

FIREWORKS
Principles and Practice
2nd Edition

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Fireworks Principles and Practice

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Preface to Second Edition

It is now over sixteen years since this book was first put together. Progress there has been, but fundamentally fireworks are much the same as before. Over the last few years one or two important new books have been published along with a number of useful essays on individual topics. Reference has been made to these in the bibliography.

I am grateful to a number of friends who have helped with this revision particularly Robert Cardwell the Editor and creator of *Pyrotechnica*. Robert has done much to further the firework cause by the production of this interesting and scholarly periodical. I am grateful to him for revising our notes on the contemporary American firework industry. Similarly Bill Withrow of Euless, Texas, a good friend over the years has been tireless in his help and encouragement to get this book completed. Mention must also be made of the late Max P. Vander Horck. Max did so much to encourage the writing of the First Edition and when it was completed he maintained that if Weingart's *Pyrotechnics* was the firework maker's Bible, then 'Fireworks, Principles and Practice' was the New Testament.

I am also grateful to Dr. Tom Smith, Mr. L. Jackson and to Mark Lancaster for their help with photographs and drawings, to Tony Cardell and Walter Zink for some extremely helpful information, to Mrs. G. Crocker for allowing material to be used from the Gunpowder Mills Study Group and to Mr. J. Salmon for his excellent drawings of the Faversham Gunpowder Mills.

Last and not least to Mr. Bryan Earl who kindly allowed me to quote from his splendid, scholarly work 'Cornish Explosives'.

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Preface

For many years Weingart's "Pyrotechnics" has been regarded as the amateur firework enthusiast's Bible, and it was news of the re-print of this work in 1968 which prompted the writer to suggest a revision of it. As it happened the suggestion came too late with the result that a new work has evolved.

From the beginning the writer was anxious to share the task of writing this work, and accords grateful thanks to the other three contributors:- Dr. Shimizu, who very willingly translated part of his book "Hanabi" from the original Japanese. The script of chapter 19 is more or less as he translated it, and a great credit to him. To the best of our knowledge this was the first treatise on Japanese firework manufacture in the English language.

Ronald Hall, one of my long-standing firework friends who has long experience as a chemist in the explosives and firework industries. Has also been responsible for the introduction of polymerizing resins into commercial firework manufacture and is especially interested in forensic aspects of explosives.

Last but not least my thanks go to my teaching colleague and friend Roy Butler; an able firework maker who has given even more of his time to write a precis of available historical records, adding also more up-to-date material.

Turning to the general preparation of the book, I would like to express grateful thanks to Peter Smout Esq., M.A., Senior Master at Kimbolton School who has so kindly read through the script and made many helpful suggestions.

Helpful comments have also been made by Peter Watson, Esq., B.Sc. Senior Chemistry Master at Kimbolton School, Dr. Herbert Ellern, the author of Military and Civilian Pyrotechnics, and Mr. J. Barkley and Mr. J. Wommack, two other American friends. My wife, Kathleen Lancaster, B.A.Dip.Ed., has kindly assisted with drawings and diagrams along with P.R. Lambert, a member of the School Sixth Form.

In particular also my grateful thanks go to Edwin Bailey who kindly used his printer's expertise to convert many of the drawings into a suitable form for printing.

Preface

Several commercial firms have been kind enough to supply technical information. These were Imperial Chemical Industries, Albright and Wilson Ltd., Frederick Allen & Sons Ltd., Anchor Chemical Co. Ltd., F.W. Berk & Co., Ltd., Columbian International Ltd., Du Pont de Nemours & Co., K. W. Chemicals Ltd., W.S. Lloyd Ltd., Magnesium Elektron Ltd., Chas. Page & Co. Ltd., L.R.B. Pearce Ltd., A.F. Suter & Co. Ltd. and Bush Beach, Segner Bayley. I would like to express my gratitude to all those people who helped me along the firework road in those early days when help was required to cross the threshold which separates amateur and professional firework manufacture. In particular I would mention the Greenhalgh Family of Standard Fireworks Ltd., Huddersfield, along with W. Stott Esq. and J. Seymour Esq. who also live in Huddersfield, my native town. Kindly friends abroad include Walter Zink of Zink Feuerwerk, Weco of Eitorf, Lünig of Stuttgart; Nico of Trittau, Hamburg; Moog of Wuppertal; Hamberger of Oberried and the Barfod Family of the Tivoli Gardens in Denmark.

