WA Sc
454

Extracts re
Feuerwerkbuch

Gunpowder – The History of an International Technology

WASC 454

CHAPTER 4

DAS FEUERWERKBUCH: ITS IMPORTANCE IN THE EARLY HISTORY OF BLACK POWDER*

Gerhard W Kramer

There are three main themes in this account of the Firework Book: the book itself and the libraries associated with it, especially that in Freiburg; the types of black powder made and the weapons used; the preparation of black powder, the chemicals employed, and the recipes followed.

There are occasional citings of this work in Anglo-Saxon literature, but it is little known even in the German-speaking world. To the weapons historian only the section on gun technology is of interest, and historians of chemistry have hitherto ignored it despite the sections relating to black powder. The Firework Book is thus virtually unknown despite its importance. One reason for this is that it has been published only once, drawing without comment on the text of 1529.[1] The medieval German and Gothic script in which it is written are an obstacle, even for Germans. An attempt will now be made to describe the history, compilation, and contents of this text.

The original copy appears to exist no longer, and its author is anonymous. It must have been written circa 1400, plus or minus ten years, using texts of about 1380. The oldest dated copy is 1428–1430. The oldest dated and comprehensive copy, of 1432, is in the University of Freiburg.[2] It is this Manuscript 362 which has been used for this research and for the commentary published by the Deutsches Museum in 1995.[3]

Unlike the overwhelmingly theological and alchemical writings of the period which are of scholastic interest only, the Firework Book is a practical text on the methods of the gunsmith. Most of the young gunsmiths were literate, and they would copy down their master's version. It was therefore natural for individual copies to differ, with additions to the text and rearrangements of it. The text of the oldest dated and complete manuscript in Freiburg

*This chapter has been based on a translation of the author's paper.

has such a clear style and is so systematically structured that it is possible to recognize the alterations made by the first copyist, about 1415–1420. The second copyist of 1432 has reproduced the text very precisely, but has added unsystematic notes or comments. But even then, manuscript 362 of the Firework Book is very close to the original, which is a matter of great importance for its interpretation.

German libraries still have about 47 copies, written between 1430 and 1550, and often significantly different. The losses resulting from the Second World War are not known. The Firework Book was the most frequently copied text book of the period. The characters of the scripts suggest knowledgeable writers rather than professional scribes. The gunsmith Franz Helm of Cologne had the 1529 text printed.[4] The Book then disappeared from the technical literature, for which there is a simple explanation. In the Middle Ages firearms technique in Europe as in China and Arabia was based on calcium nitrate as the oxygen carrier. The Firework Book deals specifically with the chemistry of that salt, the significance of which was lost with the discovery of potassium nitrate in the middle of the sixteenth century. This was non-hygroscopic, and was prepared by the decomposition of calcium nitrate with wood ash, in a process first described by Biringuccio in 1540.[5] This discovery made calcium nitrate redundant. In 1555 Agricola described in German and in great detail, the method of using potassium nitrate for making black powder.[6]

As far as can be ascertained the Firework Book is unknown in writings on the history of German chemistry, yet a close study of it reveals important facts which played a key role in weaponry and the chemistry of black powder in the fourteenth century. It is suggested that the Book was written by a Swabian who lived between the Danube, Lake Constance, and the River Iller in the south German region of Allgäu.

First the form. Manuscript 362 (Figure 1) is a quarto volume, 30.5 by 21.5 cm, bound with three other different texts in 1444, in a codex within a wooden binding. The pages are a little smaller, 29.3 by 22.0 cm, and they contain six different watermarks. The Firework Book takes up pages 73^{r} to 89^{r}. They were written by Scribe no 6 whose work does not resemble that of the others. The headings for the individual paragraphs are written in red ink, the rest of the text in grey-brown. The date at the end of the text is "anno tricesimo 2", or "in the thirty-second year". Since the paleographical evidence shows the script to be of the mid-fifteenth century at the latest, the year 1432 is indicated, which is contrary to Hassenstein's careless and incompetent suggestion of 1420.

