



Design Notes...

Page 1



Time Fuse and Spolettes

Introduction:

There is probably no component more critical to the proper operation of any pyrotechnic device than it's fuse. This is especially true with aerial shells, where the fuse serves not only as an ignition device but also as a delay element.

The two types of fuse most commonly used for timing and ignition in aerial shells are time fuse and spolettes. These devices have three primary functions: 1) take fire 2) provide delay and 3) pass fire. This article will take a look at the design and construction of both commercial time fuse and home-made spolettes, as well as the advantages and disadvantages with each of them.

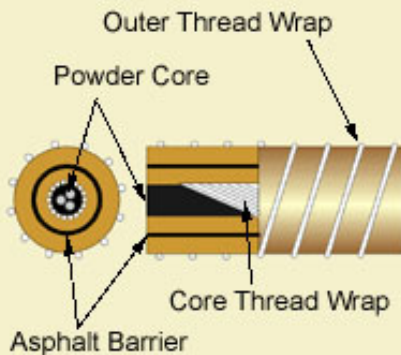


Figure 1: Cross section of typical Chinese time fuse.

Time Fuse:

Commercial time fuse is a type of mass produced fuse that is purchased in continuous rolls that are then cut to the desired size when needed. Several varieties exist, such as Japanese time fuse, Chinese time fuse, Bickford etc. While Japanese time fuse is the best quality available, the lower cost and availability of Chinese time fuse makes it the most popular choice for the hobbyist.

Time fuse is fabricated using a machine that produces continuous lengths of a cord-like fuse constructed as shown in Figure 1. A central powder core containing cotton twine coated with black powder is shrouded with a tight wrapper of small threads. This helps seal any gaps between the powder core and the paper cover that is formed around it, thus preventing unwanted fire propagation that would render the timing unreliable. Two kraft paper sleeves are tightly wound around the powder core, with a thin layer of asphalt between them. The asphalt creates a moisture barrier so that moisture absorbed during gluing and pasting does not absorb all the way to the powder core and damage the fuse. A final wrapping of twine helps keep the paper sleeve from unraveling during storage and use.

The burn rate for typical time fuse runs between 2 and 3 seconds per inch. Since the burn rate can vary even between different batches from the same manufacturer, it is always best to time a sample from a given spool prior to use. This is done by burning a longer piece, such as 10 inches or more, then dividing the burn time by the number of inches to get your rate.



Figure 2: Methods of priming time fuse for taking fire.

Priming:

Figure 2 shows the three most common methods for priming time fuse so that it easily takes fire. Both ends of the time fuse are prepared in the same way, with the distances between the ignition points carefully measured to achieve the desired delay.

The first method involves punching a hole through the fuse at least 1/4" from the end of the fuse, then threading it with a small stick of black match. The time fuse is then squeezed at the junction to make sure the stick of match can not slide out from the centrifugal forces generated when the shell spins through the air. This method, known as "cross-matching," is fast and reliable, making it the most commonly used.

The second method, commonly used by the Chinese, relies on a slurry prime of black powder applied to both ends of the fuse. The ends of the time fuse are often cut at an angle in order to increase the exposed surface area of the powder core. While this method is faster than cross matching, it is less reliable. It is common for two redundant fuses to be used for each shell to insure ignition when using this prime method.

Another cross-matching method involves slicing the time fuse down the center from each end, inserting the cross match stick, and then tying the end closed with a piece of twine. While this is the most laborious method, it does not require any special punch tools and also insures that the cross match is held firmly in place.