Lastly, and in more recent times, gratitude is due to Pains-Wessex Ltd. to whom I was Firework Consultant from 1963 to 1977 and to John Deeker F.C.A. and David A.S. Little for their help and friendship.

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Introduction

It is illegal to manufacture fireworks in most countries unless a license has been obtained from the government. This is absolutely right, for nowhere else does the old saying "that a little knowledge is a dangerous thing:" apply more than here, perhaps with disastrous effects. Accidents occasionally happen in the most experienced hands and old and hardened manufacturers shudder at some of the experiments of the uninitiated.

Why then write a book about fireworks?

There is a need for an up-to date description of general firework practice. Firework manufacture may be a mixture of chemistry and cooking, but is an important branch of pyrotechnics. All the books in existence lack either accurate detailed information or publish information that may be incorrect, dangerous or useless. Naturally this has been deliberate because firework manufacture has been in the hands of private families and is still more or less tied up with money and competition. This is a pity, but like so many commercial enterprises, considerable sums of money are invested in plants or research and returns are naturally expected. Indeed, the writer has done little more than skim over the surface, quite deliberately; nevertheless all the compositions are typical of those in use in Europe and are reasonably safe as such things can be. Clearly the intention of this book has been to attempt to show that much of the available printed information is dangerous.

Over the last few decades the attitudes of the manufacturers have changed. In the past each one regarded his compositions as a great secret, the "boss" himself frequently doing the mixing and giving the chemicals false names to fool the industrial spies. All this has more or less gone. Chemical suppliers became fewer and larger, selling the same material to everyone; gunpowder manufacture is virtually a monopoly,

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workers in some countries change their employment from one company to another.

Most good firework makers share the same basic formulations; only the finer points and the techniques are more or less secret and naturally these are details which do not reach publication. In any case half the battle of firework manufacture is experience, namely the constant observation of the burning characteristics, and performance of fireworks and consequently the experience of knowing what adjustments to make and what to look for.

In the opinion of the writer, the argument that explosive information should not be published, does not hold water. Determined people can get a good deal of information, for there is plenty of it in print, and after all, legal and other restrictions make it very difficult for anyone to start manufacture.

The writers naturally would be greatly disturbed to feel that this book has caused anyone to damage people or property but such risks have to be taken at all levels of life. Fireworks are dangerous but so are domestic electricity supplies, oil burning heaters, pans of boiling fat, gasoline pumps, gas supplies, children's bicycles on roads..... the possibilities are endless.

From time to time attempts are made to ban the sale of fireworks to the public. Recent voting in Great Britain indicate that the majority of the voters were against such a move, and quite rightly so, after all people have the right to act responsibly and should be free to exercise their responsibility in this direction. Britain, in common with most European countries, has rigid legislation and inspection of firework manufacture and an agreement amongst manufacturers that flash crackers and certain dangerous fireworks should not be sold to the general public. The result is that a fairly wide range of fireworks can be purchased in the shops at certain times of the year, and display fireworks can be organized by people with specialized experience. The U.S.A. could do well to benefit from our experience, for it would appear that a country priding itself on its freedom can nevertheless allow some bureaucratic fire marshal or other excited group to bring in legislation to outlaw fireworks in individual states. The result appears to be that it encourages people to buy fireworks over the border in a more permissive state and fire them illegally. Restrict the dangerous explosive items by all means, but "safe and sane" as the Americans put it, covers *very* much more than sparklers.

The Germans say in effect that once a person has smelt black powder, he will be with it for the rest of his life. There is undoubtedly some

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truth in this, for real fireworkers all over the world love to get together and talk about the fascination of this, their mutual interest. It is to be hoped that it will always be possible to strike a happy balance between the enthusiast and the legislation.

