British Pyrotechnists Association

Guidance for organisers of professionally fired firework displays

The HSE guide “Working Together on Firework Displays” (HSG 123) was originally written in 1995 to provide guidance to organisations staging firework displays where professional firework operators are responsible for setting up and firing the fireworks.

The British Pyrotechnists Association (BPA) was involved in the production of the original guide, and with its subsequent revisions. However, there have been significant developments in firework displays since the HSE guidance was produced and many of the recommendations in the original guide are no longer appropriate. In particular this guide addresses the following changes:-

- Changes to the types of fireworks used and hence to the means of rigging/firing
- Changes to Risk Assessment methodology
- Changes to display design and hence to means of rigging/firing

The British Pyrotechnists Association (BPA)

The BPA represents the major professional display companies in the UK. Details of current membership, together with more information about the BPA can be found at http://www.pyro.org.uk.

The BPA organises a training and registration scheme for professional firers in the UK. BPA members arrange training for firers from both BPA member companies, and other professional operators culminating in an examination which is set and marked independently. Candidates, who are required to have completed a number of displays prior to sitting the examination and to maintain a log book of displays fired, are examined at 2 levels and successful candidates awarded a certificate and firer’s ID card. A publicly available database of all firers is maintained at the BPA website.

Level 1 firers will usually be assistants at displays and it is intention of the BPA that all professional firers should be aspiring to a Level 1 qualification. The BPA recommends that the senior firer on a display site will be qualified to Level 2.

It is planned in the future to extend the BPA training scheme to display managers within companies, and also to make awareness training available to event organisers and enforcers.

Changes in display design and display sites

There have been significant advances in display design in recent years, primarily through the development of computerised firing systems which allow the display designer to develop a variety of new effects. As a consequence, the means of rigging displays and the types of fireworks used have changed. For instance, there has been developed a range of “single shot” Roman candles and mines which allow “chases” such as those seen on the Sydney harbour bridge and the Eiffel Tower in which a large number of such items are fired in extremely quick succession along the structure.

This in turn has led to the development, in some case, of modular firing systems which can be attached to these structures but which maintain a low level of risk.

Traditional safety distances are not particularly relevant to the firing of such items - in general the fireworks are designed to present the minimum of debris, and the modular firing systems which fix them to the structures adequately contain the fireworks and ensure that they are only able to be rigged and fired in the design direction.

Furthermore, the effects used are relatively low powered devices designed to produce a rhythmic or “wide” effect rather than one in which height (and therefore power) is paramount.

In addition there has been developed a vast range of multishot devices, colloquially known as “cakes” which have become a common feature of many displays. These devices produce a number (typically ranging from 25 to 1000) of “shots” each shot coming from a separate tube. The mass of tubes, usually in a rectangular or round design, is relatively wide compared to its height (cf a traditional Roman candle) and the appearance of which gives it its common name. These fireworks produce a continuous effect, often lasting up to 2 minutes, and are available in a very large variety. They produce relatively low debris, in the same way that the “single shot” devices described above do, however they do require careful handling and setting up by the display operator to prevent misfires.

Changes in rigging techniques

In addition to those changes in rigging techniques outlined above, there have also been changes to the rigging methods of firing more traditional firework types. Two examples illustrate the issues involved:-

Roman candle batteries (particularly where the candles are “fanned”) used to almost exclusively be made by wiring the candle tubes to wooden frames, which were then secured to stakes for firing. The demands of modern display design have meant that today, candles are often rigged by inserting the tubes into holders on frames (often fabricated in metal) which have been designed to fire at exactly the desired angle. Furthermore such frames are often designed to interlink to provide a rigid and stable structure for firing.

Mortar construction, and the construction of mortar crates have also changed. The use of modern materials for mortars (eg HDPE, fibreglass or aluminium) has generally overtaken the use of fibreboard or steel. The advantages of the modern materials are in their durability, their strength/weight ratio, and their means of failure (ie not producing steel fragments if a shell bursts in the tube) but there are potential disadvantages too.