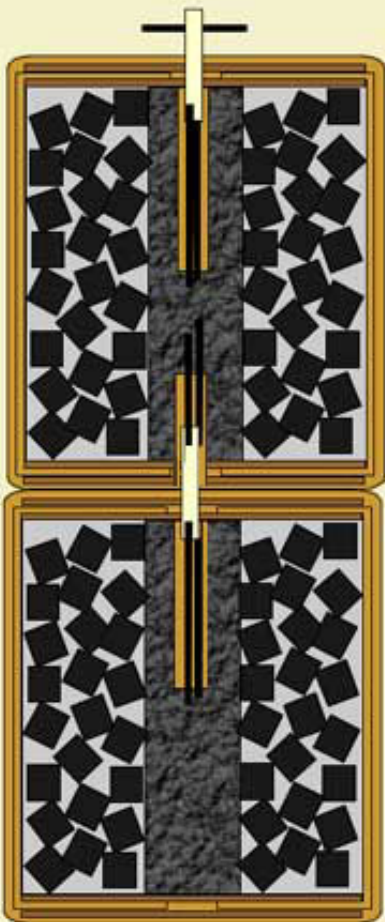


Figure 3: Time fuse used for two or three break shells.

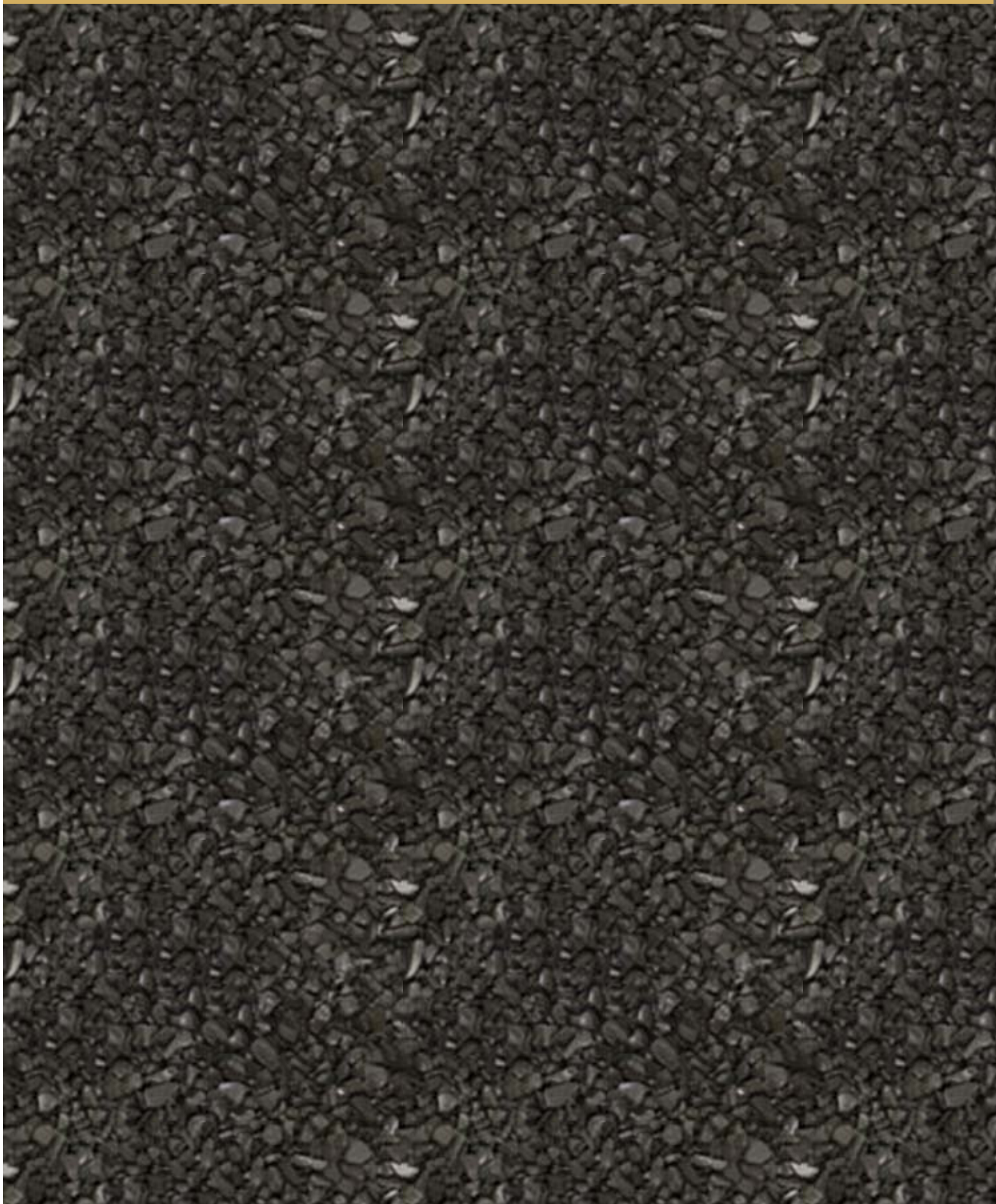
Applications:

The popularity of Chinese time fuse is due to the fact that it is cheap and easy to use. While spolettes have to be manufactured one at a time by the hobbyist, time fuse is merely cut to the proper length and installed. The smaller diameter of time fuse also makes it less likely to blow into the casing from lift pressure or burst pressure in multi-break shells. There is also no risk of the powder core blowing through from lift and burst pressures, as is the case when using spolettes.

The main limitation with time fuse occurs when very short delays are needed, as when building multi-break shells. As seen in Figure 3, time fuse can be used for two and even three break shells where the delay between breaks is long enough to allow at least a 1" segment of fuse between cross match points. But as the number of breaks increase and the delay requirement decreases, the length of the fuse shrinks to the point that it can not protrude through the layer of paper, twine and disks that pile up where two breaks connect.

Other limitations with time fuse, when compared to spolettes, include a less vigorous transfer of fire to the inside of the shell, less precise timing and an inability to show the shells trajectory once fired from the mortar. However, as evidenced by the fact that commercial shells almost exclusively rely on time fuse, this type of fuse still performs quite well.

[More...](#)





Time Fuse and Spolettes...

Page 2



Figure 4: Typical spolette and placement in a canister shell.

Spolettes:

Spolettes are the traditional fuses used to transfer fire from the lift charge to the inside of aerial shells. The concept is quite simple: a small tube is charged with powder of a known burn rate such that it ignites at one end when the shell is fired, then burns through the other end when the shell reaches the proper height.

Figure 4 shows the construction of a typical spolette. The charge typically fills less than half the tube, depending on the delay requirement. Several sticks of black match are inserted into the tube and held in place with nosing paper and twine. The matched end is inserted into the shell, while the flush end protrudes about a half inch or more from the top of the shell. The flush end of the spolette is prepared by first scratching a line or two into the powder charge, which helps give the smooth, hard surface of the rammed powder some edges to aid in fire transfer. A stick or two of black match is then tied directly across the top of the spolette so that it comes into contact with the powder core.

Spolettes are usually made from thick walled tubes of strong virgin kraft paper, which are rammed with the appropriate increment of commercial meal powder to give the desired delay. The powder must be rammed tightly into the tube, since there are no clay plugs to hold the charge in place in the presence of high pressures such as those caused by lift or burst activity. Because spolettes must be rammed very hard, thin walled tubes or tubes made from inferior paper will split open during ramming.

Since tube strength is required only for loading purposes, as spolettes do not generate internal pressure the way a rocket does, lesser quality tubes may be used if they can be loaded without splitting. One trick to using cheaper tubes is to use a ramming block as shown in Figure 5. The block must be thick enough to support the tube for the entire length of the powder charge, and may also need to have a clamping mechanism that can be loosened once the loaded tube is to be removed.

The fastest burning meal possible is used due to the fact that the delay time is often only three to five seconds, which would result in a very thin charge if slow burning powder were used. Small powder charges present a problem known as "blow through," where the forces from lift or the burst pressure in a multi-break shell can blow the charge out the bottom of the spolette and ignite the shell contents prematurely. The smaller the charge is, the less friction there is between the powder core and the tube walls to hold the core in place while under pressure. Blow-through forces are also reduced by using a smaller I.D. for the spolette tube, which provides less powder surface area for the pressure to act on. Spolette tubes with 1/4" I.D.s are often used for this reason.

