# TRADITIONAL CYLINDER SHELL CONSTRUCTION

## Part I

A. Fulcanelli

*Siccome alla fucina in Mongibello*
*Fabbrica tuono il demonio Vulcano*
*Batte folgori e foco col martello . . .*
— Berni, *Orlando Innamorato*

## INTRODUCTION

The present work describes the construction of the Italian (or, more properly, Italo-American) style cylindrical shell. The Italian style shell seems to have developed sometime shortly after the introduction of potassium chlorate had greatly improved and expanded the range of pyrotechnic colors about the mid-nineteenth century.

The Italian pyrotechnists used empirical methods to arrive at highly complex and sophisticated shell effects. Although most pyrotechnists were without a scientific approach and many were no doubt illiterate, it must be remembered that the human eye is an optical instrument with incredible resolution which can perceive vast ranges of light magnitude. The human ear can detect a wide range of sounds, pitches, frequencies and intensities, and when these sense organs are combined with the brain's miraculous capacity for logic and memory, much can be accomplished without a knowledge of the scientific method, a notebook, stopwatch, or formal study of physics and chemistry. Thus there is often more to accumulated folk wisdom than would meet the analytical, scientific eye.

For most all of pyrotechny's recorded history, the rocket has been the predominant aerial firework. Before chlorate colors were introduced, shells were used much less frequently in recreative fireworks and were considered mainly for military applications. Most all shells described in English, French and German pyrotechnic literature before the mid-nineteenth century were spherical. They were often constructed from wooden hemispheres filled with cut stars and a small amount of bursting charge. They usually broke into a disorderly "heap" with no consistency in the results. Using less expensive and less sophisticated materials, the Italian pyrotechnists were able to obtain more beautiful effects, more symmetry in the breaks and more consistent results in the effects desired by relying on a cylindrically formed shell design. In addition, by bringing the spolette to its full potential as a timing device, they succeeded in producing an almost infinite number of complex combinations of color and sound.

The Italian style shell was well developed by the end of the nineteenth century. Unfortunately, economic and political upheavals in Italy came to a head at this time, forcing many Italians, especially those from southern Italy, to emigrate to the United States, bringing their firework skills with them. They went into business, mostly in small shops like the ones they had in Italy. Most of these Italian immigrants were very secretive about their methods of manufacture and passed this tradition on to their sons. Many of these descendants would probably scoff at an attempt to put technique into print, feeling that not only would it be unwise, but also impossible. They point to the fact that two workers given the same instructions, tools and materials more often than not will produce two very different results, proving that it is not so much the information which is important as it is that the worker have a "feel" for what he is to do. There is some truth to this argument, which the tyro will readily discover should he be lucky enough to observe an old, Italian master craftsman build a complicated shell. The tyro returns to his own workshop confident that he will duplicate the work he has seen, and is often greatly disappointed with his first trials.

Nevertheless, this argument against the publication of technique weakens with the passage of time because the technique is passed on to fewer and fewer family members with each successive generation, and now risks being lost entirely. Many of the more complex shells are rarely (if ever) seen at displays by the general American public. Thus it was felt that a detailed written account should be made in English, before a time comes when these techniques are impossible to reconstruct. Materials change and memories fade, yet one must know what came before in order to create what will follow.

While it is the purpose of this work to preserve the high art of multi-function shell construction, one must start at the beginning. Therefore the assembly of single-break shells will be treated in this first published installment.* The pyrotechnist should be familiar with the materials and nomenclature which are used in shell construction and this is discussed in the first section. The traditional procedure for assembling a single-break star shell then follows, with each step of the assembly described in detail. Finally, reports or salutes are discussed as well, since they are an essential part of so many Italian style shell effects. The methods described, though Italian in origin, have evolved to become thoroughly Italo-American in nature and the materials employed can be readily obtained throughout the United States.

*Multiple-break and more complex multi-function shells will be treated in Part II.

## MATERIALS AND NOMENCLATURE

The construction of traditional Italian style cylindrical shells requires that the pyrotechnist be familiar with many raw materials which have numerous other purposes in industry. Such materials as black gunpowder, papers, cordage and glue come in many different varieties and grades and the pyrotechnist must know which type to purchase for making shells, or run the risk of buying large quantities of unusable supplies. Therefore, a survey of the materials used in shell making and the nomenclature to be encountered follows.

### Burst and Lift Powders

The most common powder in use for shell burst and for shell lift in the United States is *FFA Blasting*, which is commercially manufactured and can be purchased by the pyrotechnist through dealers in industrial explosives. It should be pointed out that the standard U.S. grades of black powder have varied widely in quality through the years, and formerly the granulation of FFA powder was more uniform in size, with less of the finer-grained powder it is now often found to contain.

*FFFFA Blasting* powder is occasionally used for lifting smaller shells and it is also used in making various shell components.

*Meal D* powder is used for charging the tubes for spolettes. In some countries, manufactured black powder is too costly or difficult to obtain, and pyrotechnists there have made a practice of making meal powder by ball-milling, later making the meal into grain powder by damping, pressing and screening it.

Black powder grades also vary from country to country. The U.S. system of grading has often confused pyrotechnists in other countries. For the sake of clarity, the table below, from Lancaster (1972), describes the mesh sizes of the powder granulations unique to the American system, offered as a comparison with foreign powders.

**Table 1. U.S. black powder grades (from Lancaster, 1972)**

| Type | U.S. Sieve Numbers |
|---|---|
| FFA | 4/12 |
| FFFA | 10/16 |
| FFFFA | 12/50 |
| FFFFFA | 20/50 |
| FFFFFFA | 30/50 |
| FFFFFFFA | 40/100 |
| Meal D | + 50 |
| Fine Meal | + 100 |
| Extra fine meal | + 140 |

Some blasting powders are *glazed* with graphite powder during manufacture and this is usually destined for sale to the black powder firearms market. Unglazed powders are preferred for use in shell manufacture.

*"B" Blasting* powders are not used for shell manufacture because they are too weak and slow-burning, as well as hygroscopic (being made with sodium nitrate instead of potassium nitrate as used in "A" Blasting powders).

### Rough Powder

A rough, home-made powder is sometimes used in the manufacture of shells, often called *polverone* (literally, "large powder" or "coarse powder"). This is a sieve-mixed composition of saltpeter, charcoal, sulfur, and dextrine to bind it, made without milling or grinding, dampened and granulated by rubbing through a coarse screen.

The mixtures in use approximate traditional gunpowder proportions, often with a slight increase in the percentages of charcoal and sulfur. The following receipts in Table 2 are typical.