Similarly the use of mortar racks, and the means by which they are erected and positioned on site, should be subject to risk assessment by the company. Mortar racks offer significant advantages over the use of individually mortars for the firing of shells, particularly in reducing risks arising from the reloading of mortars during a display.

The BPA is currently working with HSE and the insurance industry to assess the risks from a number of mortar and crate designs. However it would be inappropriate to change existing designs on the basis of the information currently available - and any such change might actually increase risks to operators and public alike. When the research is completed the BPA will make the information available to all members and non-members alike and will make recommendations if changes, if any, are identified. At present companies should evaluate the use of their mortars and crates as they would any other aspect of their display.

Types of fireworks

As noted above, the variety of types of fireworks available to the professional display operator has extended somewhat in recent years. The table at the end of this document illustrates the most common types of fireworks used currently, together with a brief description of the firework's effect and functioning, and any particular hazards that may be associated with the type. Please note that this list is not exhaustive.

Non-firework elements to displays

Many displays now incorporate other elements in addition to the fireworks themselves. Traditional Guy Fawkes night firework displays, in which a bonfire is also part of the celebrations, now form only a relatively small proportion of all displays fired in the UK. In addition to pyromusical displays (see later) many events now incorporate lasers or other lighting effects. Although such elements rarely increase risks arising from the rigging or firing of fireworks, they may introduce considerable problems when planning how all the various elements of the event may be arranged on the display site whilst maintaining adequate safety distances for each. The desire of clients, organisers and producers to incorporate these additional elements should never mean that safety distances for fireworks are compromised.

Pyromusicals

Pyromusical events, where fireworks are fired accompanied by, or synchronised to music - be it live or recorded - form an extensive and increasing part of the professional display company's repertoire. As above, there is often little impact on the safe rigging or firing of a fireworks display, except where theatrical pyrotechnics are to be used in close proximity to staging, the performers or the audience. In such cases the use of such pyrotechnics should be subject to both recommendations from the suppliers (eg manufacturer's safety distances) and site and product specific risk assessment which takes into account the proximity of any features (such as elements of the set design such as curtains and screens) and their potential flammability. In many cases it will be appropriate to treat such items with a flame retardent to further minimise risks arising from the use of proximate pyrotechnics.

Fallout from fireworks

There are three main types of fallout that must be considered:-

1. Fallout arising from the normal functioning of the fireworks, for instance pieces of display shells that are affected by the wind and travel downwind of the firing point.
2. Fallout arising from the "normal" functioning of fireworks and pyrotechnics but where the item is firing in an unintentional and undesirable direction (eg when a device has fallen over)
3. Fallout arising where, for instance, a display shell is fired normally, but the internal delay fuse fails to burst the shell at its design height and where the shell falls to the ground unfired, or bursts at a very low height.

Fallout from fireworks must always be considered in any display, and the display design or any late modifications (to reflect weather on the display date for instance) should reflect the distances available where any potential fallout from the fireworks will land.

Where a display site is restricted, or where an adverse wind may mean that debris could potentially fall on the audience on in an uncontrolled area, the display company may be

forced to chose the types of fireworks very conservatively - allowing for such a “worst case” scenario. In contrast, where the display site in unrestricted and the available fallout distances extensive irrespective of weather conditions - then the display designer may be able to use a wider range of fireworks.

However, it is important to understand that all displays present a potential risk from any fallout, and that, given the nature of fireworks themselves, that a risk free (or totally safe) display does not exist! The following section on risk assessments will consider this in more detail.

There are no set “safety” distances for the use of professional fireworks in the UK, and the BPA would argue strongly against their introduction. In some case the demands of a particular site or a particular display design may mean that such distances do not provide an adequately low level of risk, and conversely, there are many occasions where by careful choice of fireworks and specialist rigging techniques extremely short distances may be appropriate. For example when firing off structures the distance to the structure itself is effectively zero!