Next, the contents. The text begins with a preface and

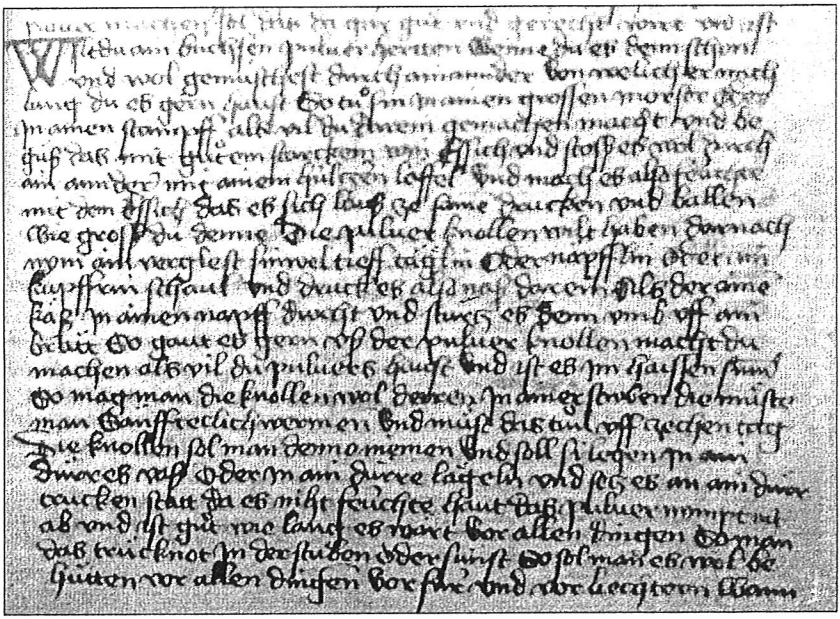


Figure 1 Extract from fol.80r of Manuscript 362 Freiburg. The chapter heading was originally in red but this has since faded. Here may be seen the first description of the 'hardening' and 'forming' of black powder into lumps. The term 'pulverknollen' is to be found in line 9. In modern German these pieces, roughly half-thumb size, are called 'kunkeln'. Reproduced by permission of the University of Freiburg Library.

ends with an epilogue, and an addenda of 26 separate working procedures which originated with the copyist of 1432. The text proper has a short section on weapons and a longer one on black powder, between which was inserted the oldest version of the invention by the pseudonymous "Niger Berchtoldus", and notes on the requirements and characteristics of a gunsmith. This insertion may be considered central to the work because it directs attention back to the preceding description of the heavy wall-[illegible] of stone of the alchemist Niger Berchtoldus, and forward to [illegible] coming section on nitrate chemistry, and the description of granulated powder.

In contemporary German the "Büchse" is a light weapon used by hunters, but in earlier times it was a cannon which fired stone balls on a flat trajectory. Today, it could be referred to as a "Howitzer". The "Steinbüchse" or stonegun was quite different from Chinese and Arab quiver guns because it followed newly-discovered thermo-dynamic laws which in modern practice may be recognized as those of Gay-Lussac: that wherever thermal energy is converted into a reciprocating system this utilises kinetic energy, in this case in the form of an explosion.

author of the middle section. It is to be found [illegible] surrounding the twelve questions at the top of Figure 2, based upon the discovery that heated powder grains kept in a gas-tight seal produced pressures that were previously unknown. These were considerably raised by the part-loading of the powder chamber, and by the granulation of the powder, on which combustion was critically dependent.

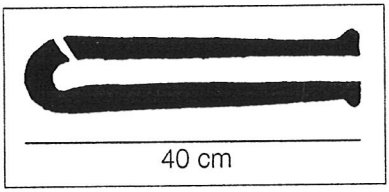
Little is known of the range of weapons at this time. In

Figure 2 The Older Section of the 1380 Text. This was taken by the anonymous author circa 1400 from a 'relic' test and put together as the "Firework Book." Insertions by a first copyist circa 1415-20 are identifiable. The page numbers given above relate to the transcripts of the "Firework Book" in G W Kramer, *Chemie und Waffentechnik,* München, 1995.