**Table 2. Rough powder formulae**

| | 1 | | 2 | | 3 | |
|---|---|---|---|---|---|---|
| | Parts | % | Parts | % | Parts | % |
| Potassium nitrate | 18 | 68.6 | 20 | 65.6 | 24 | 65.8 |
| Charcoal, air-floated dust | 4 | 15.2 | 5 | 16.4 | 6½ | 17.8 |
| Sulfur | 3 | 11.4 | 4 | 13.1 | 4 | 11.0 |
| Dextrine | 1¼ | 4.8 | 1½ | 4.9 | 2 | 5.5 |

After breaking up any large lumps that may have formed in the saltpeter, the ingredients are hand-mixed and sieved two or three times through a 20-mesh screen (common window screen is quite adequate). The resultant mixture is dampened with water until it is wet enough to cohere in clumps when squeezed together in the hand; it must neither have a tendency to flake apart (not enough water) nor be muddy, like powder slurry for priming (too wet). Because the moisture content of the charcoal, local atmospheric humidity, and such conditions vary so greatly, it is almost impossible to specify moisture content to be added, but it will be found that from one-tenth up to one-fifth the weight of the dry mixture of water may be required. Some shell makers add more or less water to the composition depending upon the use to which the powder is to be put. Less water makes a softer grain, more likely to crumble to powder; more water makes a harder grain.

Work the water into the composition with the hands (rubber gloves are desirable in this dirty operation) until it is uniformly damp and can be worked into a large, coherent mass. It is necessary to have a granulating screen at hand, made with 4 x 4 hardware cloth (wires form ¼" squares) and 1 x 2 lumber for a rim. Star-drying screens are also required, of approximately 2 x 3 feet, and are to be lined with 30-lb. kraft paper. Lay the granulating screen atop a paper-lined star-drying screen, so it is supported by the rims of the drying screen. Break off a chunk of the dampened composition about the size of a softball, and rub it through the screen. When all the composition has passed through, rub the screen with the hands, shake it, invert it, rub and shake again to clear as much of the damp composition that may be adhering.

Proceed to another screen and repeat the operations until all of the composition has been granulated. The powder should not be much deeper than ½" on the bottom of each drying screen, as the granules have a tendency to stick together under their own weight. About 2½ - 3 lbs. of composition (dry weight) per screen is a desirable amount.

If dried in a well-ventilated, shady, warm location, the rough powder should be dry in 2 - 3 days. Avoid placing it in the sun immediately after granulation, lest the saltpeter leach to the surface of the granules. When dry, it should be taken up off the kraft sheets lining the screens, any large caked masses of granules broken up with the hands, and finally sieved through one of the granulating screens.

Some of the rough powder, all of which has passed the ¼″ openings when wet, will not pass the screen when dry. This powder should be set aside and kept separately from the powder which passed through the screen. The coarser powder is used for filling the tops of shell casings until level after the stars and powder cores have been put in them. It is suitable for this purpose because it does not all sift down between the interstices amongst the stars, sitting instead on top of them and acting as an even "packing" material.

The finer powder, which has passed the screen, is used for all other purposes: filling the interstices between the stars in multiple-break shells, where a solid fill is indispensable to the shell's structural integrity; filling around serpents, whistles, and other tube-type garnitures, and as a burst charge (either alone or in a mixture with commercial FFA powder) where a gentler break is desired than that obtained with commercial powder alone.

**Garnitures**

The general term "garniture" refers to the contents of a shell (e.g., cut stars, pumped comets, serpents, whistles, reports, tourbillions; essentially anything that will fit in a shell). A method for making cut stars, the most commonly used shell-filler, is given in PYROTECHNICA I ("Cut Star Making — A System and Its Uses" by Jim Stone, 1977, pp. 4 - 8). Most other components are well described in the existing literature.

**Papers**

Papers of several types are used in the construction of shells, and all share common characteristics. Among the most important of these is *grain*. Paper is in effect a thin web of cellulose fibers derived from various vegetable sources, such as wood, cotton, flax, sugar-cane waste (bagasse), manila hemp, etc. These fibrous plants are treated either mechanically or chemically (or by both means) to remove (more or less) the non-cellulose components, leaving cellulose fibers in water suspension. A paper machine consists essentially of an endless belt of wire cloth travelling at high speeds with a hopper full of this cellulose suspension ("pulp" or "furnish") at one end, and a series of hot steel rollers ("calender stacks") on the other. It functions by feeding the pulp onto the screen, where most of the water is drained, leaving at the other end a web of fibers of uniform thickness, which is further dried, compressed, and regularized by passage between hot rolls. In this process, the fibers are aligned in the direction of the travel of the wire cloth belt ("Fourdrinier screen"). The result is that the finished product, like wood, has a definite "grain" lying along the direction in which the fibers are aligned. The paper is thus more pliable *with* or parallel to this grain, than *against* or perpendicular to it. The diagrams below illustrate this.

It should be mentioned that hand-made papers, which are not made by a process that aligns the fibers so markedly, have little or no grain direction; this is often an advantage in specialized applications, but the expense is prohibitive. Japanese hand-made tissue paper ("Gampi") is thus prized for shell and rocket parachutes because it has little tendency to become set in its folds.

In pyrotechnic case-rolling operations, it is important to roll with the grain, as in most situations, rolling against it is more difficult. It is often difficult for persons unfamiliar with paper to detect grain direction. Usually, paper folds or rolls with greater ease with rather than against the grain, but the difference is subtle in the lighter weights. An infallible test for grain is to dampen one side with a sponge. The sheet will then curl so that the curvature is with the grain (see Figure 2). It also ought to be mentioned that when paper comes in rolls, the grain runs with the circumference of the roll, and when it comes in sheets, it is *usually* (but not always) with the longer of the two dimensions of the sheet.

Paper is bought by the sheet or roll, and such characteristics as size, thickness (caliper), grade, color, and the like, are meaningful to the customer in making his selection. However, it is long-established custom in the paper industry to sell paper by weight. The calculation of the weight of a given number of sheets of a given size and thickness in a given grade requires some specialized understanding.

Various sheet sizes are available in each grade (grades being, e.g., book, bond, index bristol, tagboard, wrapping, etc.), but in each grade one size is designated as the *basis size* for that grade. This is the size of which one ream (500 sheets for printing grades, 480 sheets for "coarse" grades) weighs the *basis weight*. The basis weight is that weight by which all paper of a given weight, regardless of size, is described (e.g., 70-lb. wrapping, 20-lb. bond, 100-lb. tagboard). Thus, 500 sheets of the basis size book papers (25 x 38 inches), basis 50 (50-lb.), weighs 50 pounds; 480 sheets of the basis size of wrapping papers (24 x 36 inches), basis 70 (70-lb.), weighs 70 pounds.

