Medieval Gunpowder Research Group

Investigating incendiary devices

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Introduction

The Ho Group, dedicated to the investigation of medieval gunpowder, met in August 2008 to investigate medieval and early modern incendiary devices. Our primary focus was to look at the recipes for fire arrows in the firework book of Johannes Bengedans and the fire lance described by Biringuccio in his book Pirotechnia.

Fire lance

The fire lance, or fire tube, was probably a weapon first developed by the Chinese in the 12th or 13th century and used subsequently in Europe. However though we know that they were being used we have no recipe or a description of how they were made till the account by Biringuccio in his book, Pirotechnia, of 1540. In it he describes them as follows

> *So that you may know how such things are made I wish to teach you both. The bodies of these are made of wood, although the tubes could be and indeed are also made of Lombardy iron or of sheet copper. Make it of any of these things that you wish, for each will serve you. To do this, make a wooden tube about one and a half or two braccia long. This is sawed in the middle and a channel is cut out in each part, exactly half the diameter and half the circumference of a ball you have chosen. It should be as large as those playing balls known as Florentine. At the foot make a plug of wood to close it, but with a hollow in the middle like a socket, so that it can be fastened to the end of a pole. Over the whole of this tube, if it is of wood, wrap good annealed iron wire, with one wire lying close against the other, or a thin reinforced string. If it is made of sheet it is strengthened with five or six little forged and welded bands of iron. If I had to make them, to save expense and to make them lighter, I would make them of paper, wrapped with several folds, and I would paste the last folds either with paste or with a glue of hide scrapings; and for greater strength I would also apply iron wire all over.*
>
> *Of whatever you have made this tube or may wish to, it is filled in this way, unless indeed you wish to fill it with a single composition. First put four dita of good gunpowder in the bottom, and then put in a little ball made of tow or cloth rags and filled inside with good fine powder. The ball has one or two little holes and it is covered with pine resin, sulphur, and some powder. Then above this put dita of coarse powder composed of Grecian pitch, crushed glass, coarse common salt, roughly crushed saltpetre, and sawdust of dry elm or ground iron scale, and press it well with a ramrod. On top of this, then put two dita of fine gunpowder and press it; on this put another ball made in the same way. Thus, four dita at a time, proceed to fill the whole inside of your tube up to the mouth. When it has thus been filled, it is covered with a little tallow of with a plug of cork or paper so that the powder may not run out when it is handled. When these tubes have been made in this way, they are put on the end of a pike or other long pole and fastened with two nails at the foot. Then, when you wish to use them, fire is applied through the mouth with a fuse or with a little gunpowder.* (Biringuccio, Pirotechna pages 426-7)

For our reconstruction we made a wooden lance reinforce with iron bands. Biringuccio describes the bore as being as 'large as those playing balls known as Florentine' and we made ours 30mm in diameter.

For the 'good gunpowder' we used a small grain modern black powder. However it was the 'little balls' and the 'coarse powder' that proved problematic. Though Biringuccio tells us what is in the coarse powder, saltpetre, sawdust, glass, pitch and salt, he does not provide any quantitative data. On the face of it we were, to say the least, sceptical about a mixture like this burning at all. After discussion we decided to try a mixture composed as follows:

	First mixture %	Second mixture %
Grecian pitch	25	3
Crushed glass	1	1
Salt	1	1
Saltpetre	70	70
Sawdust	3	25

We made up a 100g of the first mixture and packed it into a short cardboard tube, 100mm long with a bore of 20mm, to test it and were not greatly surprised when nothing happened and it did not burn. After discussion we decided to try a second mixture, as given above, and, to our surprise, found that this did work – about 50mm of the mixture packed into the tube burned for some 30 seconds. After our initial trial we decided to try to improve it by thoroughly drying out the sawdust before use. Unfortunately after testing we were not convinced that it worked any better but for all our tests we used dried sawdust.