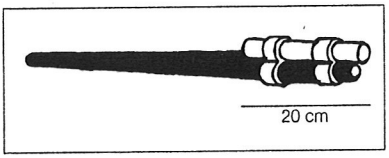
the 1520s the lead balls of the Conquistadores' arquebuses could not pierce a leather jerkin at 50 metres. It is therefore all the more surprising that the Firework Book of 1432 says in folio 88^{v}, line 35, that the range of the stonegun was 1,500 paces, and with more powerful powder was 2,500 paces. Its precursors could not fire heavy stone shot. Needham gives the calibre of Chinese mortars as 6 to 10 centimetres, but these were really arrow projectors.[7] The first stoneguns of 1375 had a calibre of 15 centimetres, and when used by the Venetians against a Genoese invasion fleet at Chioggia in 1380, fired shot weighing 75 kilograms.

How did Niger Berchtoldus obtain a completely gas-

Figure 3 The oriental and early European fire-lances took the form of a simple tube (quiver) with a touch hole/firing vent. They were between 30-50 cm long. The tamping of the propelling charge and the exactness of fit of the projectile were poor. The shooting range was particularly short and the penetration weak. From these were developed the hand-held weapons or arquebuses.

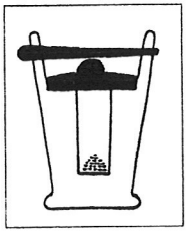


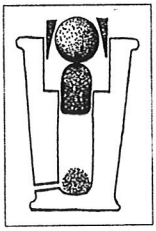
3a Principally for hurling fire arrows during seiges.



3b 'Stangenbüchse' or arquebus, barrel about 15-25 cm long. Referred to as 'Handgone' in Germany in 1338.

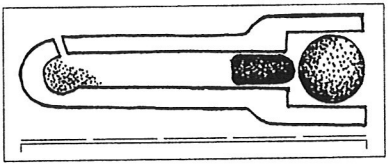
The Steinbüchse was developed by Niger Berchtoldus c. 1375 from a pressure autoclave. Because it could not stand the pressure produced by saltpetre mixtures, he replaced the bolted lid with a gas-tight wedged block. In front of it he placed the rounded stone and wedged it in. So arose the Stonegun. See Ms. 362 fol.74^{v}.





3c (left) Pressure mortar vessel with lid and sealing bolt.

3d (right) The principle of the Stonegun



3e Stoneguns invariably show two different diameters for the powder chamber and the barrel. The "Firework Book" gives us the dimensions, five equal parts, fol 83^{v}.

tight closure in his stonegun? It seems that when experimenting he recognized the explosive power of mixtures of saltpetre, sulphur, and oil in a closed vessel. Realizing the significance of this for weapons technology, he made trial mortars of cast copper. These had a powder chamber of smaller diameter than the barrel, which was sealed by a thick block of lime wood thus trapping the charge in the chamber. The stone shot was placed in front of the block and centred by wedges (Figure 3). The account of this copper mortar distinguishes the stonegun in design and function from its arrow- and ball-throwing precursors, as described by Walter de Milemete in 1326/7.[8] All this is set out in 12 questions in the central part of the manuscript which ends with the words, "Thus the art of gunmaking has been completely renewed and discovered and its functions described – as you will understand from the following text". After a brief extract about the gunsmith, there are extensive references to the chemistry of lime saltpetre (calcium nitrate), sulphur, and charcoal. It must be emphasised that nowhere in the text is there a reference to potassium nitrate. The Chinese and Arabs did not know of it, or the Firework Book would have referred to it in the section on the purchase of imported saltpetre.

In 1388 the first saltpetre plantations were reported in Frankfurt. These were open pits in which calcium nitrate was made – they were alternately filled with straw, leaves, and slaked lime; roofed-over; and irrigated with animal urine for about a year. There were a few other methods of manufacture, but the pit method was the most important in continental Europe until Napoleonic times. The fact that the Firework Book does not mention this development shows it must date from before 1388, and that the copyist of the 1400 version must have used a pre-1388 text. This will later be substantiated with proof.

