect (as it has been wrongly assumed that burning pyrotechnics consume atmospheric oxygen) except in so much as the presence of large quantities of, particularly, gaseous combustion products reduce the concentration of available oxygen.

Table 5- toxic and health effects of combustion by-products

Combustion Product	Known effects	Regulatory issues (*)	8hr limit TWA OES	STEL limit
Sulphur Dioxide	Very high toxicity		2ppm	15mins - 5ppm
Nitrogen Oxides	Highly toxic	Monitoring under COSHH (as NO <sub>2</sub> )	3ppm (as NO <sub>2</sub> )	15 mins - 5ppm
Carbon Dioxide	Highly toxic		5000ppm	15mins - 15000ppm
Carbon Monoxide	High concentrations may be rapidly fatal		50ppm	15mins - 300ppm
Nitrogen	Asphyxiant (but present in air)			
Barium Carbonate	Highly toxic, moderate irritant, possible systemic effects	Monitoring under COSHH CHIP requirements cover Ba salts		
Barium Sulphate	Highly toxic, mild irritant		2mg m <sup>-3</sup> as Ba	15 mins as Ba
Potassium Sulphide	Highly toxic, corrosive			
Potassium Carbonate	Moderate toxic, corrosive			
Potassium Sulphate	Low toxicity			
Potassium Chloride	Low toxicity			
Barium Oxide	Irritant		0.5mgm <sup>-3</sup> as Ba	15mins as Ba
Aluminium Oxide	Low toxicity, irritant		10mg m <sup>-3</sup>	15mins - 10mg m <sup>-3</sup>
Magnesium Oxide	Moderate toxic, moderate irritant		10mg m <sup>-3</sup>	15mins - 10mg m <sup>-3</sup>
Potassium Oxide	High toxicity (as KOH)			15mins - 2mg m <sup>-3</sup>
Carbon	Low toxicity		3.5mg m <sup>-3</sup>	15mins - 7mg m <sup>-3</sup>
Copper salts	Low to High toxicity		Typically 1mg m <sup>-3</sup>	15mins - 2mg m <sup>-3</sup>

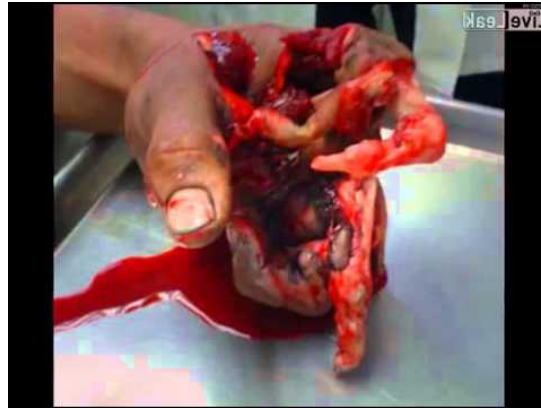
Combustion Product	Known effects	Regulatory issues (*)	8hr limit TWA OES	STEL limit
Lead Salts	High toxicity	Monitoring under COSHH	Typically 0.5mg m <sup>-3</sup>	15 mins 2mg m <sup>-3</sup>
Antimony salts	Low to High toxicity		Typically 0.5mg m <sup>-3</sup>	15mins as Sb
Bismuth salts	Low toxicity			
Strontium salts	Low to moderate toxicity			
Sodium salts	Low to moderate toxicity, mild irritants			
Calcium salts	Low to moderate toxicity		10mg m <sup>-3</sup> (as sulphate)	
Iron salts	Low toxicity, possible long term effects		5mg m <sup>-3</sup> (as Fe)	15mins - 10mg m <sup>-3</sup> (as Fe)

We have not been able to determine if there are any possible synergistic effects from exposure to a mixture of combustion by-products – however we believe that this is unlikely.

Of course precautions need to be taken if, for instance, a firework is damaged. However, we believe this is not a significant issue and that the overall risk from exposure to chemicals in the device itself is extremely low.

## Injuries

The following images have been found on the internet and are illustrative of the types of injuries inflicted by fireworks in our experience. However, given their provenance, we cannot vouch that all images of the injuries were as described or indeed actually originated directly from firework malfunction or misuse.



*Figure 50- Hand damage from exploding firework*



*Figure 51- Hand damage from burning firework*



Figure 52- Burns to leg

These images illustrate the explosive and thermal effects of pyrotechnics. In extreme cases significantly more serious injuries or even fatalities could arise from inappropriate use of high powered items, or from the effects of blast/fragments from devices exploding in close proximity to people.

Damage to structures, including the ignition of structural elements or of flammable materials is also a serious concern even in stadia that have addressed other potential (lower energy) ignition sources.

#### Other issues and future work

The following issues are also relevant to the use of pyrotechnics in football stadia.

##### Low impact pyrotechnics

There is some development of low impact pyrotechnics (cool-burn and low smoke). However, these still pose significant risks to Health and Safety of persons if they are not used in accordance with their instructions, or if they malfunction.

##### Alternative devices

There is potential for use of non-pyrotechnic items such as “LED Flares” and we suggest that these devices are studied further.

##### Dealing with pyrotechnic devices

There should a review of the methods and training to deal with pyrotechnic devices in stadia that do not significantly increase the risks to stewards, security personnel, players, officials and others.

##### Professional use of pyrotechnics

The professional use of pyrotechnics in stadia also presents some risks to Health and Safety and should be considered as part of the overall review on pyrotechnic use.

##### Modification of pyrotechnic articles

The modification of pyrotechnic articles, for instance, the packing of a large number of sparklers into a thin walled metal tube, could produce an effective “pipe bomb” which would cause significant injury to those in close proximity as the device functions. This could be an attempt to “enhance” the pyrotechnic effect but also is a potential route for terrorist related activity.

##### Outside the stadium

Pyrotechnics used by people *en route* to the stadium (in public areas) or onto the approach and entry to the stadium itself pose very similar concerns to public Health and Safety.

## Conclusions

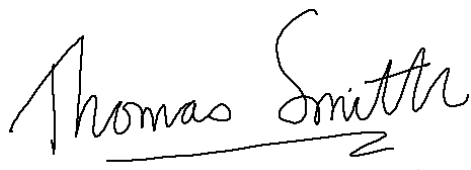
This report identifies a number of issues associated with the use of pyrotechnics in stadia.