In recent years while pyrotechnics have been striding ahead, the art of firework manufacturing appears to be relatively static and old-fashioned. Nevertheless this should not be a matter exciting too great a concern, for the firework maker can only display his art on those grand and comparatively rare occasions when large sums of money are spent on a single display. The burst of an 8" golden octopus ,crossette shell or a Japanese chrysanthemum will still thrill people for many years to come, in spite of the fact that the composition may be primitive. Public taste will not have the opportunity to become bored by those fireworks which really display the maker's art.

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Fig. 1:1 Fireworks on the Thames, London, England

Chapter 1

The History of Fireworks

R.E.A. Butler

Firework manufacture has a long history, but development of the pyrotechnic art has been remarkably slow. The Chinese may have made fireworks of sorts over a thousand years ago; displays have been fired at public and private celebrations for five hundred years, and their popularity, now throughout the world, seems undiminished. Nevertheless, basically firework displays have changed little over several centuries, and rockets, shells and Roman candles, in various forms, remain the main display components. Certainly colors have been improved, and the range of colors extended, shells are more spectacular, rockets are propelled higher, the use of the new materials has brought some new effects, and set pieces and the style of displays have been changed, but the essential ingredients of the firework exhibition do not alter. The fireworker still strives to excite and delight with a combination of color and noise. He creates patterns of beauty and brilliance using natural materials and employing a knowledge of chemical reaction, together with the benefits of experience, and often much patience, dedication and intuition. The beginning of the pyrotechnic art was heralded by the invention of gunpowder, and this dark mixture is still the firework maker's principal material. Thus, in this capacity as a bringer of pleasure and beauty, gunpowder makes some amends for its evil reputation as a source of death and destruction.

It is probable that the first gunpowder was formed when, quite by chance, charcoal, saltpeter and sulphur were brought together. The result of this accident would be obvious if the mixture was exposed to some means of ignition, and the potential use of this new explosive material would soon become apparent. Traditionally the Chinese are

credited with the discovery at a time well before historical records. Certainly the evidences suggest that gunpowder originated in the East, with China or India being the likely source, although the Arabs and Greeks have certain claims. Moreover, coded writings by the English friar, Roger Bacon, in the thirteenth century, are generally accepted as a description of a gunpowder mixture for the production of an explosion. The invention of the gun, which probably represented the greatest step forward in the application of gunpowder, was almost certainly made in Germany, at Freiburg, by a Franciscan monk called Berthold Schwarz, although the inventor could well have had Asiatic origins. It was over two centuries later that the first artillery was seen in China, and that was on Portuguese ships in 1520.

However, the Chinese had employed pyrotechnic mixtures long before this date. Ancient manuscripts describe explosive bombs, which were fired from giant catapults, and burst on landing or in the air. Similar missiles were merely dropped on the enemy from fortress walls. Firecrackers were used in early times, just as they are now, to scare away evil spirits from wedding and birth celebrations, and from funerals, and they were also much in evidence at various religious festivals. These crackers were often made by packing gunpowder into bamboo cases or rolled paper tubes, so laying foundations of modern firework making.

An encyclopedia by Fang I Chih in about 1630 included a mention of 'fire trees and silver trees' used in the Tang dynasty (7th to 10th centuries) in which gunpowder was thought by the author to have been used. These fireworks may have been forerunners of those used in big displays which were frequently put on in China in the seventeenth and eighteenth centuries, and which were described in various writings by travellers returning to Europe. Apparently the development of Chinese fireworks proceeded very slowly, and in 1821 Claude-Fortune Ruggieri, the French pyrotechnist, remarked that his information was that the 'Chinese fireworks were no different from what the Chinese have been making for three or four centuries; this convinced me that we in Europe are far superior to the Chinese'.

In India too progress appears to have been slow, for war rockets were in use at a very early time. Here, as in China, fireworks of sorts were frequently seen at celebrations and public festivities, and fifteenth and sixteenth century writings, such as the Marathi poem of Saint Ekanatha,

describe displays, and mention rockets and fireworks producing garlands of flowers, a moonlight effect and hissing noises. By the eighteenth century displays were being organized on a lavish scale. The first English display in India was in 1790 near Lucknow, and was said to have taken six months to prepare.