In this the longest section of the Firework Book there is a description of the purification process by re-crystallization. A distinction is drawn between three types of saltpetre:

1 "Salpetre" = raw nitrate, occurring naturally, mostly imported.
2 "Salniter" = re-crystallized, pure, de-hydrated saltpetre.
3 "Salpertica" or "Salbratica" = highly purified form of nitre which crystallizes on the inside of porous earthern dishes.

The text also mentions double crystallization, which reached a higher degree of purity but was more wasteful of material. The process of clarification usually took place during the re-crystallization. It involved boiling the crude nitrate liquid for several hours. At first sight this section seems not very clear because the author puts in some alchemistry relating to putrification. But on

checking it is clear that boiling has a real purpose – it leads to the partial or complete splitting off of four molecules of water which bind the crystalline formation of the calcium nitrate. Through this the nitrogen content of the calcium nitrate rises, and can even at 14.0% exceed that of the potassium nitrate at 13.86%:

$Ca(NO_3)_2 \cdot 4\,H_2O$		$\xrightarrow{100°C}$	$Ca(NO_3)_2 \cdot 2\,H_2O$	+	$2\,H_2O$
Mol mass:	236		Mol mass:	200	+ 36
N content:	11.86%		N content:	14.0%	

N content of potassium nitrate: 13.86%

What was considered the fantasy of the alchemist is shown here to have a realistic, experimentally provable basis. The purchase and testing of imported nitrate from the Orient shows for the first time by a qualitative test that we are dealing with calcium nitrate. The first gravimetric test of the saltpetre content of a solution was undertaken by Lazarus Ercker.[9]

Working methods are summarized in Figure 2. Calcium nitrate is very hygroscopic and becomes deliquescent during long storage, as must have happened throughout peacetime. The Firework Book therefore contained instructions for the regeneration of saltpetre, in order to minimise the loss of this expensive ingredient. Some instructions refer to the identification and removal of impurities. Saltpetre, particularly from the Orient, frequently had large quantities of cooking salt added. If this was the case it was possible to separate the saltpetre from the salt or sodium chloride with which it was adulterated. It is not proposed to refer to the four instructions regarding sulphur and charcoal. Carbon or charcoal was made by gunsmiths burning old textiles with the exclusion of air. Old linen sheets were particularly suitable for this purpose.

The sections on powder and gun technology which follow provide a clue to the dating of the text. It has already been pointed out that there is no reference to saltpetre pits, which implies a date that is pre-1388. In addition, the measurement of the stonegun given in folio 83^{v} reveals a very short gun such as was only made in the years 1375 to 1385. The length of the barrel of this gun was only that of the diameter of the ball, so that the stone when loaded could be seen protruding. The conclusion is repeated that the Firework Book was written by two authors – the older text dates from circa 1380, the younger from 1400 plus or minus ten years. The latter contains a preface, a central portion with a report on Berchtoldus, and the epilogue. The authors remain anonymous.

The section on powder technology begins with a

description of three types of powder with an increasing saltpetre content. Then follows the most important part of the Book, on the preparation of hand-mixed granulated powder, the grains to be formed by hand in small lumps half the size of a thumb. The text (fol 80^{r} see Figure 1) advises that "In order to harden gunpowder after thoroughly mixing the components, you should place it in a big mortar and pound it with a wooden pestle, after adding vinegar to make it sufficiently damp to allow the making of balls of the size desired. You should press the mixture into a suitable small dish or copper bowl, and then turn the contents out of the mould onto a wooden board, as with cheese making. It should be easily released from its mould. Make as many lumps as you have powder. The pieces can then be dried in the sun, or in a lightly heated room, where the process will take about ten days". This creation of individual pieces suggests we are dealing with artillery and not gun powder.