Hence, the distances given in HSE’s guidance should be considered as indicative only. Professional operators, and all BPA members, may deviate from these distances, either upwards or downwards, dependent on their own site and product specific risk assessments for the event. The changes noted above to the types of fireworks available, and to modern rigging and firing techniques mean that the HSE’s guidelines are no longer relevant.

Other countries, notably the USA, have adopted a complex system of “safety” distances for each firework type and calibre, and the means of rigging and firing. The major problem with these tables is that they are not “safe” distances at all - in fact they are distances based on reduction of risks to a low (but not zero) level. They may provide useful baseline information but they are not “safe”. The BPA prefers to assess risks on a case by case basis taking into consideration:-

- The nature of the site
- Particularly adverse features, such as the possibility of an adverse wind blowing debris towards a road or the audience.
- The fireworks chosen for the particular event and site (considering that some items may need to be removed or modified if conditions dictate)
- The rigging and firing methods used.

This is in contrast to displays fired by amateurs using British Standard compliant fireworks. In such cases the firer is not a professional and does not have, and should not have, access to product specific performance criteria nor to deviate from the rigging and firing instructions presented on the firework itself.

Risk assessments

Risk assessments are used to assess the RISKS arising from any operation, in this case the risks from firing particular fireworks, rigged in a particular manner, at a particular site. Risk assessment initially considers two factors

- The hazard of an occurrence (ie the intrinsic hazard - what is the consequence of a particular sequence of events, to whom and of what severity)
- The frequency of such an occurrence.

The BPA has promoted a semi-quantified approach to risk assessments, in order to be able to adequately assess which risks need particular attention and mitigation, and to develop

displays which present a very low overall risk to operators, other performers, vulnerable structures and the audience alike. It is important to note that such an approach:-

- Does not mean that there is NO risk from the use of fireworks - as noted above this is an impossibility
- Attempts to identify situations where the reduction in risk to one particular sector does not inadvertently lead to an unacceptable increase in risk to another sector, or identifies means by which such an additional risk may be adequately controlled.
- Allows displays to be selectively modified according to the conditions prevailing when the display is fired.

HSE's guidance on risk assessments considers two particular types of risk.

- Individual risk - the risk to a specified individual (for instance a display firer, or a member of the audience in a particular spot)
- Societal risk - the risk to society as a whole.

In general it is much easier to quantify the former, and HSE's guidelines suggest that an individual risk of fatality of about 1×10^{-6} (ie one in a million) is considered "broadly acceptable". Levels of risk above this (1×10^{-5} to 1×10^{-4}) are in the so called "ALARP" region - As Low As Reasonably Practical - and may still be considered acceptable provided that they have been properly assessed, and that additional control measures are cost effective.

Societal risk is more difficult to quantify - for firework displays the societal risk should consider the risk to all people involved in or watching displays throughout the UK in any particular year. Fortunately, for firework displays, individual risk is an adequate measure of overall risk because the total aggregate amount of time that displays are fired and the number of people who are at potential risk is very small.

Rating both hazards and frequency, and applying the simple formula

RISK = HAZARD x FREQUENCY

allows risks to be ranked for further consideration (see below) or determined as being "broadly acceptable. It does not matter particularly what system is used, and whether it is qualitative (eg High, Low, Medium), semi-quantitative (using simple numbers to represent frequencies of levels of hazard) or fully quantitative (which produce risk levels relating, say, to the risk to an individual in terms on probabilities), the important thing is to be able to

1. Determine if risks are "broadly acceptable", unacceptable, or whether they are in the "ALARP" region where additional control measures may reduce them to an acceptable level
2. Rank the risks to be able to address the highest risks first
3. Measure whether risk control measures actually reduce the risk to all those who may be affected
4. To form a basis for consideration whether control measures are cost effective (by cost/benefit analysis)
5. To provide a basic operating procedure - ie those things as identified as reducing the risk
6. To monitor whether changes in rigging or firing techniques, or changes in the types of fireworks used, have adverse consequences for risk control

The BPA favours a semi-quantified risk assessment methodology where hazards are rated according to severity from 0 - 10, and frequencies similarly rated from impossible to absolute again on a range from 0 - 10.