**The report concludes that there are significant health and safety risks arising from their use in close proximity to other people and in contravention of the safety distances which are specified on the pyrotechnic articles themselves. All pyrotechnic devices have a “safety” distance for good reason and which will to exceed the available space within a crowded stand or stadium. It concludes that is not safe, therefore, for any pyrotechnic device to be used in spectator areas within football stadia.**

In particular, the risks relate to:-

- Burns to flesh
- Burns to clothing
- Burns to structures and other hazards
- Explosive effects on persons
- Explosive effects on structures
- Smoke – acute toxic effects
- Smoke – chronic effects
- Impacts to head, eyes etc
- Vision
- Hearing
- Panic

The report also refers to other issues relating to the use of pyrotechnics in stadia including the Health and Safety of safety and security personnel.

A handwritten signature in black ink that reads "Thomas Smith". The signature is written in a cursive style with a horizontal line underneath the name.

**Dr Tom Smith**  
*CarnDu Ltd*  
*October 2016*



## Annex 1 – Categorisation of pyrotechnic articles – summary

The following tables describe the types, effects and potential harm issues of the most common and other pyrotechnic articles used in stadia.

### Most common devices

Type and synonyms	Brief Description and Effects		Categories (Note 1)	Area of effect (note 2)		Harm issues (note 3)					Comments
				Local	Remote	Burns	Proj	Exp	Smoke	Other	
Hand held flares	A tube usually constructed of plastic or card with various ignition methods	Produces a bright light (white or coloured – often red) at the mouth of the tube	Solas P1/P2	x		x			x	x	High potential dross from poorly manufactured
Distress flares <i>Parachute flares</i>	A tube, usually constructed of plastic or metal with various ignition methods	Ejects a star (sometimes with a parachute to slow its descent) which burns for an extended duration	Solas P1/P2		x	x	x (100m)		x		
Smoke devices <i>Smoke bomb</i>	A tube, usually constructed of plastic or card with various ignition methods	Produces dense pyrotechnic smoke (usually orange coloured – distress, or other colours for stage or other use)	Solas T1/T2 P1/P2	x	x				x		All pyrotechnic articles produce some smoke – these devices are those considered to produce dense smoke as the primary effect  Specialist P1/P2 items may contain pesticides (eg Mole smoke)
Strobes	A tube, usually of card which burns away during functioning		F2/F3/F4 T1/T2	x		x			x	x	Strobes can induce epilepsy in vulnerable persons

Type and synonyms	Brief Description and Effects		Categories (Note 1)	Area of effect (note 2)		Harm issues (note 3)					Comments
				Local	Remote	Burns	Proj	Exp	Smoke	Other	
Bangers <i>Reports</i> <i>Flash reports</i> <i>Crackers</i>	A tube, usually of card but may occasionally (and dangerously) of metal	Produces a large flash and a bang and ruptures the case	F2/F3/F4 T1/T2 P1/P2	x	x	x		x	x	x	Fragments of the case can cause significant injury (including death)  P1/P2 devices include railway signals, signalling devices and distraction devices (used in anti-terrorist operations etc)
Fountains <i>Gerbs</i>	A tube, usually of card but may occasionally of metal	Produces a shower of sparks	F2/F3/F4 T1/T2 P1/P2	x	x	x			x	x	May burn from <1sec ("Jets") up to 45 seconds or more  Potential dross from burning item  P1/P2 devices include specialist ignition devices
Sparklers	A pyrotechnic coated wire	Designed to burn from the tip in a controlled manner emitting sparks	F1/F2/F3	x		x					Burning of multiple sparklers at once can lead to a rapid acceleration of burn rate  Apparently sparklers are widely used in Germany

Less common devices – including those which may be used in future

Type	Brief Description and Effects		Categories (Note 1)	Area of effect (note 2)		Harm issues (note 3)					Comments	
				Local	Remote	Burns	Proj	Exp	Smoke	Other		
Rocket	A device, normally with a motor and head and a means of stabilising in flight (usually a stick)	Designed to fly through the air and (optionally) burst at the apex of their flight to produce a spread of stars	F2/F3/F4 (T1/T2)		x		x (30- 100m)	x			x	If equipped with a stick the stick itself creates a hazard as it falls to earth. Bringing a large sticked rocket undetected into a stadium would be difficult.  Some devices are stabilised with fins  Specialist T1/T2 items (line rockets) are available but we do not consider them a viable device within stadia
Roman Candle	A long cardboard tube with several effects fired sequentially	Produces stars, mini star bursts or reports over an extended period	F2/F3/F4 T1/T2		x	x	x (20-70m)	x			x	Once ignited the device will burn to completion  Some inert debris from spacers within the long tube which are ejected during functioning
Single shot	A short cardboard tube which fires a single ejection	Produces stars, mini star burst or a report	F2/F3/F4 T1/T2		x	x	x (20-70m)	x				
“Cake” <i>Multishot</i>	Several single shot tubes, linked together and fired sequentially	Produces stars, mini star bursts or reports over an extended period	F2/F3/F4 (T1/T2)		x	x	x (20-70m)	x				Once ignited the device will burn to completion  T1/T2 items are relatively rare

Type	Brief Description and Effects		Categories (Note 1)	Area of effect (note 2)		Harm issues (note 3)					Comments
				Local	Remote	Burns	Proj	Exp	Smoke	Other	
Mine	A tube (usually card) with a single ejection of effects	Ejection of a single conical display of stars or other units	F2/F3/F4 T1/T2		x	x	x (20-70m)	x			A mine is a specific type of
Whistles	A tube (usually card)	Produces a high intensity whistle	F2/F3/F4 T1/T2 P1/P2	x	x					x	The whistle can cause hearing damage at close proximity

### Notes

*Note 1 – The following categories are included: - Solas – distress flares for use at sea. There may also be distress devices designed for example, for mountain rescue. F1/F2/F3/F4 – the four categories of fireworks, T1/T2 – the two categories of pyrotechnic articles designed for use on stage or as special effects, P1/P2 – so called “other” pyrotechnic articles whose intentional use or design does not fit within the definition of “fireworks” or “theatrical pyrotechnic articles”*

*Note 2 – any of the devices could also be thrown by the user and hence create a remote effect (which is considered within the body of this report). However, these columns describe the likely area of harm if the device is used “normally”.*