Next the account of the manufacture of powder for fire arrows is also unexpected, for it shows the old firelances were still of importance. The reason for this appears to be that their higher angle of flight allowed them to transport incendiaries over fortified walls, which the flat trajectory of flight of the stoneguns could not achieve. After this section there are the first instructions for making fuses or sulphur candles by drawing a rope through a mixture of molten saltpetre and sulphur. It should be noted that potassium nitrate cannot be fused with sulphur but that calcium nitrate can.

Passing over the next recipe which was a later addition to the manuscript, we come to the fifth important description. In those days the determination of relative weights was difficult, for there were no standards set in Europe. It was therefore a practical impossibility to set out in a text book the given weights of powder mixtures. The author solved this problem in an intelligent and original manner. On a balance with two equal quantities of saltpetre, one was removed, and replaced with sulphur. The sulphur was then taken and weighed first half and half and then quarter and quarter. The charcoal was then weighed in a similar manner. It was thus possible to obtain a powder in the mixture of 4:2:1, or in other proportions required. It was only a question of patience.

The next section on working procedures deals with the regeneration of damp powder or the correction of faulty powder mixes by five methods. Another four procedures are described for igniting the powder and making more powerful propelling charges. The chemistry of powder is described in folios 81^{v}–83^{r}, followed by instructions on how to make wedges, and the important notes mentioned earlier on the measurements of the stonegun which help

to determine the age of the text. Finally there are instructions on how to make fireballs, petards, and, on folio 85r, flare shells for night firing. Altogether there is advice on 60 procedures in the chemistry and technology of powder making. Between 44 and 47 are original, whilst between 10 and 13 may date from about 1415, and may be the work of a copyist.

Finally, the addenda of 1432 which follow the epilogue may be of interest. They are in folios 85v–89r (Figure 4) and consist of 26 unrelated paragraphs. They describe a few variants such as self-igniting red or white powder, together with features of interest

Folio	Lines	Contents
85v	34	Defence against enemy wall demolition
86r	20	Defence against enemy at close quarters
86v	1	Self-igniting powder
	8	White gunpowder
	15	Red gunpowder
	20	Powder for fire arrows
	32	Making deafening shots
87r	5	Loading a gun for long range shots
	15	Proper mounting of guns
	23	Making good tinder
	29	A slow burning smouldering fuse
87v	2	Half- to whole day time fuses
	14	Production of sulphuric acid
	26	Production of nitric acid (curtailed)
87v	31	Firing with poles
	40	Firing a fusillade
88r	10	Making and firing "bristling guns"
	18	Liquid propellant which fires up to 3000 feet
	33	About shooting range of various propelling charges
88v	1	Safety rules for loading and firing
	6	Producing an intenisfier
	20	Loading a stonegun as a blockgun
	36	Burning down a wooden buttress
89r	11	Incendiary shot
	19	Strong shot and burning projectiles
	36	How 'water' is ignited (only heading remains)
		End of the "Firework Book"
		Year: "anno tricesimo 2"
		Paleographic dating: 15th century

Figure 4 The Addenda of the 1432 Copyist. These comprise 26 randomly-ordered work procedures and directions

such as a time fuse for detonating powder, a liquid propellant which projects stone balls up to 3,000 feet, and the "Klotzbüchse" or Blockgun for firing several shots. The extracts also contain a recipe for nitric acid and for concentrated sulphuric acid, referred to as sulphur oil and produced by distilling a mixture of sulphur, very pure saltpetre (salpratica), and a little vinegar until droplets are formed in a condenser. This procedure should not be used with potassium nitrate, for when this method was tested in a laboratory a stream of sulphur trioxide was obtained, which shows that the recipe is none other than the well-known "lead chamber process" used by John Roebuck in London in 1750.[10]

This completes the survey which reveals the fundamentals from which modern powder technology grew. The Firework Book represents an historical turning point, when the first systematic description of the steps involved took the place of the uncertainty and ignorance of the earlier European phase.