It will be evident that a ream of paper of some different size than the basis size will not weigh the basis weight, although that basis weight continues to be used to describe the paper. For example, a ream of 22½ x 28½ inch tagboard, basis 100, weighs 74 pounds. Its designation is thus 22½ x 28½-74(100) — or sometimes 22½ x 28½-148M(100), signifying that 1M

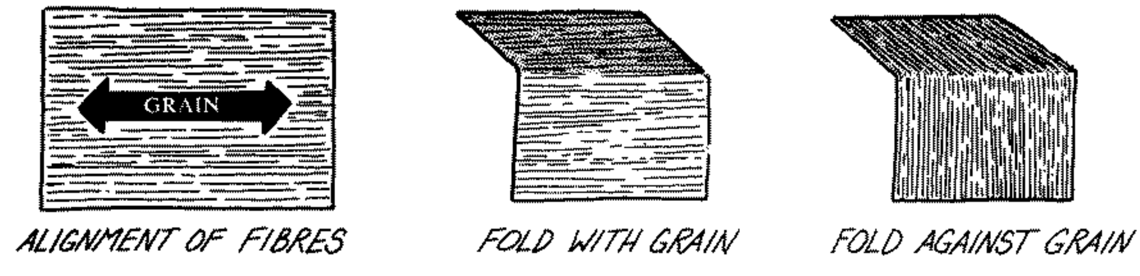



*Figure 1. Property of grain in paper.*

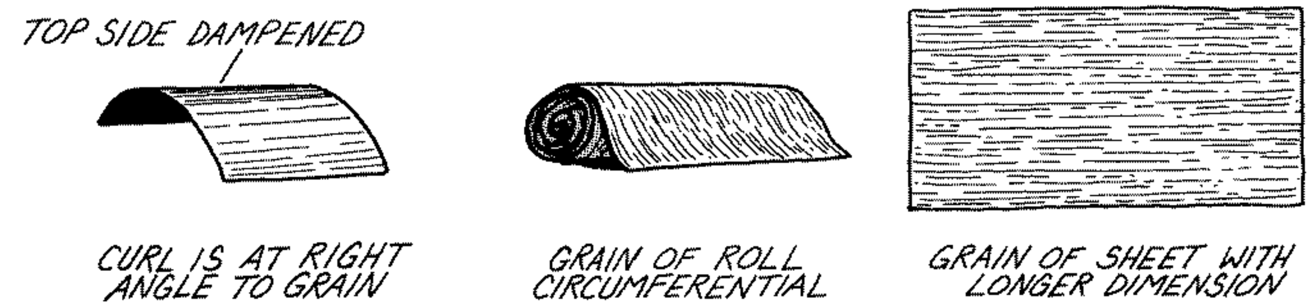



*Figure 2. Paper grain detection.*

(1,000) sheets weigh 148 pounds, i.e., twice what one ream weighs.

Although it may be in roll form, paper is still described by weight with reference to its *basis* sheet ream. This is particularly common with wrapping grades; e.g., one might buy a roll of 70-lb. kraft wrapping, thickness (caliper) .007″, and the weight reference would refer to the weight of 480 sheets of 24 x 36 inch paper. It should be pointed out that thickness (caliper) is not an infallible clue to the *weight* of paper, since paper may be made of relatively greater or lesser density, yet have the same thickness.

The following types of paper are in wide use in pyrotechny:

KRAFT WRAPPING—basis size 24 x 36 inches, available in 30-, 40-, 50-, 60- and 70-lb. weights (basis ream is 480 sheets). It is available in sizes 24 x 36, 30 x 40, and occasionally 36 x 48 or 40 x 48; also commonly in rolls ranging from 12″ - 72″ wide. Generally the lighter weights come in narrower rolls and the heavier weights in wider ones, but there is no standard roll width. The caliper (thickness) of the respective weights is in a neat correspondence as follows:

**Table 3. Kraft paper weights and calipers.**

| Paper weight | Caliper (thickness) |
|---|---|
| 30 lb. | .003″ |
| 40-lb. | .004″ |
| 50-lb. | .005″ |
| 60-lb. | .006″ |
| 70-lb. | .007″ |
| 90-lb. | .009″ |

Kraft wrapping is normally brown (a wide variation is found in shades), and is used for many purposes in pyrotechny. The heavier weights, 60- and 70-lb., are used for rolling shell cases and for pasting-in larger shells; medium weights, 40-, 50- and occasionally 60-lb., for nosings and for pasting-in; and the light weights, 30- and 40-lb., for match pipes, nosings, and pasting-in small shells. The light weights are also used for "lift wrap" in finishing shells, and often colored kraft paper is used as well as the natural brown kraft for this purpose.

So-called "recycled kraft" papers (more appropriately called "bogus kraft," since they are not kraft at all) are sometimes encountered, and they should not be used as they tend to fall apart when wet with paste. It is wise to test the wet strength of paper, by wetting a sample thoroughly, crumpling it, then smoothing it out — if it survives this test, it will be suitable for shell building.

TAGBOARD — basis size 24 x 36, in 100-lb. and 125-lb. weights (basis ream 500 sheets) and *index bristol*, basis size 25½ x 30½, in 90-lb. and 110-lb. weights (basis ream 500 sheets) are roughly comparable types of paper, tagboard being made with a longer-fibered furnish and slightly stronger.

One hundred-pound tag and 90-lb. index bristol both have a caliper of .007″; 125-lb. tag and 110-lb. index bristol both have a caliper of .009″. Other weights are occasionally available but find little use in pyrotechny. The paper colors are white and *manila*, which used to refer to the use of manila hemp in the furnish, but now refers to the light buff color of the unbleached grade of this paper (which is cheapest and quite adequate for pyrotechnic purposes). Table 4 indicates the standard paper sizes.

**Table 4. Tag and index sizes.**

| Tagboard | Index bristol |
|---|---|
| 22½ x 28½ | 20½ x 24¾ (rare) |
| 24 x 36 | 25½ x 30½ |
| | 22½ x 35 |

These grades of paper are used where a thin, strong inner liner for small insert components or occasionally shell casings is needed. Formerly, tagboard or *pressboard* (an almost extinct grade) was used for hand-rolling shell fuse tubes.

CHIPBOARD is made from mechanically pulped newsprint scrap, wood chips, and other cheap and low quality fibers. It has completely supplanted *strawboard*, a thick yellow paperboard spoken of by Weingart and other earlier writers.

Chipboard comes in calipers of .018″, .022″, .026″, .030″, and .042″, and occasionally in thinner and thicker calipers. It is not sold by the ream, but by the 50-lb. bundle, denominated by "count," i.e., the number of sheets in a bundle. Thus, "26 x 38-70 count chipboard" would be a chipboard of which 70 sheets made up a 50-lb bundle; in this case, the caliper is .030″. It is ordinary to denominate chipboard by caliper as well, so ordering is uncomplicated. Common sizes are 22½ x 34½, 23 x 35, 28½ x 34½, and 26 x 38. Note well that in this grade (as opposed to those discussed previously), the *lower* the number following the size designation (the count number as opposed to the weight), the *greater* the thickness of the sheet.

This grade of paper is used for inner liners for reports, occasionally shell case inner liners, and in the heavier weights, for end discs. A thinner chipboard, .010″ - .012″, is sometimes available in rolls and is commonly used for various case liners or for case rolling. This supplants the groundwood "bogus bristol" spoken of in the past.