In Europe pyrotechnics for military purposes saw an early peak of achievement in the form of Greek fire. Highly combustible material, including sulphur, resin, camphor and pitch, was blown by a bellows device out of copper or iron tubes, or even hand pumps, and was almost inextinguishable. Old manuscripts suggest several ways of attempting to combat the fire, especially the application of wine, vinegar, sand and even urine. For four hundred years the Greeks guarded the secret of their devastating weapon, and used it with spectacular effect on land and sea; but by the tenth century the Saracens had learned the formula, and used it against the Crusaders. By the fourteenth century gunpowder had made its appearance in European warfare, and made the short-ranged Greek fire powerless against far-flung missiles.

In the wake of gunpowder came the arrival of firework mixtures, both of them appearing in Europe, probably as a result of information on their manufacture being brought from the East. Italy seems to have been the first area in Europe to make fireworks, as opposed to military pyrotechnics, and to put on displays. It is clear that before 1500 fireworks were employed extensively at religious festivals and public events, and frequent displays were becoming popular entertainments. Florence was probably the center of an expanding manufacturing industry, as demand for the new spectacle increased. Before this period fireworks had been used as scenic effects at theatrical productions. In fact, fiery torches and the like had been added embellishments in the amphitheater of classical Roman times. Now the fireworks became the main concern, although elaborate scenic sets and buildings were to form backgrounds to displays for many years to come.

Firework displays were seldom seen in England before the end of the sixteenth century. Shakespeare refers to 'fireworks' on several occasions in his plays, suggesting that the term was in general usage in England at that time. Other literature of the period often mentions the 'green man' whose function was to walk at the head of processions carrying 'fire clubs' and scattering 'fireworks' (in this case probably meaning sparks) to clear the way. The origin of this character and his title are a mystery, but we are told that he was usually made up to appear very ugly, and he certainly survived well into the next century.

The earliest record of a firework display in England was in 1572, when a large show was put on at Warwick Castle to mark the visit of Queen Elizabeth I. The Queen is said to have enjoyed the spectacle immensely, and this approval served to encourage the organization of many more displays, including two shows fired at Kenilworth Castle, Warwickshire, to entertain Her Majesty during a visit there in 1575. The first of the displays on the River Thames was in 1613 to celebrate the marriage of King James's daughter, Elizabeth. The site has been used with great regularity ever since.

The early displays in England were mainly the work of firework makers from France and Italy, especially the latter, who seem to have been supreme in Europe until the end of the seventeenth century. It was not until considerably later that English pyrotechnists began to challenge the continental lead. Responsibility for the provision of fireworks and the organization of displays was put in the hands of the military, and Ordnance officers, ranked Firemasters, were appointed to take charge.

While the English lagged behind, two distinct schools of firework making became apparent in Europe. In the Northern area, such states as Poland, Sweden, Denmark and the German states were developing new methods of firework presentation, which differed markedly from the traditional style of the Mediterranean countries. Brock considers that the split was closely related to religious matters, and that the intense feelings which the Reformation aroused found outlet in more sectarian spheres, including pyrotechnics. In fact, the fireworks made in the north and south remained very similar in effects; the divergence was more in the composition of displays.

The Italian style, illustrated especially by the Ruggieri brothers of Bologna, and followed by the manufacturers of France (who were joined by the Ruggieri family at a later date), had grown from the early ceremonial displays in Florence at the Feast of Saint Peter and Saint Paul. Invariably collections of small fireworks were arranged on, and in front of, huge, elaborate structures, built in the form of castles, temples or classical edifices, and known as 'machines' or 'temples'. The imposing frontages were lavishly adorned with rich decorations, and the whole was illuminated from without and within. The audience was thus entertained before the actual display began, and when the fireworks were lit they tended to heighten the general spectacle of the 'machine', rather than provide purely pyrotechnic amusement.