The man who is described by the author of the later text as the inventor of the stonegun and of granulated powder was Niger Berchtoldus – to whom also is attributed knowledge of the chemistry and technology of powder making and its use. In a copy of the manuscript in Vienna a reference dated 1444 has been found, which states that Niger Berchtoldus invented the powder and the gun in 1380, and that for his inventions he was executed by the Kaiser Wenceslas in 1389. He is also described as a monk of St Bernard, named after Bernard of Clairvaux and an Order which was involved in mining and metallurgical engineering. It may be assumed that he took refuge in his Order between 1380 when his stonegun was first used by the Venetians for military purposes, and 1389.[11] This may explain the silence of contemporary sources, and perhaps suggests that the older version of the manuscript is Berchtoldus' own. The use of the first person singular and the note in an abstract "written by Berchtoldus" point to that. Thus the Firework Book evolved, the ownership of this dangerous manuscript passing anonymously from one gunsmith to another until the situation changed decisively with the Reformation.[12] The taint of alchemy associated with powder making was then dispelled and a version of the Book was published in 1529.

Gunpowder - The History of an International Technology

WASC 454

CHAPTER 5

THE ROYAL ARMOURIES "FIREWORK BOOK"

Sarah Barter Bailey

The copy of the "Firework Book" in the Royal Armouries Library (Manuscript I. 34) is made up of three parts. The first is a version of the classic German Firework Book text. To this has been added a series of incendiary receipts of a type similar to, but different from, those contained in the main text, and a group of illustrations which do not illustrate the main text, but which are related to the subsidiary text. The manuscript is not unknown to the literature: older works refer to it as being in the Hauslab library and one or two of its illustrations appear in the classic nineteenth century histories of early firearms. It entered the collection of the Royal Armouries in 1950, thanks to the generosity of the National Art Collections Fund. It has not, however, to my knowledge been described in any detail in this century.

Physically, the manuscript consists of 140 leaves, small foolscap in size, which were foliated at an early date and from which four leaves were removed after the numbers had been inserted. It is made up of 12 gatherings, of which the first seven and the last one have the watermark of a crenellated tower and the others that of a version of the famous "Ox-head", with a flower between its horns. According to G Piccard *Wasserzeichen*, (Stuttgart, 1966, 1970) both of these watermarks were in use about the year 1450 in southern Germany and in the regions served by the trade routes across the Alps.

As indicated above, the main text is a version of the standard Firework Book text. It begins with an invitation to any ruler who wants to know how to defend his territory or attack his enemy to consult "*disem puch das do haist das fewrwerk puch*" [this book that is called the Firework Book]. It continues with the 12 "Master questions" that a gunner was supposed to be able to answer, in a

literature, Max Jähns, considered to be early and perhaps to date from before 1445. It then goes on to give a string of advice, receipts and instructions, which vary from the practical details of how to choose and prepare saltpetre or sulphur, how to store it and keep it in good condition and even revive it if it should suffer from damp or adulteration. What type of wood to use for charcoal, how to produce complicated incendiary devices both for war and for celebrations, where to obtain various ingredients – some were apparently simply to be acquired from "the apothecary" – and what the skills and moral qualities of a good Master Gunner should be: all of these topics are touched upon. The order of the various sections differs somewhat from that given in the standard reference books, or from that in the early-sixteenth century printed version, but this is not unusual. Many of the receipts, moreover, are repeated or a variant receipt is given for a similar device as if the compiler was adding to the collection or improving it as he compiled it, without taking the trouble to go back and eliminate duplication. The hand however is a regular copyist's hand not that of a man making a series of scribbled personal notes.

The second text follows on immediately from the first, without any specific introduction. The first text ends with the phrase, "*Et sic est finis*" on page *li* recto, the second begins on page *lii* recto with the somewhat informal ritual question, "*Wiltw ein hqflich kwnst machen ...*" [Do you want to know how to make a clever device ...]. Each receipt starts in the same way, outlining the purpose of the receipt and then going on to say, "*Wiltw dise vor geschriben veur machen, so volg disem nach geschriben kapitell noch ...*" [Do you want to know how to make the fire that has just been described, then carry out this next chapter of instructions ...]. The script is different and the dialect and spellings are different from that used by the compiler of the first text, and the advice given is strictly limited to receipts for various incendiary devices and a little advice on gunnery, but there is none of the extraneous advice contained in the first text. It is strictly a receipt book laid out in a logical manner, listing the ingredients at one side and then outlining the method. It ends as it began, without formality: after ten pages of receipts it simply stops.