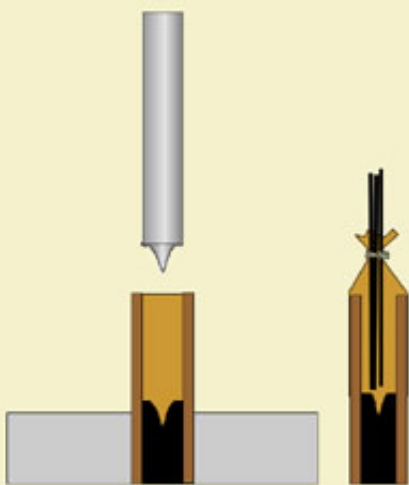


Figure 5: Rammer and base for making cavity on passfire end of spolette.

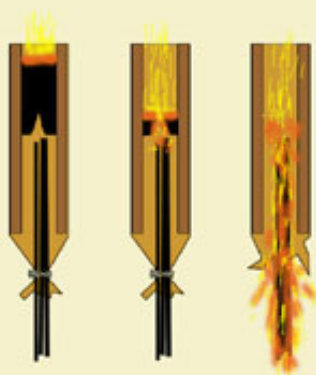


Figure 6: Improved fire transfer using the cavity.

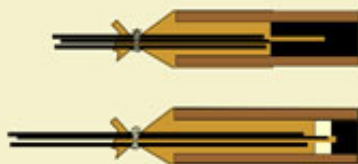


Figure 7: Two methods of avoiding blow-through when using spolettes with short delays that require small powder charges.

Improved Fire Transfer:

Figure 5 shows the use of a special spolette rammer that gives the final powder increment a conical cavity. The purpose of this cavity is to improve the fire transfer between the powder core and the black match that sits against it. Figure 6 shows the fire propagation from the end that takes fire to the end that gives fire. Note that at the point where fire breaks into the conical cavity, there is still burning comp left in the tube to keep fire directed at the match pieces. Without the cavity, only a brief burst of flame is generated at the instant the last bit of powder burns up, giving the black match less chance to ignite.

Using Small Delays:

Because spolette tubes can be any length regardless of their delay times, they are ideally suited and essential to building multi-break shells containing three or more breaks. However, as powder charges shrink below 3/4" in length, additional precautions must be taken to prevent blow-through. Figure 7 shows two methods that help prevent blow-through when using small delay charges.

The first method involves making an excessively long charge and then "drilling back" the charge on a drill press. A small hole is drilled such that it stops where the delay charge would have stopped if only the required amount of powder was used. This allows the additional support of the extra powder gripping the tube walls while still transferring fire at the instant the flame front reaches the vent hole.

The second method involves using a clay bulkhead to support the powder from behind. The clay bulkhead also has a vent hole drilled through it and slightly into the powder charge using a drill press as before. The advantage to this method is that the powder charge does not need to be rammed as hard and less powder is used. The bulkhead is rammed on top of the powder until the tube bulges out slightly, which will provide adequate support even if thin walled tubes are used. The disadvantage to this method is less fire transfer to the black match compared with the first method. It is recommended that one stick of black match be inserted all the way into the vent hole to help insure fire transfer.

[More...](#)





Time Fuse and Spolettes...

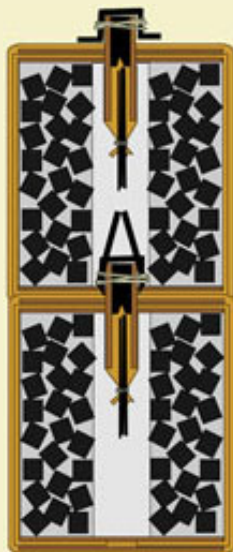
Page 3

Spolette Orientation in Multi-Break Shells:

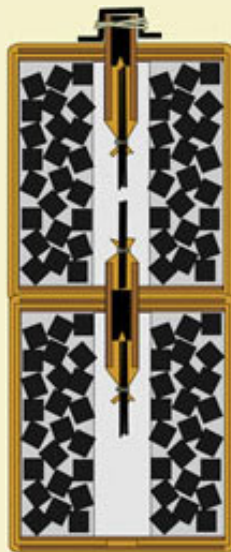
The following illustrations show various methods of orientating spolettes between successive breaks of a multi-break shell. Each method has its own advantages and disadvantages, which will be discussed here. Note that the orientation for the spolette in the first break does not change regardless of how the inner spolettes are arranged.

