

Firework Displays: Explosive Entertainment

**A guide to getting the most from your firework
display for designers, firers and event organisers**

Dr Tom Smith

Davas Ltd

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LOW RESOLUTION IMAGES-
ORIGINAL DOCUMENT WILL CONTAIN
HI-RESOLUTION IMAGES AND TEXT

Fireworks Displays: Explosive Entertainment
A guide to getting the most from your firework
display for designers, firers and event organisers

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ISBN: 978-0-8206-0064-2 (B&W Hardcover)

ISBN: 978-0-8206-0090-1 (Color Hardcover)

ISBN: 978-0-8206-0091-8 (eBook)

Chemical Publishing Company:

www.chemical-publishing.com

Printed in the United States of America

Preface

This book is designed for amateur and professional firers, designers and event organisers of display fireworks to enable them to get the most from the fireworks they use and to learn about planning events for the future. It will also be useful, we hope, to designers and event producers — if only to assist them in taking a common language to the firers!

The text has been prepared by a number of authors and the inclusion of a particular approach, technique or method by one should not be taken as endorsement by all! If you put 20 fireworkers in a room and ask them how to rig a particular item, you are apt to get 20 different, but valid, solutions!

Dedication

This book is dedicated to the memory of Mark Blanch, my cousin, who was the last of the Blanches directly involved in Brockham Bonfire, and who sadly succumbed to pancreatic cancer during the preparation of this book; and to the memory of Dr Takeo Shimizu, who taught so many people so much about the art and science of fireworks and who died at the age of 98, just before this book was completed.

Foreword

Tom Smith is to be congratulated on putting together this delightful book on the theme of firework displays. Aimed at display firers, both amateur and professional, this book covers an impressive range of theoretical and practical topics, making it unique in the fireworks literature.

Tom brings enormous experience in the fireworks industry, including a period as display manager of Kimbolton Fireworks, during which time Kimbolton won several firework competitions. More recently he has acted as a consultant for the London Millennium celebrations, the Athens Olympic Games, and the Melbourne Commonwealth Games. Together with his co-authors, Tom has assembled a truly comprehensive treatise, covering almost every aspect of firework displays, from a taxonomy of fireworks to display design, and from firework competitions to environmental impact. The chapter on risk assessment is particularly valuable, and emphasises the crucial distinction between risk and hazard, as well as adopting a very practical approach to the overall evaluation of risk.

For amateur firers the book will prove to be especially valuable. Amateurs often lack the support network, as well as the formal and informal apprenticeship opportunities, afforded to the professional. Access to the wealth of experience and information captured in this book can only lead to improved safety levels and to enhanced artistic content in amateur displays.

Beautifully illustrated, the book is also well written and a pleasure to read. Even the topic of legal issues, a subject with plenty of soporific potential, is leavened with ample personal interpretation and perspective. As a relative newcomer to the world of firework displays, I found the book to be hugely informative. This superb and comprehensive text undoubtedly has a place on the bookshelf of anyone interested in fireworks and firework displays.

Professor Chris Bishop

Vice President, The Royal Institution
Distinguished Scientist, Microsoft Research
March 2011

Acknowledgements

Firstly I would like to thank my co-authors for all the hard work and patience they have shown. Thanks are also due to Jacob, my son, for assistance in preparing the diagrams of firework types, to Ron Lancaster — for whom I worked for some 20 years as a part-time firer and then as Display Manager of Kimbolton Fireworks and who suggested the production of this book. Also to Dr Elizabeth Gilmour for her advice on medical matters and to Ben Carr and his colleagues at Chemical Publishing, my ever-patient publisher, and to David Cottingham for some inspired copyediting and corrections — any mistakes remaining are all down to me.

Finally, thanks are due to Helen my wife, Charis my daughter and Avril my secretary for their encouragement, proofreading and other helpful suggestions.

Photographs and images

Except where shown, photographs have been taken by the authors or are no longer attributable. If any reader can prove ownership of unattributed images we apologise and will be pleased to acknowledge them in subsequent editions.

Terminology

The following terms are used generally within this book without further definition.

Firing area	The area, or areas, in which the fireworks are set up
Display	The moment from the firing of the first firework to the extinguishing of the last
Fallout area	The area in which debris from the fireworks performing normally falls
“Safety” distance	The distance at which the risk to the audience or other features is reduced to an acceptable level — it is not a “safe” distance
Operator	The person or people who actually fire the firework display — whether that be in close proximity (by manual firing) or remotely (normally by electrical firing)
Audience	The people who watch a firework display — wherever they may be situated

Author notes

Tom Smith — Dr Tom Smith was introduced to fireworks by his grandfather, Jack Blanch, who was at school with and subsequently worked with members of the Brock family in the early 1900s.

Following his doctorate in chemistry from the University of Oxford, and a spell as research chemist and computer lecturer, Tom took up a full-time post as display manager with Kimbolton Fireworks in the UK, during which time the company won several firework competitions and staged some of the largest displays seen in the UK to date. In 1998 Tom left to establish an independent explosives consultancy, Davas Ltd, working worldwide on events such as the London Millennium celebrations, the Athens Olympic Games and the Melbourne Commonwealth Games as well as acting as advisor to major firework displays and explosives companies around the world. Recent firework display projects include acting as consultant to the London and Hong Kong New Year's Eve celebrations.

In addition, Tom represents the UK on a number of International Working Groups, including the development of European Standards for “professional” fireworks.

Davas Ltd now publishes the internationally recognised *Journal of Pyrotechnics* and delivers courses in Pyrotechnic Chemistry around the world.

Chris Pearce — Obtained his MSc at the University of Birmingham and, following an early career in teaching, entered the firework industry full-time in 1997. Chris is now Managing Director of Jubilee Fireworks Ltd — one of the UK's leading display companies. He was Chairman of the British Pyrotechnists Association for a five-year period and Deputy Chair of TESA (The Event Services Association). Chris contributes regularly to various academic and popular journals and oversees the BPA's Training and Examination scheme. He has been adjudicator and technical consultant for the British Musical Fireworks Championships since 2004.