The coarse powder – unlike blackpowder it is very pale in colour

A test with the coarse powder showing that it burns slowly

We now had a good approximation for the slow burning coarse powder which we felt closely approximated what Biringuccio was describing. However the small balls he describes proved to be more of a problem. He says that they are 'made of tow or cloth rags and filled inside with good fine powder. The ball has one or two little holes and it is covered with pine resin, sulphur, and some powder.' We took a circular piece of coarse cloth, about 100mm in diameter, put a small amount of modern small grain powder on the centre and then tied up the cloth to make a small ball, roughly 30mm in diameter.

The small balls

The next problem was how to cover it in pine resin, sulphur and resin? Our first attempt was The next problem was how to cover it in pine resin, sulphur and resin? Our first attempt was to heat up some pine resin (colophon) to which we added a small amount of sulphur, dip the balls into it and then roll it in meal powder (finely ground powder). On cooling the pine resin made a very hard, brittle coating. We conducted a test using a short length of tube using three of these together with a small amount of fine grain powder and coarse powder as directed by Biringuccio. We tried several experiments but in each the powder in the ball exploded while still in the tube resulting in an explosion of which was so strong that the next portion of coarse (slow) powder was not ignited. The problem seemed, to us, to be that what was required was a way to delay the burning of the ball until after it had left the tube. After some discussion we decided to make the coating in a different way – by dissolving the pine resin in alcohol to which we added sulphur, dip the balls into it and then roll them in meal powder. This did not solve the problem and on testing the balls again exploded in the tube itself.

In order to check that this was what in fact was happening we conducted a trial using balls filled with salt. This worked well, the balls being shot out one at a time from the tube indicating that the problem was that the powder in the balls was igniting too soon.

Our final test of the fire lance

Fire arrows

Fire arrows were relatively common weapons from at least the 15th till well into the 17th century. They appear to have consisted of a pouch attached to the front of the arrow and have been used to set light to the equipment and buildings of the enemy. Just how they worked has not been the subject of much research and it is not at all clear. For example was the arrow set alight at the outset so that is continued burning during its flight or did it ignite in some way on impact; and what was the contents of the pouch, or sack. We decided to use the manuscript, by Johannes Bengedans written in the middle of the 15th century. This illustrated book found its way into the Royal Danish Library and was recently published in facsimile. Bengedans includesseveral fire arrow recipes and we decided to try three of these to see how they worked and what problems they involved.

First fire arrow

The first of these was as follows:

Take some fustian or linen and make a small bag - 1 big inch wide, 3 fingers long. Take 5 pound good saltpetre and apply 2 pounds of sulphur. Add 1 pound finely crushed coal, 2 lod camphor and 1 lod amber. Mix it all with alcohol. Fill the bag and press it tight together. Take the iron tip and press it through the bag. The bag is secured with string.

Take 2 pound sulfur, 1 pound resin and ½ pound normal pitch. Let it melt over the fire – put the arrow into it.

When firing the arrow, the bag should be opened a bit on the front and set on fire.

We made up some small bags as described though we made them slightly larger in the middle than at the ends – something shown in all the images of fire arrows. We then mixed saltpetre, sulphur and charcoal in the proportions given – 5:2:1 – and then added camphor and some crushed amber in the proportions given in the recipe. We then added a small quantity of alcohol to form a loosely adhering ball and then pushed this through a coarse sieve – with a mesh of about 5mm. The resulting grains of powder were then dried in the sun.

Mixing the fine powder with alcohol

After pushing the ball of powder through a sieve it was left to dry in the sun – the largest grains are about 5mm in size

The next day we then made up two trial arrows. The first using the powder as we had made it with grains of about 5mm in size, the second using the same powder but ground up very finely. We followed the instructions given by Bengedans and first filled the small bags with the powder. We then pushed the iron arrow heads through the bag and secured it at top and bottom with string. Following the illustrations we then wound a thin cord around the bag so that the powder was compressed tightly.