Method 1:

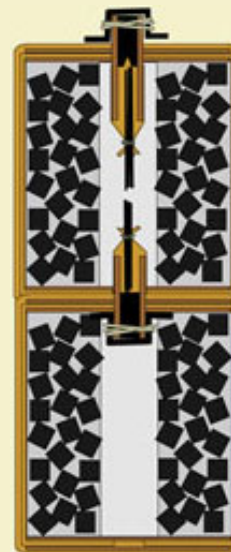
The first method uses the same spolette orientation in both breaks, which is an advantage in itself since the builder has one less thing to remember. The second spolette is prepared in the usual way by scratching the powder surface and tying sticks of black match across the top. The main difference is that the black match sticks are much longer, so that they can be bent up around the top and tied together over the spolette to form a pointed "tee-pee" configuration. More twine is wrapped around the spolette to hold the bent pieces of match tightly against the side. The bottom disk of the first break has a hole that is at least 3/8" larger than the spolette diameter so that it can easily slide over the buildup of twine and match around the outside of the spolette.



Method 1



Method 2



Method 3

This first method is also the method employed by the Maltese for use in their multi-break shells, only they tie a nail or wooden stick in with the match to give it rigidity so as to avoid bending the match pieces when they are rammed into the next break.

The advantages to this method are the fact that spolettes are arranged the same on all breaks, eliminating the need to keep track of what break goes where when assembling the shells. The passfire to the second spolette is also firmly secured to the shell, allowing it to survive the forces of the first break blowing apart.

The disadvantages to this method are argued to be the sloppy fit of the first break around the spolette, which can allow hot gases to enter the first break if not properly sealed. Some builders also find that the sloppy fit makes it difficult to align the shells during assembly, although I personally find that the slop makes it easier to adjust a shell if the holes are not quite on center.

Method 2:

The second method uses a spolette that has black match tied into both ends. The idea is that the passfire match is more secure being tied in with nosing paper, and also exposes the spolette charge to more fire as the burning match gases become confined inside the tube cavity. Because the spolette holes in all disks used to make the shell are the same size, there is no need to have two different punched disks as in method 1. This also helps reduce the gaps for potential gas leaks around the bottom disk of the first break.

The disadvantage to this method is that two different types of spolettes must be made, although the top break could also be fused with the same configuration as the successive breaks with no compromise of ignition reliability. There is also the risk that, if the nosing paper burns away before the spolette ignites, then the black match could be thrown from the spinning shell. However, this drawback could be remedied by securing the black match to the spolette tube using hot glue.

Method 3:

The third method is not recommended and is shown only for completeness. While there is no real advantage to this method, there are several potential problems. The major drawback to this configuration is that the passfire into the second break is not only lacking in flame projection, it is also located at the far end of the shell. Igniting a burst charge from one end results in twice the flame propagation time compared with igniting it at the center. This effectively doubles the amount of time for the shell contents to ignite and increases the probability that the shell will rupture at one end instead of at the middle as desired. Because there is no conical cavity at the point of burn through to the inside of the second break, the chances of a misfire through failed ignition are more likely than the previous two methods.

Spolette Dimensions and Powder Charges

Shell	I.D.	O.D.	Length	Powder Charge
3" single break	5/16"	.55"	2"	1" to 1-1/4"
4" single break	5/16" to 3/8"	11/16"	3"	1-3/8"
5" single break	5/16" to 3/8"	11/16"	3"	1-3/8" to 1-1/2"
6" single break	5/16" to 3/8"	11/16"	3"	1-1/2"
8" single break	5/16" to 3/8"	11/16"	4"	1-3/4"

Since timing will vary due to factors such as ramming pressure, increment size, quality of powder etc., these numbers are a starting point for further adjustment by the worker.

Source: *Pyrotechnica IX*

The table above shows the powder charge typically used for various sized single break shells. The powder used to charge the spolettes specified here is commercial meal D. Charge sizes will vary slightly when using homemade meal. 🔥