Andrew Wiggins — Andy is Display Manager with Jubilee Fireworks Ltd and has been involved in the fireworks industry on a full-time basis for 18 years. Andrew is responsible for the design of all Jubilee's major shows and his credits include the “Champion of Champions” winning displays at both Plymouth (non-musical) and Southport (musical) competitions. International displays include prize-winning performances in Monaco and the Philippines, along with major shows in Malta, Spain (San Sebastian), Italy, Portugal, Macau and the prestigious Alton Towers displays in the UK.

Rodney Clarke — Rodney’s pyrotechnic interests developed alongside a career in the IT industry. He was responsible for the development of firing-systems technology for Jubilee Fireworks Ltd and is now European representative for PMI (Pyrotechnics Management Inc) — manufacturers of the renowned FireOne digital firing system. Rodney’s role with PMI and as an independent consultant have led to significant involvement in some of the largest firework display projects in the world, including the monumental Palm Jumeirah show in Dubai and numerous high-profile competitions and displays in Spain, Italy, France, Monaco, Portugal, Malta, Montreal and Germany (Berlin — Pyromusikale).

Andrew Walsh — Andrew Walsh AM is one of the most experienced and respected performing arts professionals in the world. With great theatrical sense, he has extensive experience creating, directing and managing large-scale events in Australia and throughout Asia, North America and Europe. In an extensive career that commenced in Melbourne in the late 1970s, Andrew has been continuously employed in the arts. He has worked for major performing arts companies, toured with international stars and directed hundreds of productions and events. He was theatrical director for Australia Pavilions at three World Expos and has directed Sydney’s Australia Day spectacular for 14 years. He directed the London Millennium celebrations and in 2001 was the creative director for the widely acclaimed Centennial ceremony for Australia’s Centenary of Federation.

In 2003 Andrew was Director of Ceremonies for Rugby World Cup and conceived and directed the Opening and Closing Ceremonies and pre-match segments. He was Executive Producer of the Opening and Closing Ceremonies of the 2004 Athens Olympic Games and most recently the Executive Producer and Creative Director of the 2006 Melbourne Commonwealth Games and the 2011 Athens Special Olympics.

Andrew is an associate of the Graduate School of Management at the University of Technology, Sydney and a fellow of the Australian Centre for Event Management. He was awarded the Centenary Medal for contribution to Australian Society and was appointed a Member of the Order of Australia in the 2006 Queen’s birthday honours.

Darryl Fleming — Darryl has been associated with Kimbolton Fireworks for nearly 25 years and is currently the display director responsible for the creative design, choreography, delivery and production of all firework display for the company. Most notable achievements include Trafalgar 200, Dublin St Patrick’s Day Skyfest, Legoland, Cowes Regatta,

Edinburgh's Hogmanay and most recently the Mayor of London's New Year's Eve celebrations on the Thames and focused on the London Eye.

Kimbolton Fireworks have had unrivalled success at many of the large International Fireworks Competitions, including Montreal, Cannes, Madeira, Barcelona, Bilbao, Croatia, Knokke and Hannover. Darryl Fleming now has a reputation as consultant for other International companies at Cannes, Montreal and Dubai.

James Donald — Jim joined Jack Morton Worldwide in 1995 and has worked his way through the organisation and is currently one of the company's leading Executive Producers. The range of event and experiential communication projects with which he has been involved has given him insights into the demands of events on all scales and for clients in all industries. These have included delivering the Mayor of London's New Year's Eve "Marking of Midnight", from 2005 through to 2011, an ambitious, high-profile, iconic event for 250,000 Londoners live and millions around the world on TV; the 2008 Olympic & Paralympics home-coming parade through London culminating in Trafalgar Square; as well as key roles within the production team for the Manchester 2002 Commonwealth Games Ceremonies and the Hong Kong Handover in 1997.

In addition to these public events, Jim has led many global experiential campaigns for corporate markets that have included Thomson Reuters, Toyota Europe, Samsung Mobile and many more. Jim's experience has given him the ability to lead complex multi-region and multi-faceted projects.

Martin Smith — Martin is a director of Brockham Bonfire Limited and is responsible for the firework display. His grandfather helped re-start Bonfire in the 1930s and the family have been involved with the firework display ever since — Martin is the younger brother of the main author, Tom Smith. The Brockham Bonfire firework team have close links with Kimbolton Fireworks and regularly help with their displays both in the UK and overseas.

Murray Torrible — Murray has operated a specialist insurance facility for the Firework, Pyrotechnic and Special Effects industry since 1997. Following a hardening of the insurance market in 1996 Murray undertook 12 months of research into the operations and practices within the sector. Utilising this research, Murray identified an insurer that was willing to underwrite the risk at competitive premiums. Within two years of introducing the facility Murray was arranging the insurances for a

majority of the industry sector. Murray continued to innovate and react to developments within the insurance market, developing a Captive Insurance Vehicle in 2004 to stabilise premiums for the firework sector following the increases in premiums experienced in 2002 and 2003.

Murray set up Precision Broking Ltd in 2010, a specialist industry brokerage for the Firework Pyrotechnic and Production Services Sector. The new insurance facility offers liability and property with the same insurer and a broader range of covers and limits than were previously available. Since its introduction in 2010 Precision Broking has been appointed by most of the major display operators, importers and manufacturers in the UK and is now extending its operations into Europe and the Middle East.

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Chapter 1 – Introduction

Tom Smith – Davas Ltd

The use of outdoor fireworks for celebration has a long-established history, although custom and practice throughout the world vary widely.

This book is intended for that wide variety of people who use fireworks in more than just a domestic way. This covers the enthusiastic amateur firer who wants to get the most from the fireworks they are legally able to purchase all the way up to the seasoned professional, although they have established techniques, favourite fireworks and favourite ways of firing, who nonetheless would like to have more information about the ways other people use fireworks to the greatest effect. This book is not intended, however, for users of pyrotechnic articles indoors, although many of the same principles apply.