- “Local” refers to the immediate area (ie the user)
- “Remote” to persons removed from the immediate area of firing

*Note 3 – this describes the types of harm that could result.*

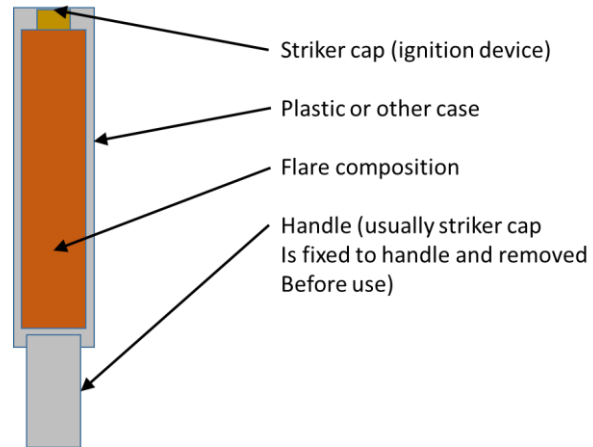
- Burns – direct action of the burning pyrotechnic composition or action of radiant heat at close distances
- Proj – a projectile effect – impact damage. A typical range when fired at 45 degrees is also shown
- Exp – an explosive effect creating a local blast wave and fragments
- Smoke – either the deliberate production of dense smoke as part of the design, or smoke generated from the burning pyrotechnic composition. Harm may be caused by the combustion by-products or by particulates
- Other – other effects – see comments

### Annex 2 - Types of pyrotechnic articles

Each type is described with its formal definition from within the European Standards and is illustrated with structural diagrams and images of their effects.

### Hand held flares

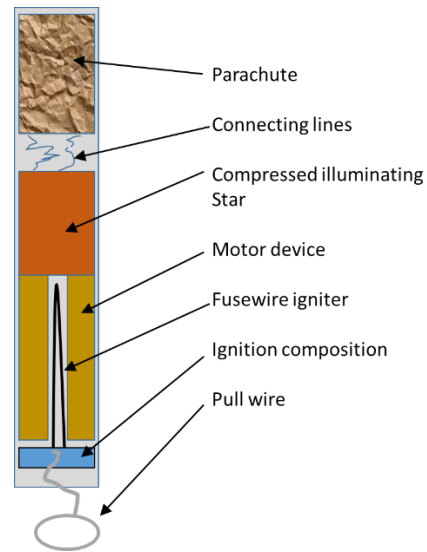
There are a variety of hand held flares available, ranging from simple tubes with compressed composition to sophisticated devices intended to signal distress at sea (SOLAS type). The following diagram is typical of such devices



*Figure 53 - Typical hand held flare*

### Distress flares

Distress flares are parachute enabled devices intended to project a long burning star into the air where it “hangs” suspended by the parachute. As such it has both a projectile effect and a star that is intended to burn for an extended duration. If the parachute fails, or the device is functioned in a low trajectory, the star can reach ground level and continue to burn for a significant time.



*Figure 54- Typical parachute flare*

### Smoke devices

**Smoke/fog generator** - An article containing smoke producing pyrotechnic composition or heat/gas generating composition designed to evaporate a substance or disperse hygroscopic particles and designed to function on the ground or fixed to a support. The casing of the article can be made of different materials. The principal effect is emission of white or coloured smoke/fog without any aural effect.



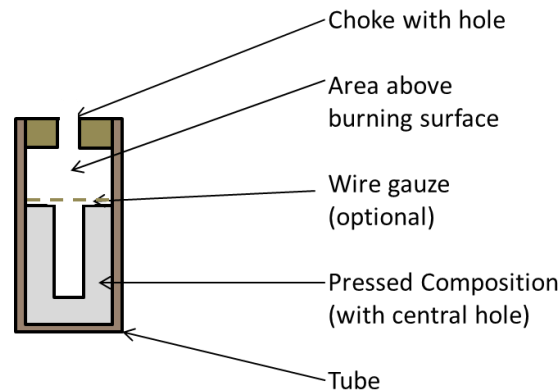


Figure 55- Smoke generator

Smoke generators are not used extensively in outdoor firework displays, although they may be used in conjunction with the use of lasers to supplement the display.

### Strobes

**Strobe** – A tube containing an intermittently burning pyrotechnic composition to produce long and rapid series of flashes at a relatively constant frequency. The pyrotechnic composition may be pressed or not. The tube has no choke and optionally burns away during functioning with the emission of series of flashes

The burning mechanism for a strobe is not well understood although there are several theories published for this peculiar rhythmic burning of what is, essentially a homogeneous composition.

The author believes that the glitter and strobe effects are both manifestations of the same basic chemical processes which lead to “flash” reactions occurring away from the burning surface (in the case of glitter) and at the burning surface (for strobes). In each case the proposed mechanisms for the observed effect require atmospheric oxygen to oxidise intermediate reaction by – products. Research is on – going to explain these phenomena more fully. However, whereas glitter effects are somewhat limited in chemical composition there are a wide variety of compositions which exhibit unstable, strobe – like, burning however counter – intuitive this may be. Pyrochemical reactions, especially those involving several steps which may or may not require the presence of atmospheric oxygen, are almost certainly not of similar mechanisms to oscillating reactions in solution.

### Bangers (Reports)

**Report** -Article containing pyrotechnic composition designed to produce a bang which may also include a coloured delay element.

*Subtypes of reports include –*

**Flash banger** – A non-metallic case containing metal based pyrotechnic composition which may be used as pyrotechnic units in shells and other articles. The principal effect is a report and a flash of light.

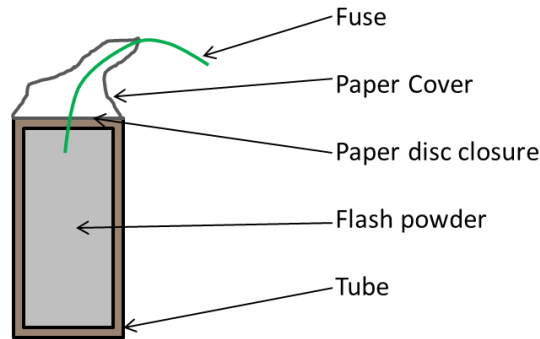


Figure 56- Flash report or Ground Maroon

**Ground maroon** – A maroon without propellant charge and with or without delay fuse, designed to produce its report on the ground.

