

FIREWORKS

Principles and Practice

3rd Edition

by

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Preface to the Third Edition

The idea of this book took place thirty years ago, and it is gratifying that it still has a place in the firework world.

The original intention was to produce a straightforward description of firework manufacture in the Western World. It was an attempt to describe what had happened in the past and to make suggestions for good practice at the present time.

It was also an attempt to be fairly basic and thereby not offend friends and competitors in the trade who had to make an attempt to make a living at fireworks. Amateurs have wonderful enthusiasm and like true scientists need to know everything—for its own sake. They also want to share findings with everyone else. However, this is in complete contrast to commerce, where survival may depend on the quality of the product or the price at which it might be produced. Needless to say this “edge” can be very costly in terms of hours of research and capital expenditure.

Recent years have seen the decline of the Western firework industry. The story is the same for almost every country where it has become uneconomical to make small fireworks compared to the price at which they can be bought from China. In the U.K., for example, there were ten manufacturers of small-shop fireworks in 1960, but there are none left in 1998. In the U.K. only Kimbolton Fireworks makes a full range of display fireworks with two other firms making special effects for the stage, etc.

Much of the material from the Far East is cheap and only partly reliable. It is also a boon to the ever-increasing numbers of unspecialized (and often legally ignorant) importers who bring in and distribute explosives in much the same way as bananas. The Civil Service, in the

U.K. at least, has been less than effective in the control of these illegalities in latter years. It was not so in the past, and while the EEC gets the blame for most things, it is clear that some of our partners in the EEC are much better 'at looking after their own' than is the case in the U.K.

This industrial decline is a great tragedy, but it is generally agreed that there will be a place for the present for those manufacturers able to make a good quality product. Those people willing to make this capital outlay need a Civil Service which creates a level playing field. In 1998 a high profile manufacturer is constantly bombarded with rules, regulations, bureaucratic nonsense, and more and more costs at every stage. Every sizeable company has to employ unproductive safety advisers, subscribe to suppliers of safety information, make space for records and risk assessments. No one can deny that the **simple** desire for good health and safety management is laudable. In reality it has become a burden with those working in it leaving no stone unturned and sometimes reaching absurdum as they justify their existence. In the meantime companies disappear or transfer their production to the Third World. All this time, the importers increase in number and have the financial gain.

It is difficult to predict what the next few years will bring. Importations from the Far East will increase, but it is clear that there are far too many Chinese exporters. Most of them are selling much the same products, and it is always more important to remain competitive than to produce superior products. A Chinese supplier may well sell the same products to several people in a limited market—a policy doomed to a very limited lifespan for obvious reasons.

Once again I am grateful to the many friends who have helped to make this edition possible. In particular to friends mentioned in Chapter 1 who have filled out the details about the firework scene in their own countries.

I would particularly mention Dr Takeo Shimizu (b.1912) whom I have known for over thirty years and who has been absolutely prolific in his research for the firework trade. What would we have done without him?

Mention must also be made of the late Chris Philip who died in January 1998. The importation fireworks in the U.K had always been a major problem because of the prohibition on the admixture of chlorates and sulfur. However, Chris Philip set out to challenge a somewhat negative attitude towards importation at that time. A total ban had been easy to control, but his success then has done no favours to the home-

based industry some thirty years later. It has not shaken the Government into being more proactive in controlling the quality of what can be sold from abroad up to 1997 either.

Nearer home I am grateful to Mark Lancaster, Dr Tom Smith, Tony Cardell, Roy Butler, and John Bennett, the Editor of the excellent U.K. magazine 'Fireworks'. This magazine has done so much to encourage an interest in fireworks and to keep some of the history intact. Lastly, to my wife Kath who has always maintained that I eat and sleep fireworks and talk about them in bed—sometimes.

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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 Horek. 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.

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 Decker 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, 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.