**Figure 1.1 – Comets fired from the London Eye and barges.
Photo: Jack Morton Worldwide**

As far as possible we have tried to be country-neutral in our approach, although necessarily there will be aspects that reflect the authors' experiences. The range of fireworks available to different categories of people and the specific laws applicable in each continent and country can vary widely. Furthermore, these restrictions and practices are not time-independent and we foresee great changes in the types of fireworks

available in the next years for a variety of reasons, including attempts to produce worldwide harmonised standards, the possibility of existing supply routes being restricted (as well as new ones opening up) and general safety and environmental concerns over the use of fireworks at all.

This is not a reason to be unduly pessimistic, however: at every stage of the author's career there have been several instances of "the worst threat ever" to the industry and its practitioners, and we have managed to adapt and survive to date! Nevertheless, the anti-firework lobby remains strong, and their novel but often misguided attempts to ban ALL use of fireworks continues.

Hopefully this book will, in some small way, help address the concerns of this lobby, and encourage users to plan and execute displays that produce the greatest possible spectacle within budget in a way that presents the lowest risk (note, please, not "safe" — see Chapter 5) to operators, the audience, bystanders, the environment and structures.

One thing is certain — there is no absolute right way to fire a firework display. In the ten years in which the author has been the "adjudicator" of the UK's largest firework competition in Plymouth (for more information see Chapter 15) there have been some 50 companies involved and nearly 50 ways or rigging and firing the displays. Only in one case was intervention necessary to ensure the fireworks were rigged to the adjudicator's satisfaction. As each year progressed, and especially because the firing site was open to members of the industry to visit, we have noted that the quality of preparation, rigging and firing techniques and the displays themselves have improved markedly.

The common approach seems to be that people look at the display site and the display, and decide there are several things they could do better, but almost inevitably also see one or two things they recognise as being better, safer, more artistic or more novel than the way they work themselves and thus incorporate these things into their next show. In this way, over time, the whole standard is improved.

Plymouth provides this opportunity quite deliberately — it is an ideal site, beautifully positioned and secure. Sadly, because of the seasonal nature of the business (in whatever country) this sort of opportunity arises rather infrequently, mostly because of the practicalities of going to see another show when you are firing one yourself, but also because there is a degree of complacency across all sectors of the industry. "I've always done it like that" is as dangerous as it is artistically stifling — and hopefully this book will encourage users to be more creative as well as improving the safety of displays.

Chapter 2 – History of firework displays

Chris Pearce – Jubilee Fireworks

Introduction

Fireworks, in various forms, have been around for at least a thousand years. Early records indicate that fireworks and pyrotechnic devices had been developed in China by around 1000 CE. Regrettably, human nature being what it is, such devices were often used in warfare and we had to wait for another 500 years or so before firework *displays* began to appear on the scene as serious forms of public and private entertainment.

A modern firework display includes a variety of devices (shells, roman candles, rockets etc.) to produce various visual and audible effects at different heights. In a sense, it is a work of art — but the main object of any display is to *entertain* — and to that end a good display designer will make best use of the range of effects available, taking into account the natural surroundings. This has always been the case, and early displays often compensated for a limited palette of colours by using elaborate structures to enhance the firework effects.

The Italians were pre-eminent in the development of firework displays. Around 1500, fireworks were in common use for religious and cultural festivals — indeed there has always been a very strong link between religion and pyrotechnics, and this continues today (particularly in countries such as Malta). Primitive firework effects were first used in theatrical productions, essentially as scenic decorations, but gradually the fireworks themselves became a more significant feature. However, these early displays were very different from the modern aerial show, with limited effects and heavy reliance on structures to enhance the presentation.

The earliest record of a formal display in England was a substantial show staged at Warwick Castle in 1572, to celebrate the visit of Queen Elizabeth I. Her Majesty was clearly delighted by the spectacle, and other displays followed as a result — although the firework presentations would have been very different from the modern-day experience. The Warwick Castle display was perhaps the forerunner of the modern “theme show” (or the “grand theatrical displays” of the 1920s and 30s); it featured two canvas forts and two hundred performers, primitive aquatic firework effects on the river Avon, accompanied by “flaming darts”, a variety of fountain effects and accompanying ordnance. The display would

have been noisy and visually impressive — but with predominantly gold and silver effects; in no sense would there have been the elements of pyrotechnic design, spatial structure or colour variation that we see in contemporary fireworks shows.

Interestingly, there was a serious incident at the Warwick display of 1572, resulting in the deaths of two members of the public (Mr and Mrs Henry Cooper). A “fiery projection” landed on the unfortunate couple’s house while they were asleep and they perished as a result. Of course, in those days there were no risk assessments, an almost complete disregard of safety with respect to the public and certainly no equivalent of the “Health and Safety Executive” to carry out an investigation.

Displays in the 17th and 18th centuries

Significant advances in the art and science of pyrotechnics took place in the 17th century, particularly in Europe. Italy emerged as an early forerunner, with distinctive styles being developed in the north and south of the country. One name, that of *Ruggieri*, still survives today — now associated with the French concern *Lacroix-Ruggieri* — a company of considerable reputation. The Italian tradition was developed from religious associations, particularly the celebration of Saints’ Days and adherence to the Roman Catholic faith, although the great division caused by the Reformation also manifested itself in a divergence of pyrotechnic styles! The use of manufactured structures as essential components of displays was important during this period. Known as “machines” or “temples”, some of these structures were very elaborate indeed and often of great architectural merit in their own right. The “machine” would form the focal point for the display in the same sense that an elaborate vase enhances a floral presentation. Many engravings survive, illustrating in great detail how the firework effects were integrated with the machine.

In England, the leading light in pyrotechnics during the mid to latter part of the 17th century was a Swede by the name of Martin Beckman. He was responsible for the coronation displays of both James II and Charles II, several shows on the river Thames, and a number of international projects — usually associated with royal events. In common with many pyrotechnicians of his day, Beckman had a military background.