BINDER'S BOARD is a strong, heavy board, gray, and made of laminated thicknesses of a chipboard-like paper said to be made from pulped, industrial wiper rags, and is thus sometimes called rag board. It is available in many calipers and sizes, for use primarily in the bookbinding industry as cover boards. Its main use in pyrotechny is for shell end discs. Popular thicknesses range between 1/16″ and ⅛″. End discs are usually not made by the pyrotechnist himself, but purchased from suppliers who die-cut the end discs.

**Cordage**

Cordage is another important article in pyrotechnic practice, and is conveniently often available from the same dealers handling coarse papers. Many types are used, and choice is largely at the taste of the individual pyrotechnist, but the following are the most common.

UNSIZED COTTON STRING — Three- or 4-ply is commonly used for making black match, usually 6 - 8 strands together. Eight-ply, 10-ply and 12-ply are used for spiking (stringing) shells. These grades are normally sold on cone-shaped spools and priced by weight.

FLAX TWINES — Three-ply and 4-ply (the plies are thicker than cotton string) are available from American and Belgian manufacturers. These twines are of a rougher finish than cotton (knots made with them hold more firmly than those made with the smoother cotton). They are a greenish-brown color with a characteristic, not unattractive odor. The fibers are longer, and the twine is exceedingly strong for its thickness. This twine is often used for tying nosings, lift- and leader-tying, and occasionally spiking large shells. It is more expensive than cotton twine, and often comes in 1-lb. cylindrical rolls. A 2-ply Italian flax twine, which was very thin and stronger than 8-ply cotton, was much favored for spiking shells, but is now almost impossible to find; it came in 5-lb. cone-shaped balls.

POLYESTER, POLY/COTTON, and HARD LAID COTTON STRINGS — A variety of these are available and are often favored for spiking shells because of their relative thinness and strength, but there are many pitfalls in selecting them. Breaking strength, tendency to stretch, and ability to be wet with paste must be carefully determined.

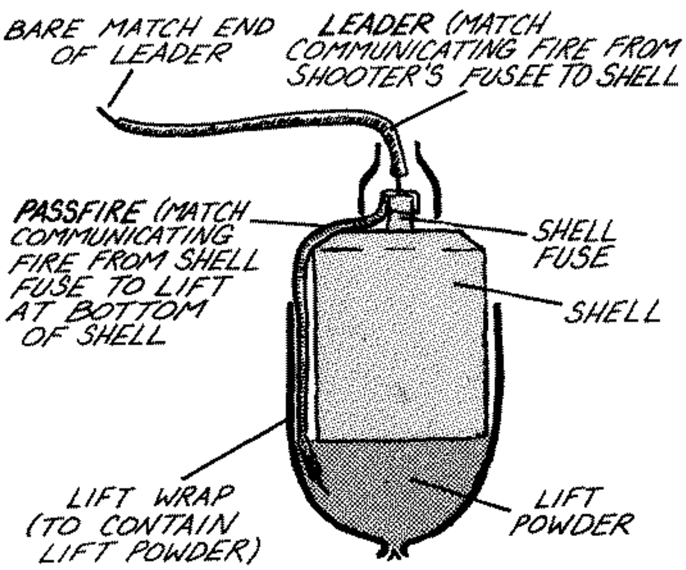



*Figure 3. Parts of a shell.*

**Nomenclature of a finished shell**

Detailed coverage of various phases of shell manufacture will treat this subject in greater depth later. Figure 3 below illustrates the basic parts of a shell.

## SPOLETTES AND OTHER SHELL FUSES

Every aerial shell must contain a timing element that, having taken fire simultaneously with the lift charge, provides adequate delay before passing fire to the burst powder and garniture, such that the shell bursts at or near the apex of its trajectory. There are several varieties of delay fuses that may be used, depending upon the size and character of the shell.

**Spolettes**

The spolette is the oldest and most versatile type of shell fuse. It consists of a small-bored and relatively thick-walled tube (usually but not always made from paper) charged partially with pure commercial meal powder. The powder charge is flush with one end of the tube and part, often half or more, of the tube is left uncharged (see Figure 4).

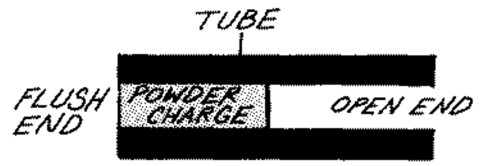
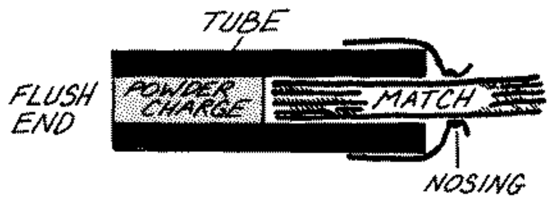



*Figure 4. Spolette, before matching and nosing.*

The open end of the tube is filled with as many short pieces of high-quality black match as can easily be put into it (without force); a nosing of strong, lightweight paper is rolled around the end of the spolette and tied snugly (but only enough to hold the match firmly in place — not so tightly as to choke off or break its black powder coating). The pieces of match should be carefully cut, with a *very* sharp knife or razor blade, because dull cutting tools crumble the powder from the match leaving cotton fibers exposed without a powder coating. The pieces of match should extend perhaps 1 - 1½″ beyond the open end of the spolette, when held firmly in contact with the powder charge in the tube. Figure 5 depicts a spolette that has been matched and nosed.

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Tubes for spolettes have in the past been hand-rolled, but because spolettes are used in such great volume and because their perfect manufacture is essential to the safe and successful functioning of shells, it is now usual to buy machine-rolled tubes. These tubes are wet-rolled, convolute-wound, and made of high-quality, smooth finished paper which is rolled long and ing. This supplants the groundwood "bogus bristol" spoken of in the past.

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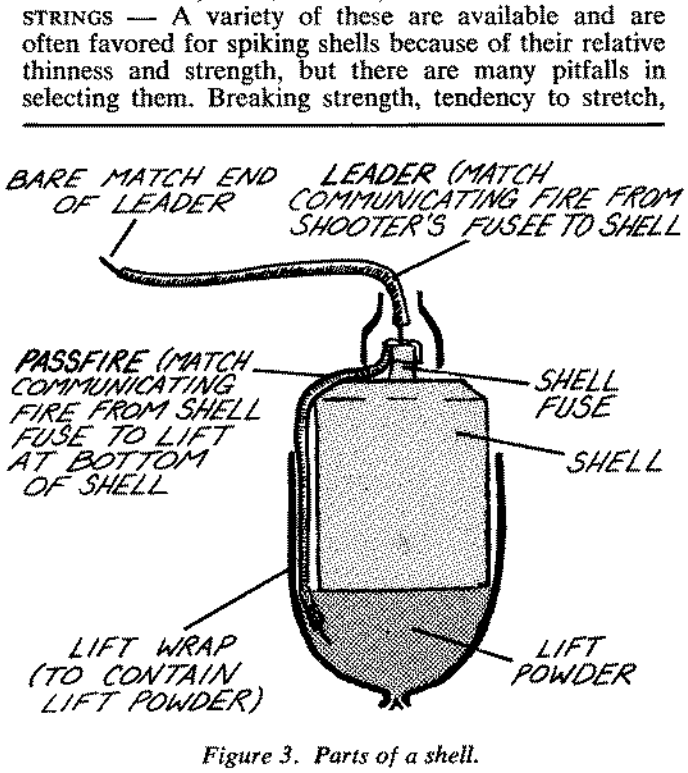