After about twenty blank but ruled and numbered leaves, the illustrations, which are the most characteristic section of the volume, begin, on a new gathering, with a change of water-mark. There are no captions and no very identifiable order. They are lightly coloured, appear in general on both sides of the page and some are, it must be admitted, neither very accomplished nor always very clear. Certainly the artist had very little idea of how to represent

perspective nor could he always indicate clearly how the different parts of the machine that he illustrated fitted together. The scenes however are lively enough and sometimes exhibit a simple sense of humour (Figure 1). They do not appear to relate at all closely to the text, although they show related subjects, and the whole collection could be asssimilated to the well-known group of German manuscripts illustrating machines which were derived ultimately from Conrad Kyeser's *Bellifortis* of 1405, except that the second text does in fact refer to some of the illustrations. Page numbers have been inserted into spaces that were left in the text as it was copied, in a way which seems to show either that the copyist knew of the existence of the pictures, or that some at least were being carried out in accordance with a definite programme. The emphasis of the illustrations is however almost entirely military, with none of the inflatable beds and diving equipment, nor any of the interest in matters astrological, that many other collections show.

Although there is no apparent order governing the arrangement of the fifty-four pictures, there are certain identifiable groups. They are not however usually grouped together in the manuscript. The most individual are two groups of scenes, one showing attacks on fortresses, the other the Master Gunner preparing his equipment. The first group (Figures 2–4) are siege scenes, illustrating the use of firearms, both hand guns and artillery, and incendiary missiles, for attack and defence, together with two showing cunning stratagems that can be used in such situations. To an extent these illustrate the written text in that they show the devices described in use. They also, of course, often show the Master Gunner, usually to be identified by his costume and more especially by the feather in his hat, prominently in action, apparently directing operations.

A group, connected to the first, consists of a series of military machines and devices, some of which have been seen in use in the illustrations of siege scenes. In some, the artist makes use of the technique of "exploded" drawing to show how some of these devices are made up (Figures 5–7). There are also illustrations of swinging shields for gunners and wheeled and basket-work shields for siege-workers, as well as the personal type which resemble a beehive held over the head and body, so that only the feet can be seen, whose advantages and disadvantages have already been shown. The most detailed of this series of illustrations may show the construction of the most famous of the military machines of the time, the "Hussite war cart". A few illustrations, perhaps half a dozen out of the total number, are civilian in character. They all resemble machines and devices which appear in manuscripts of the *Bellifortis*

type and exhibit nothing unusual. They could have a military use, but they were basically straightforward machines which interested many engineers of the period. There are for instance carts of varying types, which would obviously have both military and civilian uses. There are three water-raising machines, one pump and two sets of wheels with water scoops, and there are two lifting devices and what appears to be a pile-driver (Figures 8–12).

A group of eleven illustrations show some of the various types of carriages that were being evolved for guns and even mortars of various sizes. Both carriages and guns are relatively simple. There is an "organ" gun, but there are none of the revolving carriages for them that are to be found in some of the more elaborate manuscripts of the period, and there is only one gun that may be double ended. Again, some of the carriages are divided into their component parts, as if to show, or remind, the Master Gunner how to assemble them (Figures 13–15).

Three illustrations relate to more technical matters. Two (Figures 16–17) show methods of boring guns and a third (Figure 18) what may be some form of heat treatment, perhaps annealing. Unfortunately, the text does not include anything which appears to explain what is involved in any of this. Only a few of the comparable manuscripts include the gun-boring illustrations and even fewer seem to have discussed gun manufacture. All those manuscripts which include the gun-boring illustrations do appear to show the same methods of boring. The heat treatment illustration seems to be unique.