The 18th century provided the opportunity for some grand displays in Europe. Royal events in France were invariably occasions for elaborate

shows, and Versailles became a prominent venue for such events. The Ruggieri family were often “imported” to design and fire these magnificent displays and, as a result, eventually took residence in France.

The Treaty of Aix-la-Chapelle, signed in 1748, resulted in widespread pyrotechnic celebrations throughout Europe. It was of great significance as it marked the end of numerous small wars and conflicts. In Paris, a planned grand display was marred as a result of quarrelling between French and Italian technicians regarding who should take precedence in firing the show. The result was a disaster, with chaotic discharging of fireworks and a “mass explosion” that led to the deaths of 40 people and over 300 injuries. Again we note the almost non-existent attention to public safety.

London had planned a show of unparalleled magnificence to celebrate the Treaty. A site was selected in Green Park and a huge “machine” was erected — 114 feet high and 410 feet long — a gigantic wooden structure, giving the appearance of a palatial façade, and constructed from timber covered with canvas. It took five months to build and was adorned with flowers, statues, classical designs and a host of elaborate features. Ruggieri, along with other Italian pyrotechnicians, was brought in to design what was envisaged to be a display of unprecedented scale. Over 10,000 individual firework effects were incorporated into the show. In addition, 100 cannon were to be fired.

The composer George Frederick Handel wrote a specially commissioned overture for the event; appropriately called *Music for the Royal Fireworks*, it was to be performed in the presence of King George II and a large royal party. In no sense was the show intended to be a “pyromusical” display in the way we understand this term today, but the event began a tradition of association between music and fireworks. The development of electrical (and particularly digital) firing in the late 20th century has bonded the two disciplines into a spectacular art-form.

Sadly, the Green Park display did not live up to expectations. A dispute arose between the English and Italian pyrotechnicians regarding the relative merits of “blackmatch”, as opposed to gunpowder trains, to transfer fire between the various devices. In later chapters, we will consider the various options available to the modern display firer; in 1749 the choices were limited and an argument led to lack of attention, which in turn resulted in an explosion on-site. The north pavilion of the machine caught fire, a mishap that was eventually dealt with successfully by a makeshift fire brigade. The show itself was something of a let-down. Horace Walpole, a contemporary historian, commented that “the fireworks

by no means answered the expense, the length of preparation, and the expectation that had been raised.”

In particular, the wheels and major set piece devices disappointed Walpole, who observed that

the rockets and whatever was thrown into the air succeeded mighty well, but the wheels and all that was to compose the principal part, were pitiful and ill-conducted with no change of coloured fires and shapes.

At the end of the performance, many fireworks were left undischarged. They were acquired by the Duke of Richmond, who gave his own display on the Thames some time later. By all accounts, this was far more successful — the firework display having a better “design” and presentation, making use of the extensive grounds of the Duke’s impressive townhouse situated on the banks of the Thames at Whitehall. A musical concert was followed by discharges of rockets, water-effects from boats, a line of wheels and various gerbs (fountains) and concluding with a grand illumination of the gardens and a pavilion. This is quite the reverse of modern displays, which often commence with low-key illuminations and conclude with dramatic aerial finales.

A superb contemporary illustration (Figure 2.1) shows the whole effect of the display and also provides details of the individual fireworks. It gives



Figure 2.1 – The Duke of Richmond’s fireworks

a fascinating insight into the components of a typical mid-18th-century display, with considerable emphasis on elaborate set-piece devices.

The 19th century

The latter part of the 18th century witnessed the development of “pleasure gardens” in England. These were essentially places of recreation that provided entertainment of various forms. In their early incarnations, such places offered attractions that would be considered repulsive today — bear-baiting, dog-fighting and bare-knuckle boxing were quite common — and it was not unusual to see animals such as bulls adorned with fireworks. From the 1750s onwards, many of the pleasure gardens made efforts to provide more up-market entertainment and fireworks began to play a more significant role, coupled with “illuminations” to create a pleasant ambience for a more respectable clientele. It is not surprising that many manufacturers seized the opportunities offered by these establishments to demonstrate their products and increase business.

The principal pleasure gardens in London were Ranelagh, Vauxhall, Cremorne and Bermondsey Spa. Fireworks became a regular feature at Vauxhall from 1813 and continued until the venue’s closure in 1859. The closing set-piece for the final show displayed the message “Farewell for Ever”. Ranelagh was the most popular and fashionable and held its first display in 1761 — a “fund-raiser” for the benefit of the Middlesex Hospital.

During this period, the name of Brock became pre-eminent in British pyrotechny. The history of Brock’s Fireworks dates back to before 1720, but it was during the 19th century that the Brock family established themselves as leaders in the field. In 1865, a “Grand Competition of Pyrotechnists”, the brainchild of Charles Thomas (CT) Brock, was held at the Crystal Palace, Sydenham; it was a spectacular success, with over 20,000 people attending. Thus began a series of magnificent displays at this prestigious venue, continuing until 1936. It can be argued that the first “contest” at the Crystal Palace was the forerunner of other fireworks competitions, which have, particularly in recent years, become popular once again with members of the public.

It is interesting to note the “rules” laid down for the first Crystal Palace competition. Each participant was required to display:

1. 25 coloured lights; each 2” in length and 2” diameter, 5 each of white, yellow, green, blue and red
2. 12 rockets of ½ lb calibre
3. Three tourbillions

4. 12 shells of 5" diameter
5. one set-piece
6. a finale of 200 rockets of ¼ lb calibre, 50 containing bright stars; 50 tailed stars and 100 coloured stars

Each company was allowed up to five assistants. No work could be done on-site prior to the day of the show. Use of rockets or shells of calibres greater than those specified would lead to disqualification. Even in those days there were strict "ground rules" that had to be obeyed by each competitor so that a level playing field could be established. Significant advances in chemistry during the 19th century gave rise to a greater spectrum of colours in pyrotechnics, and it is no surprise that the first fireworks competition at the Crystal Palace included a demonstration of "coloured lights" (bengal illuminations) — one of the simplest pyrotechnic devices. This would enable the judges to assess the colour purity and intensity achieved by each competitor's products.