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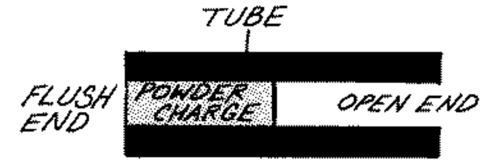


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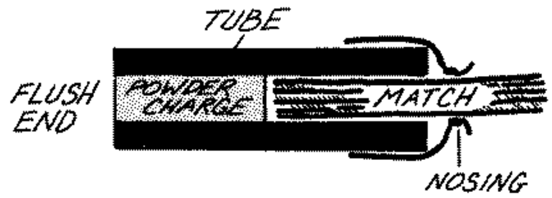


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**Table 5. Specifications for spolette tube dimensions and powder charges for single break shells.**

| | Inside diameter | Outside diameter | Length | Powder charge |
|---|---|---|---|---|
| 3″ shells, single break | 5/16″ | .550″ | 2″ | 1″ - 1¼″ |
| 4″ shells, single break | 5/16″ - ⅜″ | 11/16″ | 3″ | 1⅜″ |
| 5″ shells, single break | 5/16″ - ⅜″ | 11/16″ | 3″ | 1⅜″ - 1½″ |
| 6″ shells, single break | 5/16″ - ⅜″ | 11/16″ | 3″ | 1½″ |
| 8″ shells, single break | 5/16″ - ⅜″ | 11/16″ | 4″ | 1¾″ |

NOTE: It is impossible to give accurate equivalents in seconds for these timings as such factors as ramming pressure and increment size vary from one worker to the next. As a rough guide, one inch of powder rammed in a spolette burns approximately 3 seconds.

Special timings appropriate to multiple break and other special shells will be treated later.

later cut to length. It is the usual practice to age or "cure" the tubes after they are received from the manufacturer as they are often still slightly damp and must stabilize. Spiral-wound tubes are unsuitable for making spolettes, for obvious reasons.

Formerly, a "red-rope" tube was available, made with thin red pressboard, but recently these have been supplanted by a manila-colored paper. The tubes should be hard, rigid and smooth. Dimensions of the tubes used vary according to the size of the shell and also according to the purposes for which the spolettes are intended. Manufacturers have their own preferences in these matters; Table 5 describes one such system.

One should have appropriate tools for the size of tube selected. These include a small scoop that will deliver a charge of meal powder sufficient to form an increment of 3/16″ - ¼″ when very solidly rammed in the tube; a rammer or drift, of sufficient diameter to fit snugly in the bore of the tube (yet not so tightly as to bind) and perhaps 2 - 2½″ longer than the tube; and a solid, flat surface, preferably metal, stone, or polished wood, on which to ram. The ramming surface should be supported by a sturdy workbench, or preferably by a post sunk directly into the ground, to minimize vibration. It is also desirable to have the rammer marked with a circumscribed line at such a point on its length that when the line is parallel with the top of the case, it indicates the desired height of the powder charge (thus, if ramming a 3″ case with a 1½″ powder charge, the line should be circumscribed on the rammer 1½″ from its bottom end).

Holding the tube so that its bottom edges are firmly against the ramming surface, charge one scoopful of meal powder into it and carefully insert the rammer, pressing it down to the powder. Ram with 8 - 10 firm blows of a rawhide mallet. It is better to control the mallet and use more blows than to swing wildly and attempt extremely heavy blows. During all this time, the tube should be held solidly in place by one hand against the ramming surface. Especially with the first increment, it is important to make certain that no powder is pushed out of the tube between the bottom edge of the tube and the ramming surface. Repeat the charging of powder and the ramming, maintaining the same number of mallet blows with the same force, until sufficient increments have been charged to complete the powder charge. It is wise to charge perhaps 1/16″ - ⅛″ more powder than is desired in view of the next step.

At this point a variety of methods may be used to produce a groove, hole, or depression in the inside powder surface for purposes of assuring the passage of fire. A common problem with spolettes is a failure to transfer fire from the powder train to the match, in what is often called the phenomenon of having the flame "sucked out."* It is thought that the presence of this groove or depression in the powder surface increases the surface area of powder in contact with the match and lengthens the critical split second during which the match ends are exposed to flame.

Three methods are used:

1) After inverting the spolette to empty any loose meal that may remain, with an awl, carefully scratch or score the powder surface on the hollow end of the spolette. The groove produced by this scratching should be about ⅛″ deep. The awl may be used as a rough sort of depth gauge by holding the thumbnail to the awl and noting the difference in position with relation to the end of the tube when the tip of the awl is touching the bottom of the groove, as compared to when it is touching the rammed surface.
2) A small drill, perhaps 1/16″ diameter, may be used to make a hole from ⅛″ to ¼″ deep in the inside powder surface. The drilling may be done by hand, or (if volume of production warrants) by a drill press operating at very low RPM. If a drill press be used, great precision is possible, particularly where very short timings are involved.

*ED. NOTE: Practices and feelings about this problem vary from country to country, and from pyrotechnist to pyrotechnist; Rev. Ronald Lancaster (private communication, 1983) claims that "the shaped rammer is essential and should be ¼″ deep at least . . . I have often met failure in its absence." Lancaster reports that most Europeans now press fuses which include a recess in the powder charge.


*Figure 6. Shaped-end rammer and cavity produced in powder charge.*

3) A rammer with a shaped end may be used, producing a cone-shaped depression in the inside powder surface (see Figure 6).

To nose spolettes, cut strips of paper from 1″ - 2″ wide (depending upon the size of the spolette) and 4″ - 5″ long (2 - 3 turns). Paper should be 20 - 40-lb. kraft, with the grain running the shorter of the two directions. Match should be cut to appropriate lengths for insertion into the spolettes prior to nosing. Four to five pieces of match should suffice. Some pyrotechnists prefer to crimp the side wall of the spolette to hold match in place by driving a narrow screwdriver or chisel blade between the turns of paper, prior to nosing. Lay a piece of nosing paper out, and smear with white glue all along the top edge and the pasting edge; roll the spolette up into the paper, with perhaps ½″ - ¾″ protruding beyond the tube and over the match. This end ought then to be tied around the match with a clove hitch of flax twine or strong cotton (see Figure 7).