**Maroon** – A firework containing pyrotechnic unit(s) or loose pyrotechnic composition and designed to produce a loud "bang" report as main effect. Not to be confused with bangers, as their design is similar to small shells or bombettes.

### Fountains

**Fountain** - A case containing sparks and/or flame-producing pyrotechnic composition and designed to be placed on the ground, or to be fixed in the ground, or to be fixed to a support, or to be held in the hand. The pyrotechnic composition may be pressed or not in the tube, with or without a choke or other constriction incorporated into the tube. The principal effect is emission of sparks and flames with aural effect other than report or without any aural effect.

**Synonym** - Gerb

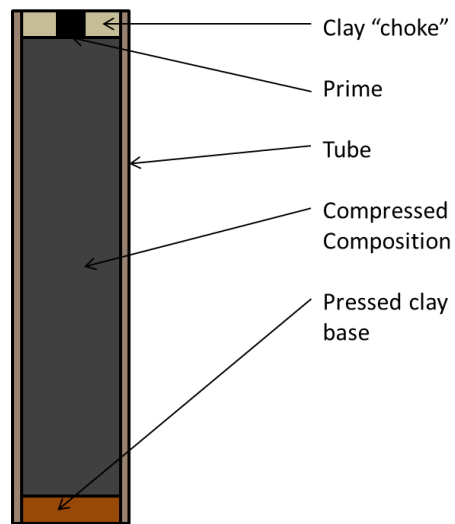


Figure 57- Choked fountain

Subtypes of fountain include –

**Bengal flame** – A tube containing a slow-burning pyrotechnic composition which may or may not be pressed. The tube has no choke and optionally burns away during functioning.

**Saxon** – A tube intended to be attached to a support in its middle so that it can rotate and containing one or two pyrotechnic compacted charges which burn on opposite sides and eject their combustion products sideways so that rotation is obtained.

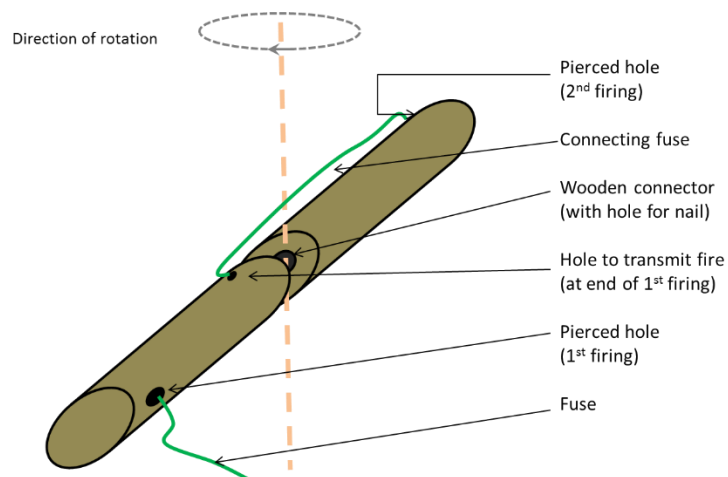


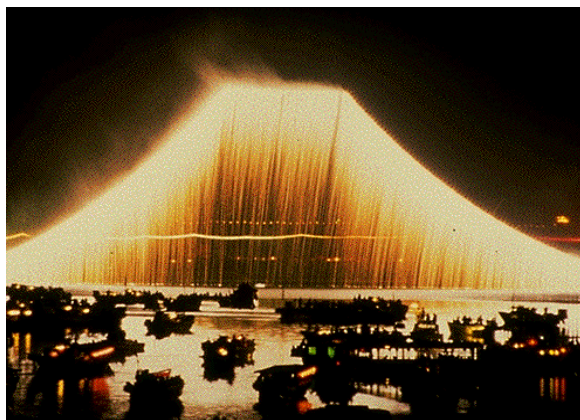
Figure 58- Saxon

**Lance** – A small diameter tube containing a compacted pyrotechnic composition, burning in a cigarette way, intended to deliver a thermal output to ignite manually other fireworks or a small white or coloured flame to be used in “lancework”. The pyrotechnic composition may be pressed or simply consolidated. The tube has no choke and generally burns away during functioning.

**Portfire** – A hand-held device, containing a slow burning pyrotechnic composition, and which emits a small flame. A portfire can be considered as a hand-held lance, as it is the case when used to ignite manually other fireworks.

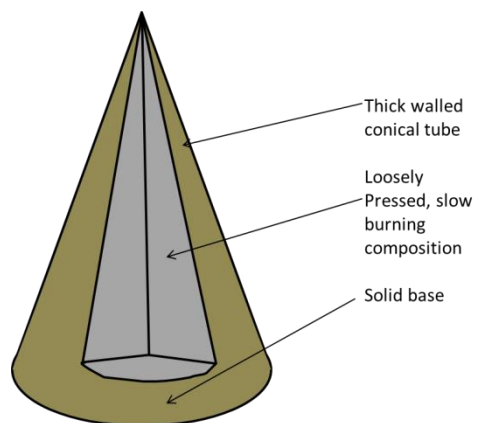
**Driver** – A device intended to produce thrust, often with limited visual effect, to cause, for instance, rotation of a wheel.

**Waterfall** – A case containing pressed or consolidated pyrotechnic composition producing sparks and flame and generally consume the tube whilst burning. Combustion products are ejected from the flame zone at low speed, then drop downwards as water in a waterfall.



*Figure 59 - Waterfall effect – Japan*

**Volcano** – A conical device containing consolidated or pressed composition in which the effect (height or intensity) increases as the device burns.



*Figure 60- Schematic of conical fountain (volcano)*

As the conical fountain burns the surface area of burning increases but the hole at the top of the cone also increases – the end result being that the height of burning remains approximately constant but the intensity of the effect increases.