It is interesting to note that in 1875 the Explosives Act was introduced, which laid down detailed regulations for the manufacture, sale and firing of fireworks. This was subsequently strengthened by later legislation and effectively replaced, in 2005, by the Manufacture and Storage of Explosives Regulations. Prior to 1875, regulation of fireworks-related activities had been poor although centuries earlier, in 1685, an Act of Parliament limited the manufacture, sale and display of fireworks. It was largely ignored.

The latter part of the 19th century, leading up to the First World War, was a "golden age" for firework displays. Brock's had become established as the leading lights in the UK and were contracted to provide shows throughout the world for all manner of celebrations, often associated with royal events. Other companies such as Pains and Wells also strengthened their reputations during this period, but Brock was pre-eminent. Their displays would invariably include huge and complex set-pieces; massive lancework devices depicting royal portraits, Heads of State or triumphant scenes such as battle victories were very common. This necessitated great expenditure and considerable manpower requirements, in contrast with modern displays that tend to be more economical in terms of personnel.

Even the more modest displays produced by Brock were often accompanied by a detailed descriptive programme. Many of these survive, and the following is the firing order for a display presented on August 23rd, 1894, at the Arboretum, Derby.

1. Signal maroon announcing commencement of the display
2. Illumination of the grounds by great "Crystal Palace" Lights
3. Salvo of rockets with various coloured stars, fired during the illuminations
4. Signal maroon announcing magical illumination of the scene by masses of coloured fire carefully arranged in positions chosen to produce the most beautiful prismatic effects on foliage, flowers, lawns and other salient features of the grounds
5. Device — the giant sunflower with glowing centre and a fringe of golden petals
6. Batteries of saucissons
7. Salvo of great rockets, fired in rapid succession, each with a different effect
8. Triple device — mosaic letters with intersecting lines of gold and jewels
9. Salvo of rockets with stars of every hue
10. Humorous mechanical device — the acrobat with wonderful performance on the horizontal bar
11. Flights of glowworms with jewelled heads
12. Device — the jewelled tree with brilliant foliage, multicoloured flowers and golden fruit, the apex towering aloft in a graceful spire, adorned with feathery fronds of fire, and lavishing bright jewels of every colour, flanked by revolving fountains of gold and jewels
13. Salvo of shells, 15 inches in circumference, fired in rapid succession
14. Great device — the revolving sun, 50 feet in circumference, whirling rapidly on its axis; its corona of golden fringe encircling a number of rotating wheels of prismatic light
15. Salvo of shells, 18 inches in circumference, producing posies of various flowers, fired in rapid succession
16. Great fixed device — the golden hexagon — a large piece with revolving centre of coloured fire from which radiate arms of golden light bearing wheels of coloured flame
17. Flights of whistling rockets, filling the air with wild notes of some fiery bird
18. Grand special device — the weeping willow — its foliage illustrating the changing of the seasons
19. Screen of diamond display by batteries of Brock's special Roman candles, emitting comet-like stars which leave a trail of scintillating sparks
20. Firework jugglery by batteries of Roman candles which toss into the air luminous spheres of every hue

21. The electric spreaders — Brock's greatest novelty in Roman candles, discharging stars of dazzling radiance never before attained in fireworks
22. Grand device — the Niagara of fire — falling in a golden torrent and rebounding in a bright spray of glittering sparks
23. Finale melee of shells, rockets, batteries of cobras etc.

Such programmes give a fascinating insight into the content and style of a typical public display at the turn of the century. Of particular note is the relatively small number of shells (described by circumference) and very heavy emphasis on set-piece devices — the performance of which was always described in lavish detail. The inclusion of “whistling rockets” is also a point of interest. It was not uncommon for a Brock's display to conclude with a giant waterfall effect, or similarly impressive device.

This general style of display remained common in the United Kingdom for many years and was adopted by all of the major fireworks companies until well into the 1960s. Displays were invariably hand-fired and generally more leisurely affairs; mortar tubes were usually re-loaded and substantial amounts of timber accompanied the display crew to enable erection of the set-pieces.

Some very large shows were fired in America during the late 19th century, often under the auspices of Pains or Brock's. Pains offered a range of “semi-scenic” theatrical and pyrotechnic productions, with great success — “The Fall of Babylon” being a typical example. In October 1892, Brock's fired a huge show in New York, the spectacular centre-piece of which was a grand waterfall that stretched along the entire length of the Brooklyn Bridge.

The 20th century

The early part of the 20th century witnessed more remarkable displays. Brock's further enhanced their international reputation; in 1905 the Princess of Wales visited India — accompanied by a team from Brock's who provided shows in Delhi, Indore, Mysore, and Bangalore. However, fireworks activities were naturally limited during the First World War, with manufacturers turning their attention to military pyrotechnics.

The Peace Treaty was signed in Versailles on June 29th, 1919, and on July 19th one of the UK's largest ever displays was fired in Hyde Park. The show was to include portraits of the King and Queen, images of the Great War heroes, numerous devices and set-pieces and the greatest concentration of aerial fireworks ever staged. Shells of calibre 5½ inch to 16 inch were fired in salvoes of three to fifty(!); rockets of 1 lb calibre in

flights of 100; Roman candles in batteries of 200 — and a finale of 2000 rockets in a single flight. It was to be a sight to behold, but that old enemy, the weather, adversely affected the show — particularly the grand set-pieces and lancework, which did not perform flawlessly after a four-hour soaking. Despite the problems, the display was greeted with rave reviews. The report in *The Daily News* was typical:

The effect was a complex of sensations that it only seems possible to express by the use of too many adjectives. The show was undoubtedly vastly more marvellous than anything of the kind seen in this country before.

This reinforces the opinion that a display can often thrill the public — even if it doesn't quite achieve what the designer set out to do.