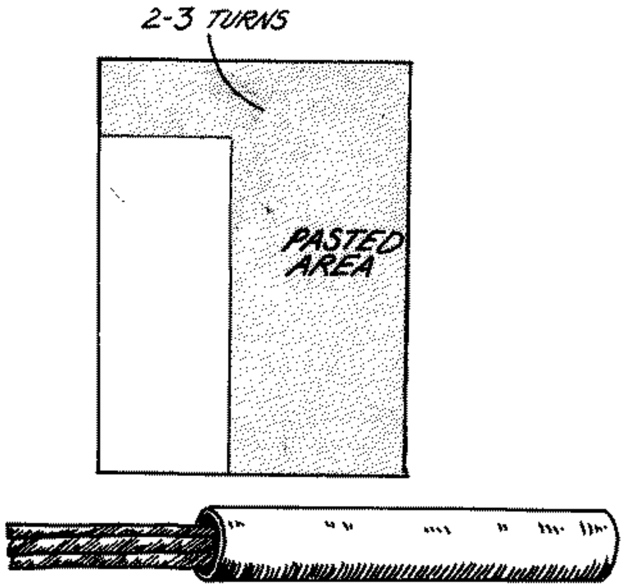


*Figure 7. Nosing spolette.*

It is advisable to pierce the nosing with an awl, beneath the tie. This relieves the gas pressure inside the spolette and permits the hot combustion gases to vent into the shell, thus aiding ignition even if the match should be choked off by the tie (see Figure 8).

If it is found impossible to master holding the spolette firmly against a flat surface while ramming, a useful aid is a ramming block in which to support the tube. The simplest and best form consists of a block of metal, perhaps 1″ thick, with a hole slightly larger than the outside diameter of the spolette tube drilled clear through it. This block may then be set or clamped onto the ramming surface (see Figure 9).

**Other shell fuses**

SPUN FUSES — Other time fuses in common use are the Japanese and American Bickford style or "tape" fuses. These are spun fuses, made by complicated machinery, and most pyrotechnists must buy them from dealers, rather than making them. They consist of a modified black powder core, surrounded by spun textile fibers, asphalt water-proofing layers, and an outer wrap. A commonly-used fuse of Japanese manufacture is slightly

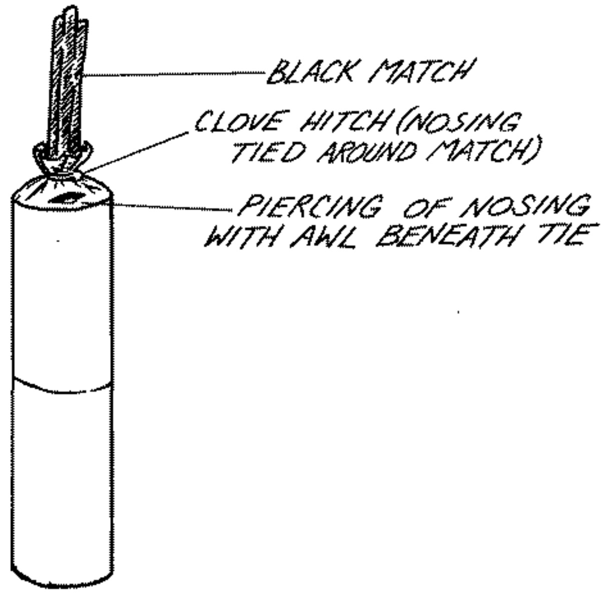


*Figure 8. Tying and piercing the spolette nosing.*

less than ¼″ in diameter and has a colored paper outer wrap held on by helical wrappings of thread rather widely spaced. Fuse manufactured in the United States is normally ⅜″ in diameter and has an outer wrapping of white cloth tape. The use of Bickford-type fuses is reserved mostly for one-break shells.

Preparation of these fuses for use in shells is relatively simple. Pieces of about 2″ in length are cut from the rolls. The fuse must then be *cross-matched.* This may be accomplished either by punching the fuse with an awl (e.g.) ½″ from one of its ends, and threading a piece of thin black match through the resultant hole, or by making a lengthwise cut, splitting the fuse (again perhaps for ½″ of its length), inserting a piece of black match in the split, and tying the split end together above the match. Figure 10 shows these alternatives.

When cutting or punching time fuse, it is most important to have a sharp and clean tool lest asphalt be smeared over the powder core in the process. Attempting to use a fine drill bit to make a hole for cross-matching will almost always insure that asphalt gets smeared into the powder core.

An arbor press is almost essential for punching the larger sizes of fuse. Two types of punching tools are in widespread use; one type, having an ogival point (like an awl) simply pierces and spreads the cross-matching hole; the other, often a hollow tube (like a leather punch) actually removes a slug of fuse material, including a portion of the powder core.

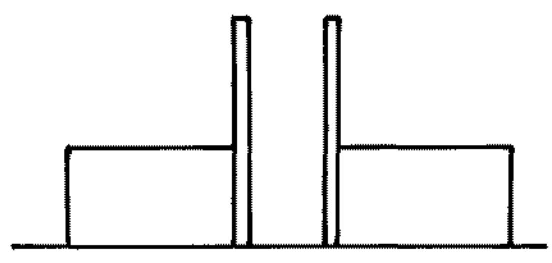

*Figure 9. Cross section of spolette in ramming block.*

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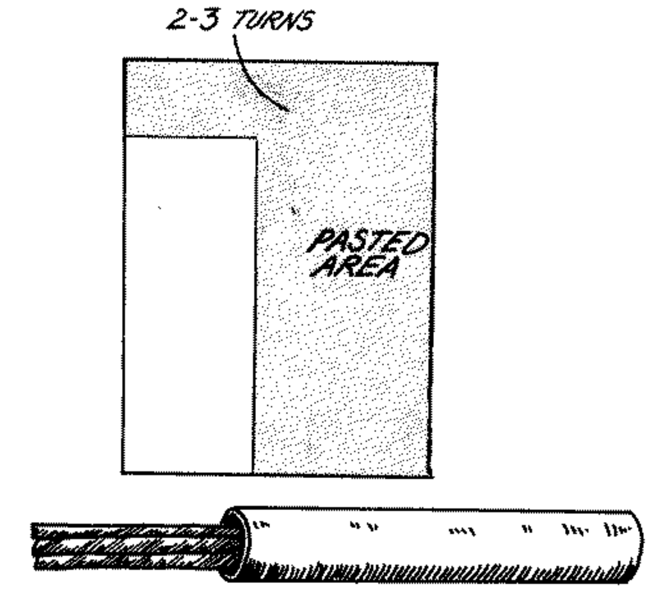