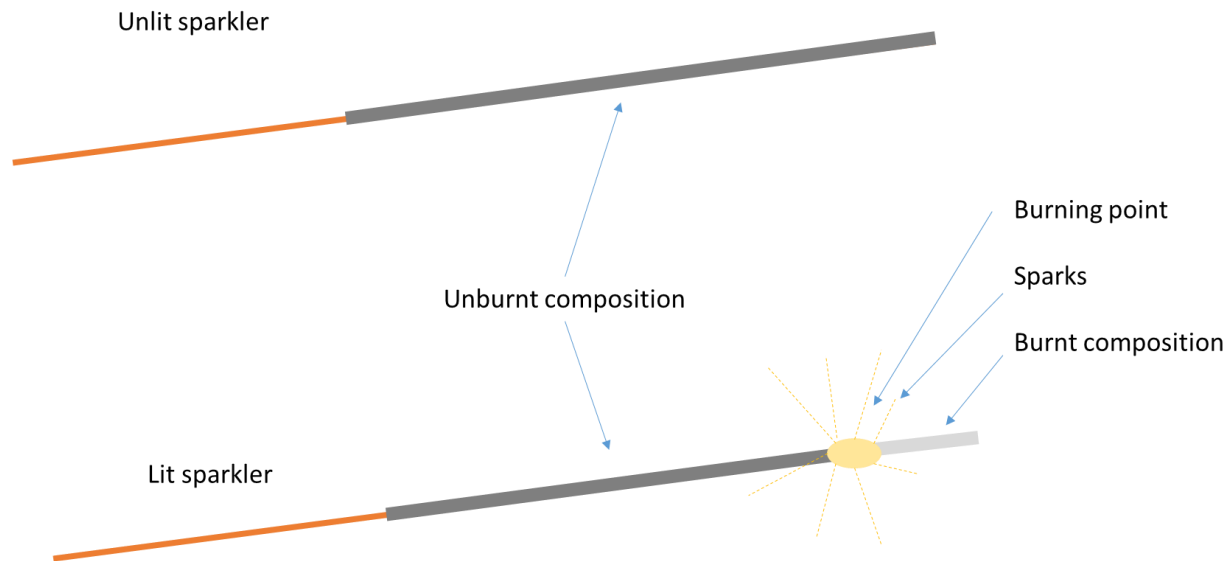
## Sparklers

Sparklers are usually lengths of wire coated in a pyrotechnic composition which is designed to be lit at its tip and then burns progressively down the composition, emitting sparks as it progresses until all the composition is consumed.

The burning temperature of the firework composition is in the region of 1500-1800C but the wire former does not reach this temperature as heat is dissipated to the environment and through the wire to unburnt parts of the composition.

The composition usually contains an oxidant (typically Barium Nitrate) and fuels/spark generators including Aluminium and Iron powders. The overall effect of the sparks (which can vary from golden to silver) is akin to those sparks generated by an angle grinder working on metal. The sparks themselves, although burning in atmospheric oxygen at several hundred degrees Centigrade, cause few injuries as the thermal mass is so low and contact times with skin are very low.

In contrast contact with the burning composition itself could cause significant burns as well as potential chemical contamination of the wound from combustion by-products.

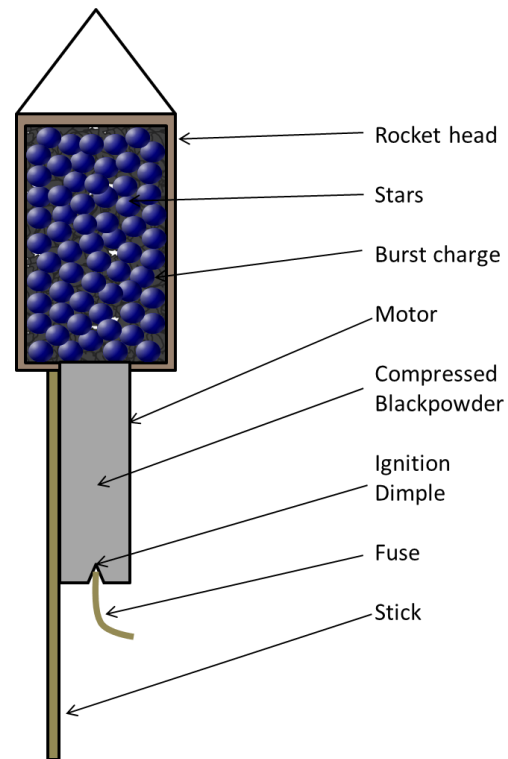


*Figure 61- Sparkler construction and burning*

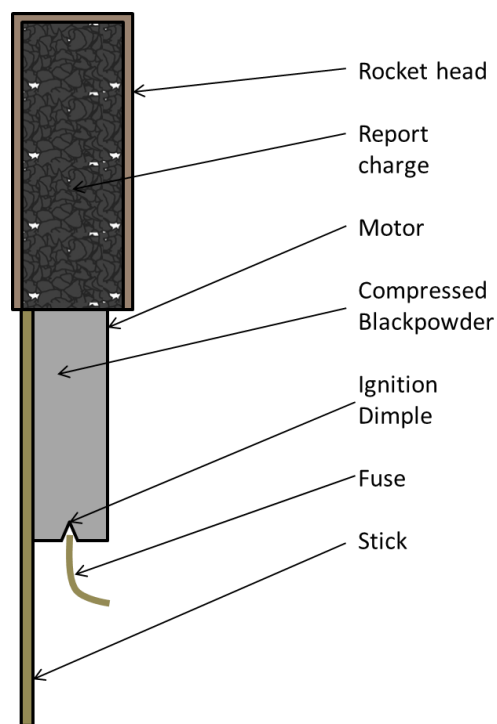


## Rockets

**Rocket** - Article containing pyrotechnic composition and/or pyrotechnic units, equipped with a launching motor and stick(s) or other means for stabilization of flight, and designed to be propelled into the air. The principal effect is ascent, with or without additional visual and/or aural effects, and production of visual and/or aural effects in the air.



*Figure 62- Generalised rocket construction (with "German" style motor)*



*Figure 63- Signal rocket*

The rocket motor may alternatively be formed on a spindle so that there is a “hole” along most of the length of the motor – this increases the surface burning area and thus the amount of gas produced, or it may be solid. A small dimple as shown in figure 28 above is somewhat of a compromise – initial thrust is increased and the “dimple” extends somewhat as the motor burns.

Rocket motors for fireworks are usually made from blackpowder, or a blackpowder-like composition. Smaller rockets may be made from “whistle powder” – so that the rocket ascends and produces a whistle at the same time. There has been some move to use military-like propellants in firework rockets, the chief advantage being a dramatic decrease in smoke, but this practice is not yet widespread.