The inter-war years were also very good for the display industry, and fireworks continued to provide high-quality entertainment for the public at seaside resorts throughout the summer. Pains shows at Cowes and other smaller regattas in the south of England proved to be very popular attractions. Brock's continued to dominate the international scene, firing shows in South Africa (eight cities as part of a royal tour), Norway and Finland — amongst others. The year 1935 was vintage, with numerous displays staged to celebrate the Silver Jubilee of King George V; over 300 displays marked the event in the UK, accompanied by 76 in various parts of Africa, eight in the West Indies, one in British Honduras, and two in British Guyana. Bombay and Karachi staged massive shows, with smaller but significant displays taking place in more exotic locations such as Aden, Mauritius and the Fiji Islands.

The second war again brought a halt to public displays for a six-year period. When hostilities ceased, Brock's was again called upon to provide a massive show to celebrate the peace. The date was set for June 8th, 1946, with the Thames being selected for the site and the location being the stretch of water between Lambeth and the Charing Cross Bridge.

The display itself was an early example of a "multimedia" show — the main aerial firework display being supported with a water-borne exhibition of illuminated fountains, rigged on 20 barges. The illumination effects were achieved by using high-intensity RAF runway projectors, fitted with coloured lenses and directed onto the water fountain jets. Twenty searchlights also contributed to the light show.

The content of the display was as follows:

- 750 aerial shells of calibres 4½", 5½", 8", 10", 12", 16" and 25" — the 4½" fired in salvoes of 50, with a single concluding 25"

- Rockets of 1 lb calibre — fired in flights of 200 (these were located on an inland area between County Hall and Charing Cross Bridge)
- Roman candles in batteries of 200
- Large mines in salvoes of 250
- 3000 aquatic devices

These effects were accompanied by two grand exhibition pieces — waterfalls spanning the entire width of the river (some 300 m), cascading from a height of 20 m, and colonnades of jewel jets displayed from two temporary bridges — one opposite the Tate Gallery and a second just below County Hall.

The Thames has provided the backdrop for many memorable displays since the Second World War. Of particular note is the 50th Anniversary of VJ Day, which was staged in 1995 and fired by *Kimbolton Fireworks*. This particular show involved five barges and some 18 tonnes Net Explosive Content (NEC) of fireworks, synchronized to music over a distance of two miles along the river. The UK's Millennium celebration display was also staged on the Thames, this time under the auspices of Australian company *Syd Howard*, working in conjunction with several British companies. More recently, the French concern *Groupe F* have presented the London New Year's Eve displays — making use of not only the Thames, but also the London Eye as a focal point for their imaginative work.

Returning to the immediate post-war period, the public's appetite for firework displays continued well into the 1950s, followed by a decline in the 1960s and 70s. Brock's, while still staging displays outside the UK (particularly in the commonwealth up to the mid-1960s), focused on the manufacture of military pyrotechnics and fireworks for the commercial market. Standard Fireworks, based in Huddersfield, had by that time become a major player — although their display work was small in comparison with their retail activities.

In the 1980s, a gradual but significant change occurred in the UK display market, largely due to relaxations in the import licensing requirements, which "opened up" the Chinese market. This gave rise to access to cheaper fireworks and led to the establishment of smaller independent outfits, whose focus was very much on displays; they were able to compete effectively with the larger more established companies. By the mid-1980s, the once mighty Brock's Fireworks was on its knees, and was purchased by Standard — but this did not give rise to a resurrection of their display division. The combined Standard-Brock operation did compete successfully in this area and began to build a reputation for itself — particularly in the provision of displays for summer proms and

concerts at various stately homes, which underwent a resurgence of popularity in the 1990s. Kimbolton Fireworks, based in Cambridgeshire, and Pains Fireworks, based in Hampshire (by now under different ownership), continued to provide operator-fired displays for numerous events throughout the latter part of the 20th century. Both companies are still trading and staging major displays at home and abroad.

Fireworks competitions were re-introduced into the UK in 1997. As a result of cooperation between Plymouth City Council and the Event Services Association, the inaugural *British Fireworks Championships* took place in August of that year — the displays being fired from the Mountbatten Breakwater in Plymouth Sound (for more details see Chapter 19). The site is directly opposite Plymouth Hoe and provides an exceptional viewing aspect for members of the public. Participants in the first year were Pains Fireworks, Le Maitre Pyrotechnics, Jubilee Fireworks, the Firework Company (now *Skyburst*), Vulcan Fireworks and Fantastic Fireworks — the eventual winners. The competition is now very well established and has attracted numerous companies, from relatively small concerns to major names in the UK industry. In 2006 a special “Champion of Champions” event was held with eight previous winners competing for the coveted prize — which was won by Jubilee Fireworks with a spectacular and innovative display.

In 1999, the *British Musical Fireworks Championships* was introduced at Southport. This has proved to be very popular with the public and is staged in a more “intimate” setting than the Plymouth competition. King’s Gardens, with its large marine lake, provides the backdrop for the event; the audience is relatively close and the setting is something of a natural amphitheatre. Competitors are encouraged to use the lake, and selected “aquatic” effects add an extra dimension to the shows — further enhanced by the use of music. The most successful displays at Southport are invariably those that are accurately “choreographed” to the musical sound tracks, an important aspect of modern show design that is covered in Chapter 16.

Over the past decade or so, the most significant impact on firework display design has resulted from the introduction of increasingly sophisticated digital firing systems. “Electrical firing” has been used, to a greater or lesser degree, for decades — enabling fireworks to be launched at the push of a button. In essence, early systems were all based on the principle of applying a voltage to an electrical igniter by closing a switch. “Field modules” (placed at various positions on a display site) distributed the applied voltage from a battery, via a switching panel, to numerous igniters — each of which initiated a single firework in the

display. Firing wide “frontages” with multiple fireworks ignited simultaneously became a routine operation in larger displays.

System design developed rapidly post-millennium, with the incorporation of digital electronics. These systems permit individual firings to take place within a fraction of a second, at various points on a display site — previously impossible within the limitations of simple “push-button” systems (which are limited by human reaction times). Hence it is now quite straightforward to design a pyromusical display where “single-shot” Roman candles eject their stars precisely on a musical note or cue; this facilitates genuine choreography as opposed to “interpreting” the music with different types of fireworks (although this approach still has its place in display design). Recent improvements in wireless technology have been embraced by firing-system designers, now an industry in itself, and large multi-location displays can be fired with signals sent from a central console to widely separated field modules. This is developed fully in Chapter 17.