Thus, risks can be rated from 0 - 100, and high risk operations could arise from either low frequency/high hazard events, or high frequency/low hazard events

Two particular types of risks are common at firework displays, and which dictate whether the display on a particular site, using particular fireworks and rigged and fired in a particular manner is as low as possible.

- High frequency/low hazard operations - for instance fallout from shells. All shells produce fallout, and that fallout will travel downwind from the firing site and land on the ground. If the debris falls on the audience it could cause minor eye injuries, or minor burns to people or property. Reduction of this risk may be achieved by maintenance of adequate fallout distances downwind of the firing site. If the display has been planned only considering the prevailing wind, and the wind at display time is from another direction or is particularly strong - then the display may have to be curtailed or abandoned.
- Low frequency/high hazard operations - for instance where a shell fails to burst and lands in the audience and subsequently explodes. In such cases there could potentially be several fatalities, but the risk can be reduced to acceptable levels by, for instance, angling mortars away from the audience (so that if a shell fails in this manner it does not fall towards the crowd), or in certain cases, by providing a barrier between the firing site and the audience to "catch" low trajectory shells.

It is important to realise that any particular risk reduction method will affect EITHER the frequency of the event OR the hazard of the event. It is rare to have risk reduction methods that affect both. In general it will be the frequency which is easier to address.

In the first case above it is not possible to reduce the frequency of debris being produced and falling to the ground - "what goes up must come down", but it may be possible to reduce the frequency of debris falling on the audience by ensuring that the audience are further away. Similarly if lit debris DOES fall on a member of the audience it is not possible to reduce the hazard to them.

In the second case, again, it is only possible to reduce the frequency of the event (the probability) of a shell falling unfired into the audience. In addition to the methods outlined above, it would be possible to reduce the frequency of a shell failing to burst by fitting, for example, two independent internal delay fuses. However - fitting two internal delay fuses increases the risk (by increasing the frequency) of a shell bursting in the mortar because of a failure of the delay fuse in which it fires instantaneously once the lifting charge of a shell is ignited.

All these factors (and many others) have to be taken into account in determining the suitability of a site itself and the suitability of certain fireworks to be fired from that site under a variety of conditions. The risks from a professional firework display are generally very low when adequate assessment and precautions have been taken - but they are never zero!

Environmental effects of fireworks

Environmental concerns over the use of fireworks have increased in recent years. Basically the concerns are in four main areas

1. The environmental impact of noise from the display. The Fireworks Act and subsequent regulations has limited the hours in which fireworks may be fired, however, unless the design requirements for the display, or particular local features dictate, noise is an important feature of any firework display, and is an inevitable consequence of fireworks

functioning. For instance the bursting of a display shell must produce some noise - reducing the burst charge could actually increase the risks from the use of such devices. Deliberately noisy displays may be inappropriate in certain circumstances - but this is a matter for the early planning stages of an event where such things may be considered.

2. Physical debris from displays. Over recent years the design of fireworks and the types available has changed and most fireworks now do not include plastic and metal components where it is possible to replace them with biodegradable alternatives such as card or compressed paper. However, there are components which cannot, at present, be replaced in this manner and will continue to be present as fallout. Display companies are mindful of these concerns and can adapt displays to minimise the use of such materials - but this may also restrict severely the types of fireworks available to them.
3. Chemical debris from the display. The functioning of fireworks inevitably produces some smoke - and this smoke contains the combustion products from the burning of the firework compositions. The combustion products include the gasses nitrogen oxides, carbon dioxide and sulphur dioxide, as well as solid combustion products dependent on the particular effect. Research by the Disney corporation has shown that the effects of such combustion products on the environment and on structures is very limited. Disney investigated the effects of firing over 2000 displays over a body of water on the same site (a rate much higher than any UK display site) and concluded that although the deposition of metal salts in the lake was considerable, the majority of the deposition was found in the mud in the bottom of the lake rather than in the water mass above it, and that there were no measurable biological effects on the flora or fauna of the lake. A recent study in London has shown that the levels of atmospheric pollution are also very low - for instance for the New Year's Eve celebrations the amount of the atmospheric pollutants Nitrogen Dioxide and Sulphur Dioxide were approximately one 300th of the amount of the same gasses arising as a consequence of people travelling by car, bus and train to watch the display.
4. Use of perchlorates in fireworks. Potassium perchlorate is an important constituent chemical of many fireworks, but the levels of this particular chemical released to the environment after the functioning of a firework are extremely low (it is usually consumed completely during the functioning of the firework). American studies have shown enhanced levels of perchlorate in ground water and soil samples around sites where a large number of displays have been fired over an extended period. However the increases in levels is extremely low and does not pose an environmental or human health concern.