*Subtypes of rockets include –*

**Signal rocket** – *A tube containing pyrotechnic composition and/or pyrotechnic units, equipped with a stick or other means for stabilization of flight, and designed to be propelled into the air to produce predominantly an aural effect. Signal rockets may also be coloured.*

**Flight rocket** – A collection of rockets designed to be propelled into the air from a frame or cone and ignited by a single or multiple fuses.



*Figure 64- Flight rockets in Maltese display held in simple frame together with mortars supported by sand bags and metal frames*

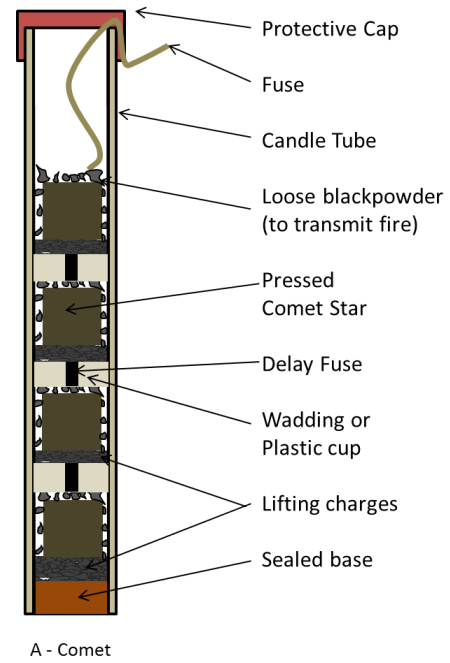
Ignition of a single rocket causes all the other rockets to light due to the close proximity of the fuses. The ignition process accelerates (as in a chain reaction) and the rockets fly into the air producing a large cone of effects.

The major safety issue with flight rockets is that the extent of the cone of flights is somewhat unpredictable, and indeed some rockets may fly at very low angles.

**Parachute rocket** – An article containing pyrotechnic composition and/or pyrotechnic units, which contains subcomponents some or all of which will descend on parachutes to the ground and equipped with a launching motor and stick(s) or other means for stabilization of flight, and designed to be propelled into the air.

### Roman Candles

**Roman candle** - A tube containing a single charge or alternate propellant charges, pyrotechnic units and transmitting fuses. The pyrotechnic units may be bombettes, comets, hummers, maroons, mini – mines, stars, whistles, etc. The principal effect is ejection of the pyrotechnic units in succession, producing a series of visual and/or aural effects in the air.



*Figure 65- Typical four shot Roman candle with comet stars*

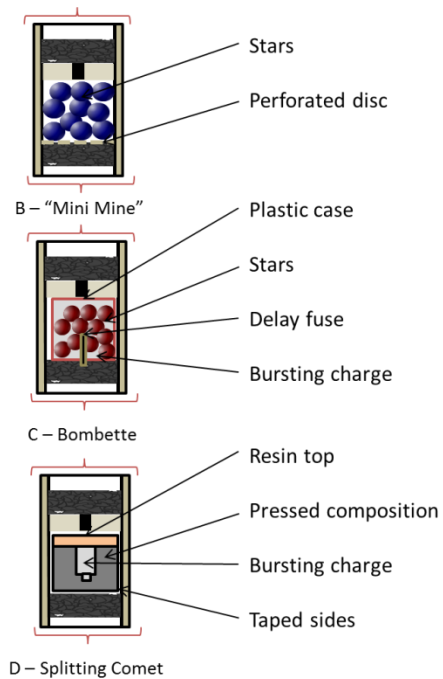


Figure 66- Alternative payloads for a Roman candle B – “mini – mine”, C – bombette and D – splitting comet

There are a very large range of possible effects that can be deployed in a Roman candle and some possible payloads are shown in figure 32.

Roman candles for display use typically range in calibre from 18mm to 60mm.

### Single shot devices

**Shot tube** – A tube containing a single propellant charge and a pyrotechnic unit, with or without a bursting charge, with or without a transmitting fuse. The pyrotechnic unit may be a bombette, a comet, a hummer, a shell (including maroon shells), a whistle etc. (c.f. mine).

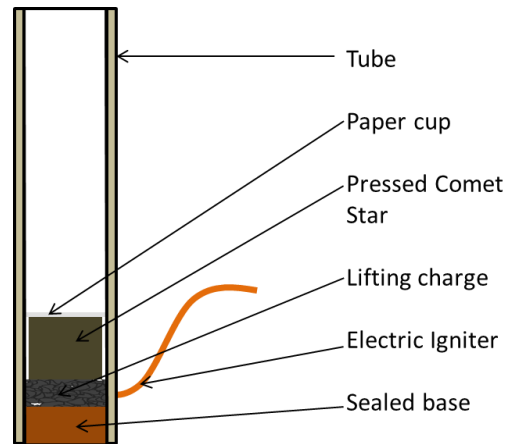


Figure 67- Comet "shot tube" or "single shot"

The shot tube, in various forms, also forms the basic component of multishot "cakes" but increasingly single-shot devices are used alone especially when fired from structures. Significant development has been made to minimise the debris produced from such devices so that they also may be used indoors or in close proximity to audience or performers, in restricted areas or where damage to the structure could result from the normal debris produced.

#### "Cakes"

**Cake** – An assembly including several elements either containing the same type or several types in which the initial fuse transmits fire from one tube to the next to fire the devices sequentially or in some other pattern. This article differs from a general battery or combination by the fact it is fully integrated in a unique pre – programmed product, at the manufacturing level, then cannot be dissociated.