A fire arrow from Johannes Bengedans

The arrow with the bag full of powder attached

Detail of gunpowder bag tied with string

We then mixed sulfur, pine resin and pitch together in the ratio 4:2:1 (2:1:½), heated it till molten and coated the bag of powder as described in the original text. On cooling this formed a hard, black coating.

The completed fire arrow head

The question we had to address then was how this was set on fire? An experiment to determine whether the coating would burn proved unsuccessful, much to our surprise. We had speculated that the coating would burn and this would provide additional flammable material making the fire arrow more effective. This left the problem of how to ignite the arrow. The original text says that: 'if you want to fire the arrow, you must cut it open at the front . . . and ignite it with a coal [charcoal].' The problem we could see was that the powder inside could take the fire immediately and explode before it was fired. In order to test what actually happened when the arrow was ignited we stuck one into a piece of wood and ignited it at the front with a piece of modern fuse. The result was that the contents of the bag burnt very fiercely and quickly – in perhaps 2-3 seconds at most. This still left us with the problem of how to set the arrow alight – a problem we did not succeed in solving.

We carried out a number of tests with the arrows set into a wood support and ignited with a fuse. All, using the fine and coarser grain powder, burned fast with a great deal of flame. In all cases the coating did not catch light though in some it melted and dripped down. In one, where the coating was particularly thick, the fire was very much directed forwards at the 'target'.

Second fire arrow

The second fire arrow recipe we attempted to make was as follows:

½ pound finished gunpowder. 4 lod greek pitch, finely crushed, 2 lod amber – finely crushed, put the pitch into it and mix.

½ pound pure linseed oil, 4 lod oleum petroleum. Mix the two oils together with the gunpowder. Make a lump out of it.

Take a bag as before. First put gunpowder in the bag. Then add some of the lump you made – the size of a walnut – fill more gunpowder into it so that the lump is in the middle. Put string around the bag and melt pitch and sulphur and put the bag into the mix. Take the iron tip and put it through the bag. Must be used within four months.

We made this mixture up as directed and added the oils. In order to test it before continuing we tried to ignite a small ball of the powder/oil composition. However we could not make it burn at all – in fact it extinguished a lighted match so that this fire arrow was abandoned.

Third fire arrow

The third mixture was as follows

6 pounds saltpetre
2 pounds sulphur
1 pound coal – keep the coal separate, grind it very fine, add alcohol and dry it in the sun
1 lod pure camphor, grind it very fine on a stone
1 lod pine resin
1 lod amber
1 lod mercurium sublimatum.
Mix with the gunpowder and make an arrow as described before.

We made up this mixture using the proportions given and, as in the first fire arrow, after adding the alcohol we pushed the wetted powder through a coarse sieve before drying it in the sun. We then made up fire arrows as in the first tests and tested these using a modern fuse to ignite them. As expected they behaved very like the first fire arrow and the mixtures burned very quickly – in just a few seconds.

Conclusions

These tests stimulated a great deal of discussion about the way that the fire arrow was supposed to work. If the incendiary mixture was to burn while in flight it was probable that the bag of powder would burn away before it reached its target. Was a fuse used? We could see no evidence for it in the text. Was the idea to set light to the coating and this would ignite the powder on impact? In our tests the coating was not flammable so this was not possible but perhaps we had used the wrong ingredients? Very striking was the way that when the coating was very thick and hard the burning flame was directed forwards at the target – was this deliberate? What was the coating for? To preserve the fire arrow and its contents from water and moisture perhaps – but then why add sulphur to the mixture? Was it supposed to burn on impact and add to the effect of the arrow itself – the speed at which the contents burned was fast so that a slower burning coating would be an added bonus to the fire arrows effect.

In some ways our experiments have thrown up far more questions than answers. What we have managed to do though is to bring up many of the problems of fire arrows and we will need to go back to the original texts and check them again in the light of our new knowledge.

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