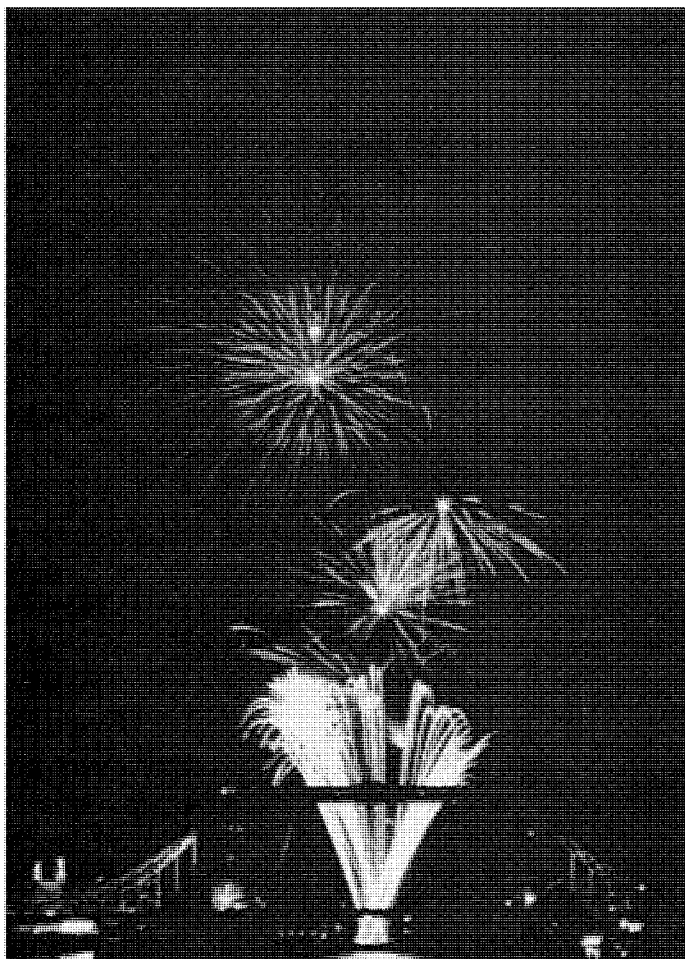
From time to time attempts are made to ban the sale of fireworks to the public. Recent voting in Great Britain indicate that the majority of the voters were against such a move, and quite rightly so. After all people have the right to act responsibly and should be free to exercise their responsibility 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 marshall 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 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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Fireworks on the Thames, London, England

1

THE HISTORY OF FIREWORKS

R.E.A. Butler

Firework manufacture has a long history, but the 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 world-wide, seems undiminished. Nevertheless, basically, firework displays have changed little over the centuries, with rockets, shells and Roman candles, in various forms, remaining the main display components. Certainly the quality and range of colours have been improved, shells are more spectacular, rockets are propelled higher, the use of new materials has brought some original effects, and fashions in set pieces and in the style of displays have changed. Although modern technology, in the form of sophisticated electronic firing boards and musical accompaniments, now enhances the spectacle, the essential ingredients of the firework exhibition do not alter. The fireworker still strives to excite and delight with a combination of colour 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 invention of gunpowder heralded the beginning of the pyrotechnic art, 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, saltpetre and sulphur were brought together. The result of this accident must have been obvious if the mixture was exposed to some means of ignition, and the potential use of this new explosive material must soon have become apparent. Traditionally, the Chinese

are credited with the discovery at a time well before historical records. Certainly the evidence suggests that gunpowder originated in the East, with China or India being the likely source, although the Arabs and Greeks have certain claims. Tradition too credits Roger Bacon, an English friar of the thirteenth century, with the invention of a gunpowder mixture. Michael Swisher, however, argues conclusively in *Pyrotechnica* (November 1997) that:

‘Roger Bacon did not invent gunpowder. He knew of it, and described it in several of his works with varying degrees of detail. The only application he describes is in a firecracker, a child’s toy made in diverse parts of the world.’

Swisher also explodes the popular myth that Marco Polo brought knowledge of fireworks back from China in 1295. Polo makes no mention of fireworks in his account of his exploits, and, anyway, the writings of Bacon and others show that gunpowder and fireworks were known in Europe well before that time.

As for the application of gunpowder, the invention of the gun is usually attributed to a Franciscan monk called Berthold Schwarz, and the town of Freiburg has erected a statue in the town square in his honour. Attractive as the image of the ‘Powder Monk’ might be, Professor J.R. Partington in his meticulously-researched *History of Greek Fire and Gunpowder* (1960) finds no evidence to suggest that Schwarz even existed. It is thought that the invention could well have had Asiatic origins, although it was over two centuries later that the first artillery was reported in China, and that was on Portuguese and Dutch ships.

The Chinese, however, 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 the foundations of modern firework manufacture. They exploded when thrown on to the fire, hence the origin of the name ‘firecracker’.

An encyclopaedia by Fang I Chih, dated around 1630, refers to ‘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 the 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 Ruggiari, the French pyrotechnist, remarked 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'. But, of course, this could have been wishful thinking!

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 festivals, 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 organised 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 appear 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 put on displays. It is clear that before 1500 fireworks were employed extensively at religious festivals and public events, as frequent displays were becoming popular entertainments. Florence was probably the centre 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 amphitheatres 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 in Tudor times. 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 following 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 fire 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 organisation 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 appeared 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 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 occurs more often in the presentation of displays.

The Italian style, illustrated especially by the Ruggieri brothers of

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