**Synonyms** – Multishot battery



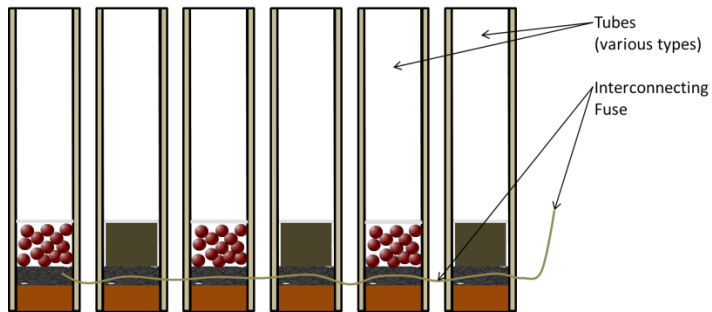


Figure 68- - Schematic cross section of a typical "cake"

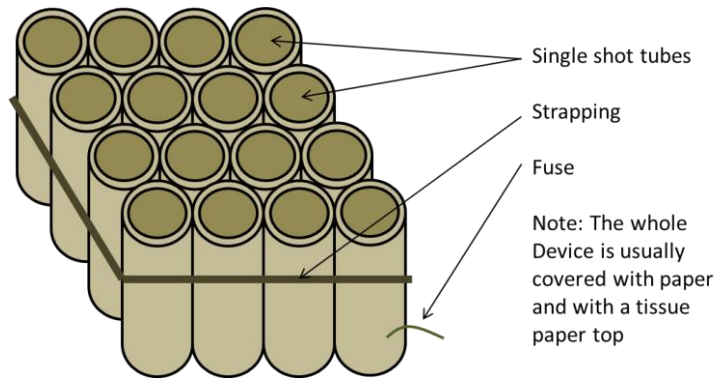
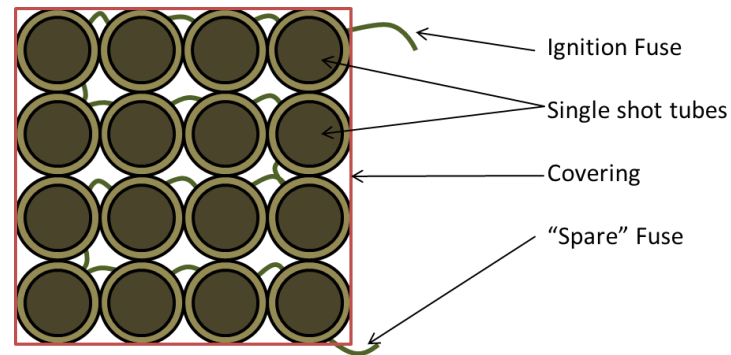


Figure 69- Schematic of 4 x 4 16 – shot "cake"



*Figure 70- Schematic of 4 x 4 16 – shot "cake" showing internal fusing*

The term “cake” originates from early examples of this type of firework which were produced in China which resemble a typical cylindrical form of the eponymous confectionary! Modern “cakes” are considerably more complex and varied in construction. In recent years a variety of complex cakes producing “chase” type effects have been developed and are variously described as, for instance, “Z” cakes (where the chase is from one side to the other, back again and repeated). However this pattern is sometimes not obvious from the external appearance of the device and care should be taken to ensure that such a device is not used inappropriately.

Given the differing orientations, different timings and different effects available within each tube, there is almost an infinite variety of cake types available and often the name given by manufacturers does not adequately describe the actual effect observed.

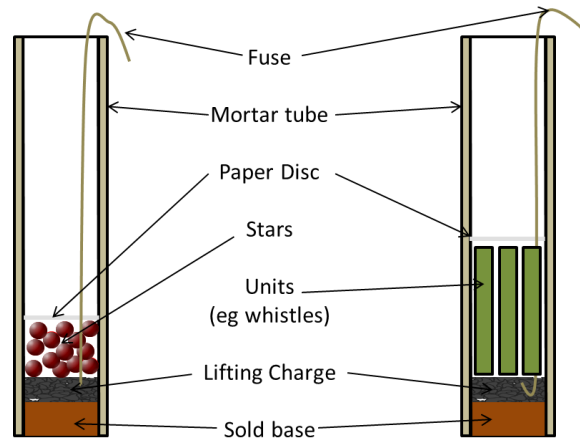
It is essential that cakes are adequately supported in their firing. Cakes, even those which are heavy and with a large base and hence a low centre of gravity, rock during firing. Accidental tipping, or disruption of the cake during firing, leads to the possibility of firing in unintended and undesirable directions.

The two main safety issues with cakes are

- That the device fails part way through due to poor construction or because of dampness. Often cakes are fitted with an auxiliary fuse to allow the finale shots to be fired independently of the main fuse. If a failure does occur then dealing with the partially fired item and disposal of it is a serious problem.
- Sometimes the cake may continue to smoulder after firing is complete, or indeed fire may spread to the box used to transport the device (which is usually not removed completely before firing).

## Mines

**Mine** - An article which may include integral mortar, containing propellant charge and more than one pyrotechnic unit, having as main effect the discharge of all the pyrotechnic units in a single ejection. The pyrotechnic units can be stars, bangers, butterflies, crackers, hummers, spinners/tourbillions, whistles, etc. The principal effect is ejection of all the pyrotechnic units in a single burst producing a widely dispersed visual and/or aural effect in the air.



*Figure 71- Two types of mine in mortar*

Subtypes of mines include –

**Bag mine, mortar mine** – A container with propellant charge and pyrotechnic units, designed to be placed in a mortar and to function as a mine. Container is typically a cloth or paper or plastic bag or cloth or paper cylinder.

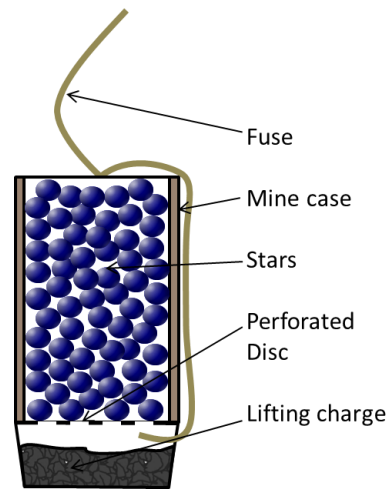


Figure 72- Bag or "mortar mine"

## Whistle

**Whistle** – A tube containing pressed, whistling pyrotechnic composition, with or without sparks, with or without report-producing pyrotechnic composition.

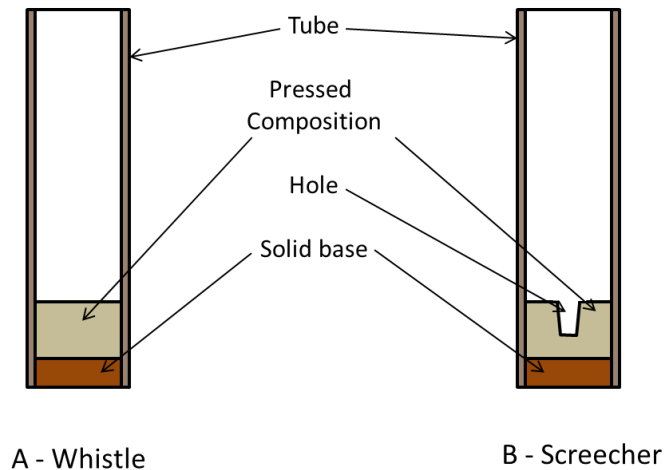


Figure 73- Cross section of A) whistle and B) screecher units

The mechanism of whistle production has been the subject of much debate but in the simplest terms it can be considered like an organ pipe, where the pressure induced increase in burn rate, and hence gas production at the burning surface reinforces the sound wave in the tube above the burning composition.