What of the future? Certainly there will be further refinements and advances in electronic firing technology. It is hard to envisage the Sydney Harbour New Year’s Eve Display or major competition shows being undertaken without the assistance of a complex digital firing system. No doubt there will be further improvements in pyrochemistry and the development of “cleaner” effects with lower smoke emission. The only limitations are those of human imagination and ingenuity — but as the boundaries are pushed even farther, it is comforting to note that the basic ingredients of a good firework display remain essentially the same as they have for centuries.

Chapter 3 – Firework types and effects

Tom Smith – Davas Ltd

The variety of fireworks types available to the amateur and professional users alike is quite diverse, and trying to rationalise this diversity is a daunting task. The following list of types has been developed from the recently developed EU Standard for Fireworks¹ and reflects the relevant Working Group’s desire to maintain as great a flexibility for professional users as possible while developing type-specific testing methods, labelling and performance criteria.

At the time of development of the Standards, the Working Group believed that all types of Category 4 fireworks (those for use by “persons with specialist knowledge”) are covered, but recognised that other types may also be available for use but are included in other standards. For instance, sparklers and throwdowns are covered by the Category 1, 2 and 3 Standards, while items that could reasonably be considered as theatrical items (e.g., jets and line rockets) are covered by T1 and T2 Standards.

Table 3.1 – Comparison of European and British Standard BS 7114

Category	Effective old BS 7114 category	Comments
Category 1 firework	Category 1 firework (indoor)	NB: The requirements of the Standards have changed from BS 7114.
Category 2 firework	Category 2 firework (garden)	
Category 3 firework	Category 3 firework (display)	There is a period (until 4 July 2017) in which BS 7114 items may continue to be supplied within the UK.
Category 4 firework	Category 4 firework (display)	
T1 Pyrotechnic article	None	For theatrical use
T2 Pyrotechnic article	None	
P1 Pyrotechnic article	None	Including pyrotechnic articles for vehicles
P2 Pyrotechnic article	None	

The following types and subtypes are defined in the Category 1, 2, 3 and 4 European Firework Standards. Where necessary, additional information

is given to clarify or expand the formal definitions developed. The original definitions (slightly adapted here) are in *italics* for clarity.

Aerial wheel

An aerial wheel consists of tubes containing propellant charges and sparks-, flame- and/or noise-producing pyrotechnic compositions, the tubes being fixed to a supporting structure, designed to rotate and ascend into the air. Some of the tubes (if not all) are fixed in such a way that the device ascends, in an unsupported manner, into the air by the action of the devices. The principal effect is rotation and ascent, with emission of sparks and flames, producing a visual and/or aural effect in the air.

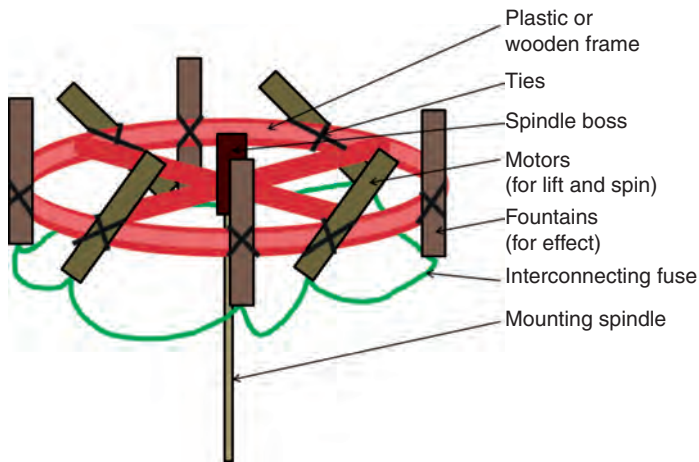


Figure 3.1 – Aerial or “crown” wheel

Such aerial wheels can be “single acting” (where the piece ascends only once) or “double acting” (where the device ascends, then drops, and then ascends again — often to the bemusement and delight of the audience). As a result there are several possible designs of this type of device, and the above illustration should only be taken as indicative.

Typically the device functions by first lighting the drivers (gerbs whose main function is thrust rather than visual effects), which rotate the wheel on its axis — to impart gyroscopic stability to the wheel, and then the rising motors function to propel the device into the air.

The major safety issue with aerial wheels is that the device is very susceptible to the effects of wind and can travel significant distances from the point of firing. Furthermore, if all the drivers do not function correctly the device can become unstable and erratic in flight.

Aqua firework (aquatic firework, nautical firework)

A firework designed to be floated on or near the surface of water by means of a buoyancy device or by itself and to function on or below water. The same effects are produced as for Bengal flames, fountains, mines, shells etc.

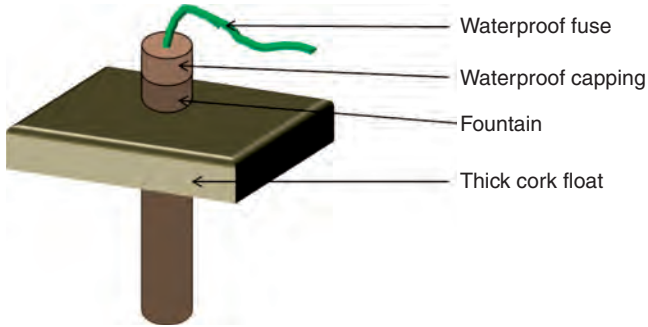


Figure 3.2 – Water fountain mounted on cork float

Subtypes include:

Underwater fireworks/sub-aquatic fireworks — Fireworks designed to function under the water near the surface. These articles have the capacity to float on or at a few centimetres under the surface of water.

Aquatic fireworks can be pre-rigged in their eventual firing position, or be propelled into their firing position either manually (for instance the



Figure 3.3 – Water shell bursting

hand-thrown water gerb illustrated in Figure 3.2) or from a mortar in the same way as a mine (for multiple effects) or a shell in mortar (for a single effect). In the latter cases the mortars are fired, typically at 45°; lifting charges used are usually considerably less than the equivalent charge if the device were fired vertically upwards.