Finally, there is a whole series of illustrations of incendiary devices and how to assemble them. Some (Figures 19–20) simply show the methods of packaging for delivery of the incendiary mixtures described in the text, but the most interesting of all from the point of view of the present volume is the sequence (Figures 21–27) which appears to be unique to this manuscript. It shows the preparation of these devices, from the weighing out of the ingredients and preparation of the materials, to the grinding and mixing of gunpowder and other ingredients, the preparation of the cases and arrows for fire arrows and their assembly and the assembly of other incendiary projectiles, all under the supervision of the directing Firemaster or Master Gunner.

Having described it, it seems worth asking what purpose this manuscript was expected to serve. It is one of quite a large group to have survived in the libraries of Europe, which include what may be called the classic Firework Book text, describing the duties and skills of a Master Gunner and providing receipts and technical advice for the manufacture of gunpowder and

its incorporation into fireworks for military and civilian use. This is, I believe, the type described in Dr Kramer's paper. They differ from later gunners' manuals in that they seldom include much information on the actual guns for which the powder is intended. They are, however, often combined with other works of military advice, and with illustrations of machines and other mechanical devices, including guns and gun carriages. They vary in size and elaboration, and their texts vary in detail and in accuracy of transmission, but they must always have represented a considerable investment in time and/or money. Most of them, for instance, are written in a formal hand, implying the use of a trained scribe or of a well-educated gunner with the time and inclination to copy what he needed from a recognised authority. Again, the illustrations are often elaborate and very detailed; some of them include captions, sometimes indeed attributing a particular device to a particular man, but many like Manuscript I.34 do not. They are occasionally signed by the Master responsible.

The obvious suggestion is that they were the fifteenth century equivalent of the later printed books on gunnery and other technical subjects which started to appear during the sixteenth century or that they were the equivalent of the notebooks which, at least in Britain, apprentice or later cadet gunners were expected to compile during their training and to present as part of the proof of their competence. Professor Hall of Toronto University, however, has suggested that they may in fact have served as the sample portfolios of what a skilled Master Gunner could offer his potential employer. One can elaborate this suggestion by saying that the insertion of the classic Firework text proved that a Master Gunner had been properly trained, while his own additions and illustrations showed what use he could make of his training. Leonardo da Vinci's offer of his military skills to a potential employer is famous, but he may simply have been one of many who sought such employment, showing not only their practical but also their theoretical skills.

Figures 26 & 27 ff lxxxviiij, *r* (inset) and *v*: These two show the preparation of other devices, including long coiled tubes with a globular container at one end, balls covered with a rope-like material which is presumably inflammable, and the distillation of some unidentified ingredients.

Bert S Hall

Historians are accustomed these days to note how often technologies change profoundly during the early period of their histories. Like adolescents trying out political causes, new technologies often appear in many guises, not all of which are ulitmately fitting. The favourite example is the motor car; before 1915, more than 1,000 marques had already appeared, and in many variations – some with steam or electric propulsion. But just as teenagers usually grow up to be stable, responsible adults, so too technologies mature into stable configurations. By 1920, "everyone knew" that a motor car was made of metal, had a petrol engine, a multi-speed transmission, four wheels with rubber tyres, and so forth.

Mutatis mutandis, similar views can be held regarding early firearms. Between the mid-fourteenth and mid-sixteenth centuries there are dramatic changes: the fourteenth century's squat, forged iron, stone-throwing bombards gave way to the sixteenth century's long, cast-bronze culverins firing iron shot. Likewise in small arms, the aptly-named *ribaldos* or organ guns mounted on tumbrils yielded to true shoulder arms and even the earliest pistols. Where an older historiography saw in these developments only the inevitable march of "technological progress", we can detect evidence of a hearty new technology in the midst of its growing pains.

Looking at firearms in this way suggests new and interesting questions. What dynamic drove these developments? Which changes were primary, and which secondary? Upon reflection, it becomes apparent that changing techniques of manufacturing gunpowder played an important role, above all the corning of gunpowder. Corning or "graining" produces gunpowder in granular form, quite unlike the finely-pulverized or "mealed"