The breakaway Northern school took their lead from Nürnberg, where experts like Hoch, Muller, Clarmer, and Miller, challenged the masters of Florence and Bologna. The displays in the North gave the actual fireworks the prime importance and diminished the role of the 'machine'. The fireworks were set out in neat rows on the ground for all to inspect before the display was fired. If a 'machine' was used, it was a much less elaborate construction than in the South, although sometimes real buildings or landscapes were utilized to add atmosphere to the shows. The effect achieved by firing displays behind a foreground of water was realized in this period, and engravings of displays at Stockholm, Paris, Versailles and on the Thames, illustrate the early beginnings of this still popular practice.

Spectators accustomed to either the Northern or Southern type of display were scornful of the attempts of the rival school, as can be clearly discerned from contemporary publications. The most authoritative was 'The Great Art of Artillery', penned by Casimir Siemienowitz in 1650. His displays, although following the techniques of the Northern school in the main, included some features from the South, so giving his shows decorative effect before firing time, yet concentrating on pure firework amusement during performance. This kind of compromise display often included figures and architectural structures, smaller and less intricate than the 'machine', and made of a wooden frame, over which was paper-mâché, which concealed fireworks. At a certain point in the show sparks and stars would be seen to issue from the model with spectacular effect. Various figures made their appearance in the different shows, although the Cupid was perhaps the most popular, and the tall 'obelisk' was a regular feature at displays for many decades.

In their various styles displays increased enormously in number and size all over Europe. Louis XIV and XV enjoyed numerous shows in Paris in celebration of royal birthdays and weddings, state occasions and victory or peace festivals. In almost every European country visiting royalty were invariably treated to displays. Peace treaties, like that signed at Aix la Chapelle in 1742, were excuses for expensive performances in many European capitals. Numerous prints and engravings of the time undoubtedly flatter many of these shows by depicting them always in full, extravagant splendor. In fact, not all displays were the spectacular success their advance publicity proclaimed.

The pyrotechnic celebration planned to take place in London's Green Park in 1742 was to have been the greatest display of all time. An official estimate of the cost was over £14,500, and Ruggieri and other no-

table Italian manufacturers were brought over especially for the occasion. Nearly six months were spent in erecting huge 'temples' and various ornate 'machines' of elaborate design. The organizers even engaged Handel to compose a musical work in honor of the event, and the popular 'Fireworks Music' was the result.

At the appointed hour, King George II, accompanied by an impressive array of aristocracy, paraded to his seat past the huge, excited crowd. However, all was not well behind the scenes, for violent arguments had arisen between the English and Italian fireworkers. These disagreements were brought to a dramatic end as an explosion rent the North Pavilion, which burst into flames. The fire caused widespread confusion and alarm, but was eventually brought under control so that the planned fireworks could begin. However, judging by eyewitness reports, the display was anything but the memorable spectacle which had been promised. Such descriptions as 'pitiful and ill-conducted', 'the Grand Whim for posterity to laugh at' and 'the machine was very beautiful and was all that was worth seeing' were just some of the less abusive comments. Certainly it was the last big display London was to see for many years.

Private firework companies had for long been operating on the continent of Europe, but in England artillery officers were still in charge of displays, although the actual arrangements were probably under the control of civilians. No doubt small English companies made fireworks for the shows, and large quantities were regularly imported from France and Italy. It is recorded that a Swede, Martin Beckman, made fireworks for the celebrations which marked the coronations of Charles II and James II, and also that of William of Orange. However, the eighteenth century, 'the Age of Elegance', gave the English manufacturers the opportunity to show their skills and to increase their sales and production.

It was during this period that the 'Pleasure Garden' became, for the respectable townsmen and their ladies, the fashionable place at which to be seen. Taking a lead from London, most towns of note established those exclusive resorts with their concerts and tea parties, opportunities to exchange gossip and to be sociable, not to mention the availability of medical waters in many parts of the country. Soon other entertainments were added to amuse and excite clientele. Male and female bare knuckle fights, dog fights and bear and bull baiting were all popular attractions, and eventually firework displays became regular items on the programs.

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