The major safety concern of propelled aquatic fireworks is the range that they can achieve and the variation in that range depending on the exact conditions in which they are fired (quantity of lifting charge, the mortar used, the angle of the mortar and its elevation).

Combination

A Combination device is an assembly including several elements, of one or more types, each corresponding to one of the individual types of firework listed in this section, with one or more points of ignition.

The individual fireworks may be fused together in series or parallel, with or without delay fuses, to give their effects in a sequence or at the same time. The combination is not necessarily made at the manufacturing level and can be achieved at the display's firing place.

Compound fireworks (in which several effects are within the same single-tubed article — e.g., a Roman candle) are not considered as combinations.

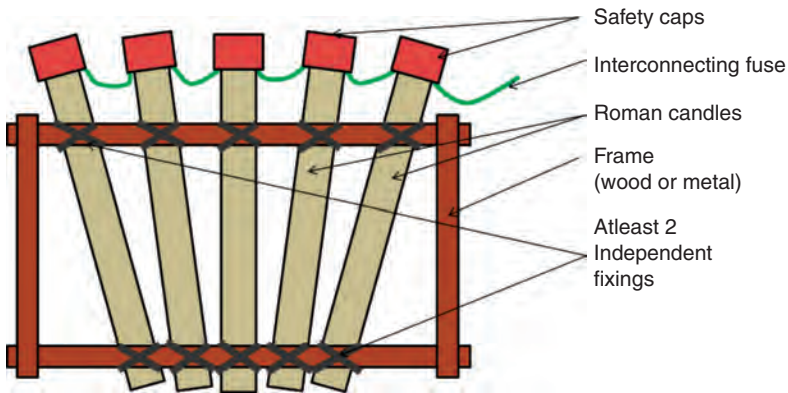


Figure 3.4 – Battery of Roman candles

Subtypes of combinations include:

Battery — *An assembly including several elements, each of the **same** type and corresponding to one of the types of firework listed, with one or more points of ignition. (This definition is included as it is used historically in category 1, 2 and 3 fireworks.)*

Figure 3.4 is typical for a Roman candle battery containing candles of the same calibre. However, more complex combinations may also be constructed containing Roman candles of various calibres and other firework types. The distinction between a “combination” and a “battery” is somewhat artificial, and serves little purpose — if there is more than one individual firework on an assembly, then the function of the whole device and the risks posed from that whole device are related to the performance and risks of the individual components.

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.

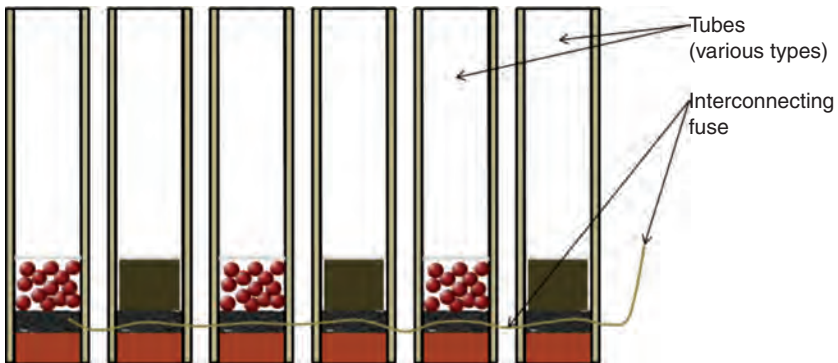


Figure 3.5 – Schematic cross-section of a typical “cake”

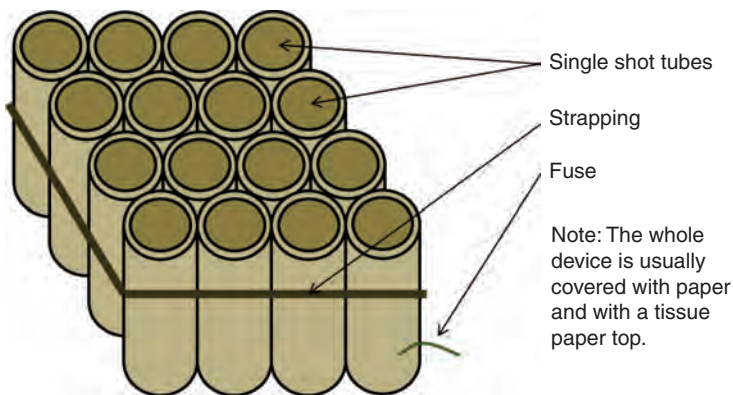


Figure 3.6 – Schematic of 4 × 4 16-shot “cake”

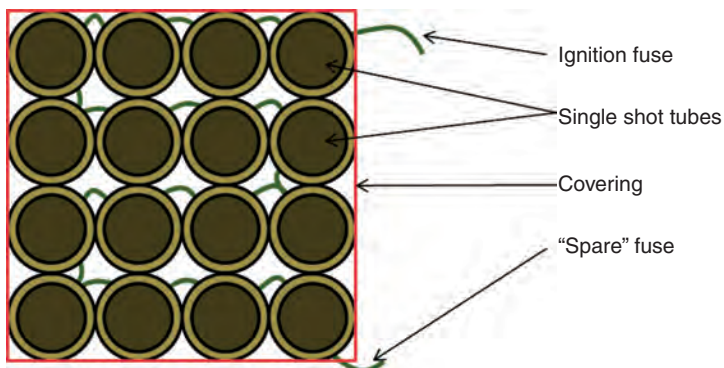


Figure 3.7 – Schematic of 4 × 4 16-shot “cake” showing internal fusing

The term “cake” originates from early examples of this type of firework that were produced in China and 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 (see Chapter 11) 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 are 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 that 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 occurs, 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).

References

Where possible URL links are also shown and are all valid at the date of publication. An updated list of references will be made available at <http://www.fd-ee.com>.

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