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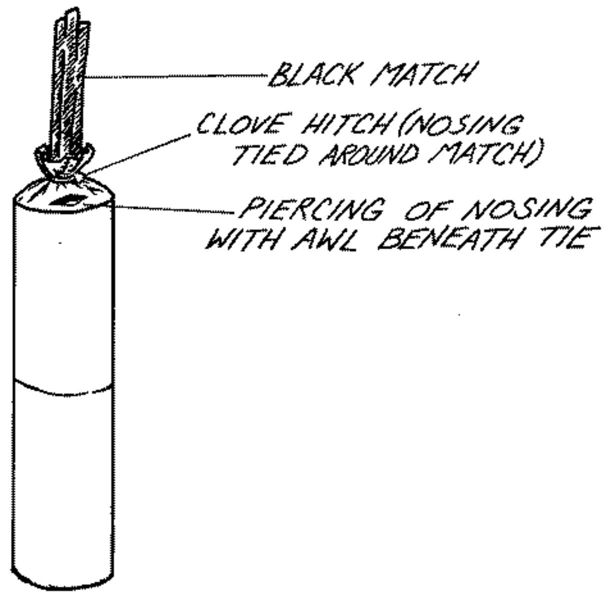


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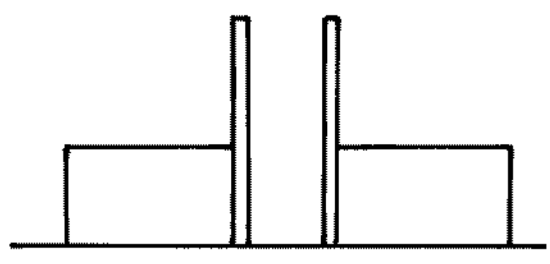


*Figure 9. Cross section of spolette in ramming block.*

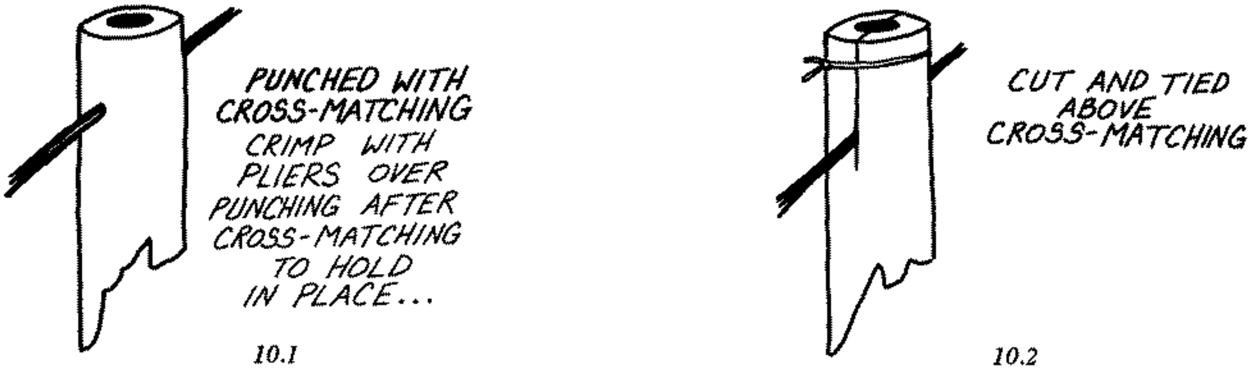



*Figure 10. Two methods for cross-matching Bickford-type fuses.*

FUSE/END DISC ASSEMBLY — Whatever fuse is selected for use in shells must be fitted through an opening in the top end disc of the shell. Discs are usually purchased with holes of the proper diameter already punched, although they may be punched with an arch punch. Spolettes should be inserted so that only about ¼" of the tube proper protrudes through the hole on the side of the disc which will be inside the shell (this applies to spolettes for single break shells and for the first break of multiple-break shells; special instructions for intermediate spolettes on multiple-break shells will be treated elsewhere).

Japanese and American spun timer fuses should be fitted in the discs with the cross-matching close to the disc on the inside of the shell. The cross-matched fuse is pulled through the hole in the disc until the cross-match actually touches the disc, and is indeed slightly bent forward by the tension. Figure 11 depicts the various types of fuse in shell end discs. It is wise to glue the fuse well in place on the outside of the shell, either when making up disc/fuse assemblies in advance, or after putting the fused disc into a shell in the process of filling shells. If made up in advance, spolette-fitted end discs can be glued around the spolette on both sides of the disc to assure a better seal; white glue is best used.

## CONSTRUCTION AND FILLING OF SHELL CASES

### Case rolling

The casing of a shell is constructed of an appropriate number of turns of kraft paper rolled up dry on a cylindrical case former, pasted on the edge to secure it from unrolling. Case formers should be provided with the following dimensions:

**Table 6. Specifications for case formers.**

| Size of shell | Diameter of former | Minimum length of former (excluding handle) |
|---|---|---|
| 3" | 2½" | 7" |
| 4" | 3½" | 9" |
| 5" | 4½" | 11" |
| 6" | 5½" | 13" |
| 8" | 7¼" | 16" |

Seventy-pound kraft paper is used for the shell casings. The number of turns rolled around the former should equal the nominal diameter of the shell in inches. These paper requirements work out neatly in terms of strips of standard length, given below in Table 7.

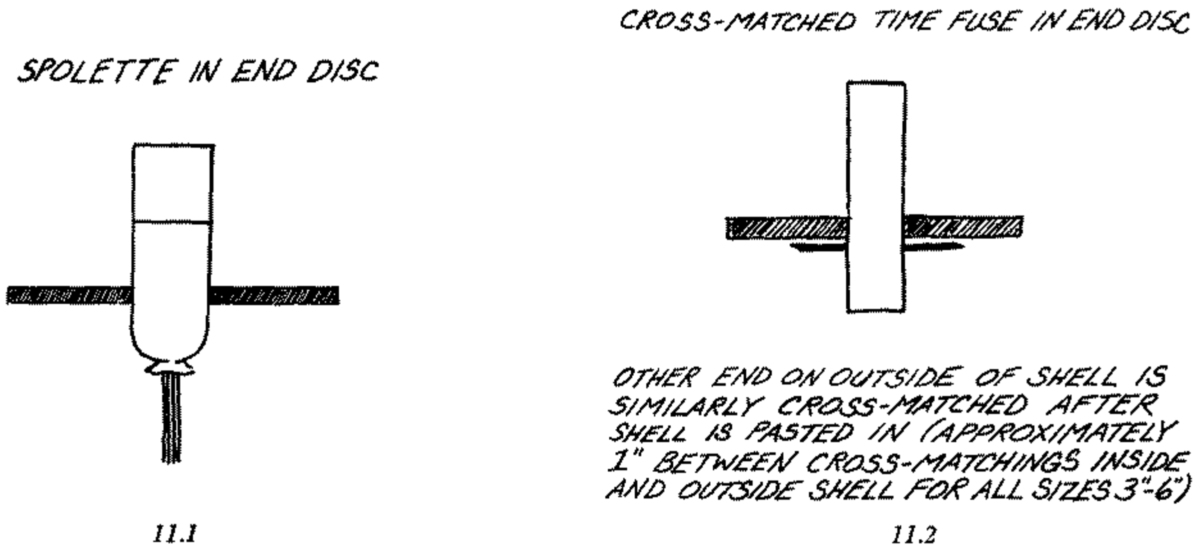



*Figure 11. Fuse/end disc assemblies.*

**Table 7. Dimensions of paper strips for making shell cases.**

| Size of shell | No. turns 70-lb. kraft paper | Length of paper strip |
|---|---|---|
| 3″ | 3 | 1 - 24″ strip |
| 4″ | 4 | 2 - 24″ strips or 1 - 48″ strip |
| 5″ | 5 | 3 - 24″ strips or 2 - 36″ strips |
| 6″ | 6 | 4 - 24″ strips or 2 - 48″ strips |
| 8″ | 8 | 4 - 48″ strips |