Responsibilities at displays

Increasingly events involving fireworks are organised by local committees, with the professional display company providing a display as part of a larger overall event. It is important for the event organiser, the venue and the display company to agree at an early stage where their respective responsibilities in staging the event lie, and to have a clear communication path for decisions prior to and during the event itself. For instance

- Who is responsible for ensuring the display area and fallout area are clear (usually the event organisers - the firework company will be firing the display)
- How can the public be informed if the display is curtailed or cancelled - and what means are in place to ensure safe egress from the display site in these circumstances.

Cleanup and disposal

The cleanup of display sites, and disposal of any waste materials, is a concern to event organisers and display companies alike. However, it is difficult if not impossible for a display company to completely clean a site in the dark after a display. Proper co-operation between

the event organiser, the venue and the display company and clear demarcation of responsibilities at an early stage in the planning of an event can avoid any misunderstandings later!

If an unfired firework component is found subsequent to the display the display company should be informed and appropriate agreed action taken.

Further information

The BPA website has recently been redeveloped and provides not only up-to-date information about topics above (as well as an up-to-date copy of this document) but further information on

- Selecting a display company
- Types of fireworks and their effects
- The BPA firework firers scheme and database of accredited firers

Please see

http://www.pyro.org.uk

Or contact the BPA at

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Firework Types and effects

Type	Function	Effect	Potential Hazards
Shells	Fired from mortars by a "lifting charge". After a delay the shell bursts to produce stars or effects high in the sky.	Varied - shells may contain stars, noise or other effects, parachutes or daylight smokes	Fallout from debris Projectile effect Unfired shells falling to ground (very infrequent)
Rockets	Usually fitted with a stick, the rocket motor propels the firework into the air with a distinct "tail" At the apex of its flight the rocket performs in a similar manner to a shell	Varied as above	Fallout from debris or from the stick falling to earth Projectile effect if launched at low angle
Mines	Fired from integral or separate mortars, mines produce a column of stars or effects	Varied - may contain stars, effects (eg noise units) or bombettes	Relatively low debris Projectile effect if launched at low angle
Roman Candles	Typically a long tube containing several "shots" which are fired sequentially	Varied - may contain stars (comets), mini-mines, effects (eg noise units) or bombettes	Internal components as debris Projectile effect if launched at low angle
Single shot devices	These can be considered as single shot Roman candles or mines	Varied - see above	Generally designed to produce very low debris.
Multishot batteries ("cakes")	A collection of single shot devices fired sequentially	Varied - see above	Debris Projectile effect if item is tipped over or launched at low angle Projectile effect if cake disrupted due to one malfunctioning item affecting integrity of the remaining tubes
Fountains and gerbs	Shower of sparks from single tube - often used on wheels as well as formal designs (Set Pieces)	Metallic or other sparks projected in the direction of firing	Local effect from sparks
Waterfalls	Usually a vertical curtain of sparks fired from many tubes fired simultaneously	Metallic sparks (usually bright silver) falling vertically downwards from tubes fired horizontally or vertically	Local effects below the waterfall from sparks which usually are designed to reach the ground
Lancework devices	Sculptures depicting messages, logos or animated scenes (eg battles or novelty effects) comprised from many small fountain like tubes arranged on a frame	May comprise many colours, and may incorporate other effects	Very low hazard from lancework itself