A “screecher” is similar in construction to a simple whistle but produces a more complex rasping sound, created by interference patterns arising from sound waves produced from a central hole within the pressed composition.

#### Component parts of pyrotechnic articles

The following are not devices in their own right, but are the functional and effect components of other devices

**Star** – A small element of compacted pyrotechnic composition, intended to burn in the air and give an individual visual effect. Stars may have various shapes: spherical, cylindrical, cubic, rectangular, etc. and be obtained through various industrial processes: pressed, rolled, extruded, etc. Their surface may be partially covered by combustion inhibitors or not. They can include a pyrotechnic charge to break them in fragments during their combustion to improve or modify the visual effect (“fragmentation” stars).

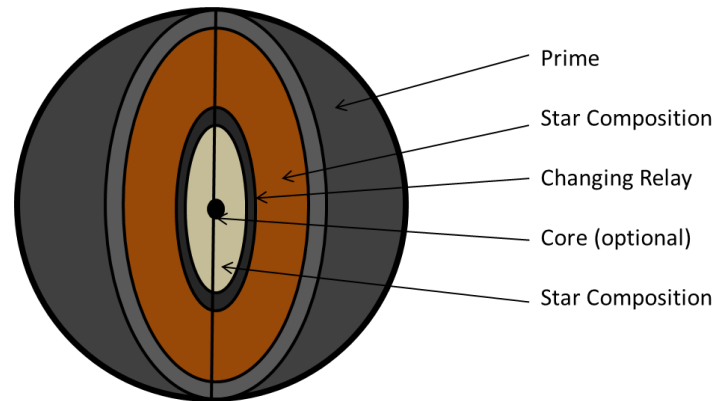


Figure 74- Cross section of colour changing star with "changing relay"

Stars can also be pressed in moulds to form highly consistent, accurate burning cylinders of, usually, blackpowder based compositions.

**Comet** – A pyrotechnic component of a firework (e.g. Roman candle or a shot tube), containing a single solid pyrotechnic composition, which leaves a trace as it ascends up to the apex of its flight.

Comets may form parts of shells (e.g. "spider shells") where a geometric radial burst of a few "thick" stars contrasts with the more usual spherical burst of typical colour shells, and sometimes the two effects maybe combined. Comets are typically made by pressing composition into a mould rather than by building up layers onto a core as in a round star. Such pressed stars can be more consistent in performance than rolled stars as well as being easier to produce in mechanised production lines but are generally restricted to compositions based on blackpowder. We expect the use of pressed stars to increase in the future.

Increasingly comets are used in "single shot" Roman candles, used particularly when fired from structures – see Chapter 11.

**Crossette** – A tailed star which breaks abruptly into burning fragments which exhibit a cross shaped expansion with tail effects.

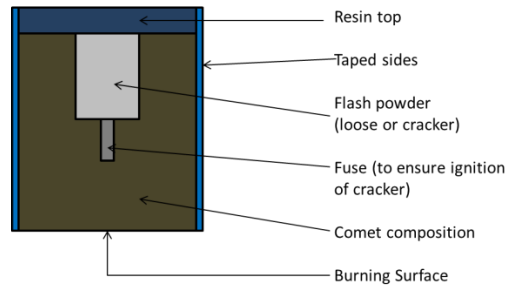


Figure 75- Crossette or "Splitting Comet"

**Butterfly** – A firework component that comprises a tube which is burst spreading stars or shining effects from both ends.

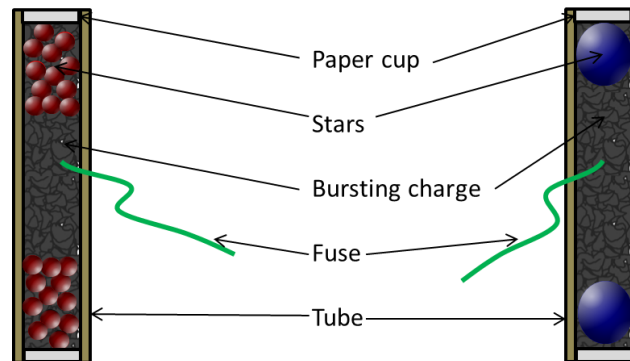


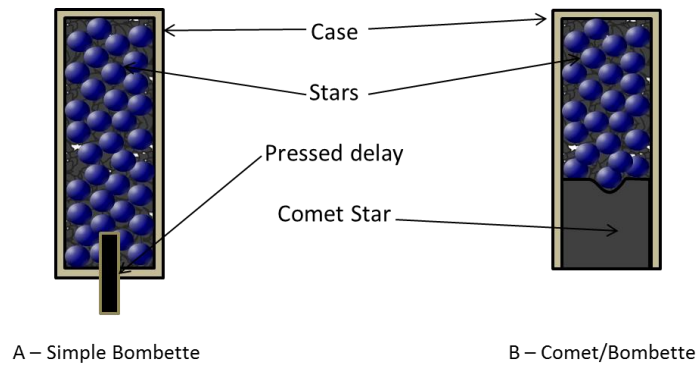
Figure 76- Two types of butterfly effect

**Cracker** – A firework component that burns with a crackling sound and may optionally emit a glittering or sparkling effect.

More generally crackers produce a small “bang” and should, we feel, be distinguished from true crackling stars which produce a column of small bangs as they burn to completion as they travel through the air.

**Bombette** – A pyrotechnic component of a firework (e.g. roman candle or a shot tube), similar to a small shell, which may optionally leave a trace as it ascends, and which bursts at or near the apex of its flight.





*Figure 77- Bombette types*

**Tourbillion** – A tube or tubes containing pyrotechnic composition, which burns in a way that gives a rotary motion to the tube. This article differs from a spinner by its design – a tourbillion has no aerofoils, and functions by the lateral ejection of the combustion products.