Lighter paper than 70-lb. is occasionally used. In these cases, more turns must be used than the above table indicates. If the nominal diameter of the shell in inches be denominated by $N$, the formula $N \times .007''$ gives the thickness required for the wall of the shell in thousandths of an inch. For example, a 5″ shell case must have a wall .035″ in thickness. If 50-lb., which calipers .005″, were to be used in lieu of 70-lb. (calipering .007″), seven turns of 50-lb. would be required to produce the required thickness as compared to only five turns of the usual 70-lb. paper.

The grain of the paper should run parallel to the axis of the shell former (i.e., the short dimension of the strip). The width of the paper strips varies according to the contents of the shells. Longer casings are necessary when tube-type garnitures (serpents, whistles, reports, or the like) are to be used. These will be discussed more specifically under the headings covering those special shells. The present discussion is confined to a general technique for making simple single-break shells of cut stars. For such a shell, the desired height is usually the same as its diameter. Thus, a 3″ shell, being rolled on a 2½″ former, is to be filled to a height of 2½″; a 4″ shell, rolled on a 3½″ former, to the height of 3½″; and so forth. In practice, especially with large shells (economy and keen competition among makers to produce the cheapest article being the overriding concern), the fill level is often less than the diameter, leading to short, squat "pancake" or "hockey-puck" shells. The paper should in any event be cut wide enough to roll a cylinder that will fold down over the top and bottom to leave an appropriate height for the shell wall.

Having cut a sufficient amount of paper for the desired number of shells, roll up the appropriate number of turns on the former for the shell of whatever size may be desired. If more than one sheet is necessary, roll up the first sheet almost completely: interleave the next sheet with it, roll it up, add another sheet until all have been rolled on; then paste the last sheet down at the edge. The rolling should be done with enough pressure that the resulting tube is snug, but not so tight on the former that it cannot slip easily from it.

Now the end of the case must be folded down to make the bottom of the shell. Two principal techniques are used to accomplish this. In one, the tube is slipped a little less than half a diameter past the end of the former, and a chipboard disc of appropriate size is pushed down onto the end of the former. The protruding paper is then pleated in towards the center, leaving a little area of the chipboard disc exposed, as illustrated in Figure 12.1. The other method is sometimes called the "tongue fold" because of the "tongue" of paper that is formed by the last paper to be folded down. In this technique, the paper width must be calculated to be a little greater. The tube is slipped almost a full diameter past the end of the former, the disc slipped in, and one side of the tube folded in over the center. Another fold, or even two, is made to the side of the original fold until all that remains unfolded forms a large, pointed "tongue" sticking up; this is last to be folded down. Because excess paper will stick out to the sides of the end, making a bottom to the shell that is not completely circular, these excess folds are tucked under the tongue, giving the appearance illustrated in Figure 12.2.

On larger shells, where the bulk of many turns of paper may be difficult to fold all at once, several inner turns may be turned down and pleated individually. This may be done either with the tongue fold method or the method of pleating toward the center. Some makers do this with all shells and claim it is more "fireproof." The choice of pleating toward the center or making the

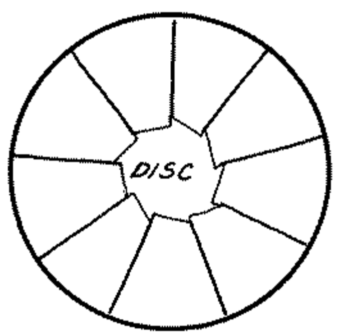



*Fig. 12.1*

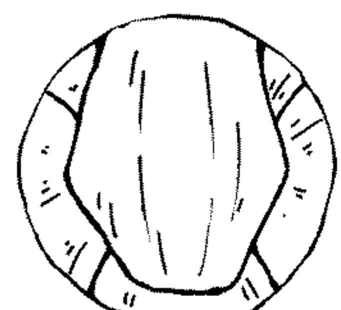



*Fig. 12.2*

*Figure 12. Two methods of folding paper.*

tongue fold is also largely a matter of individual preference. Pleating toward the center is held to make a neater bottom as each pleat subtends a much smaller section of the circle and the corners of the pleats do not tend to stick out from the circumference. On the other hand, tongue folds do not leave any of the bottom inside disc exposed and on this ground it is claimed they are more "fireproof." Tongue folds are also faster to make.

Having folded the case in on one end, persuade the folds to lie in place by pounding with a wood block or a mallet, or by inverting the former and jolting it on the workbench. The case may then be removed from the former and is ready to be filled.

**Case filling**

After the shell case is made, it is ready to be filled. To make a simple shell of cut stars, one uses a brass or copper pipe, called a "canulle," which is inserted into the case, centered on the bottom disc; stars are filled around the tube and burst powder filled in the tube. The tube is then withdrawn, leaving a core of powder surrounded by stars. The diameters of the canulles are shown in Table 8.

**Table 8. Diameters of canulles.**

| Size of shell | Diameter of canulle |
|---|---|
| 3″ | ¾″ - 1″ |
| 4″ | 1″ - 1¼″ |
| 5″ | 1½″ - 1¾″ |
| 6″ | 1¾″ - 2″ |
| 8″ | 2¼″ - 3″ |

Suitable thin-walled copper or brass pipe is stocked by commercial plumbing supply firms, although it is less common at the smaller hardware stores than formerly was the case. Canulles may also be rolled of two turns of pressboard or tagboard if desired.

When filling the stars around the canulle, some makers shake some rough powder in among the stars to fill the interstices; other do not. Generally, the shell casing is patted, tamped, or shaken to settle the stars into the most compact configuration. Often the shell maker will half fill the case with stars, shake, pat, or even tamp the stars with a wooden stick to settle them, sprinkle in a sparse handful of FFA powder or rough powder; fill the rest of the stars, and likewise settle them.

A word of caution is in order here. Great care should be taken when consolidating the stars, especially when chlorate color stars are being used. What one maker considers to be ""tamping" stars may to another constitute "pounding"; the novice shell maker should never apply pressure directly to the stars with anything other than the fingers. Sometimes it is better simply to "bounce" the case being filled on the workbench periodically during the operation. Grievous accidents have occurred in the past during this critical step of assembly.

Finally, the canulle is filled with FFA powder, then carefully withdrawn, so as not to disturb the stars around it. This is best done by rotating (⅛″ turn or less) back and forth with a slight jiggling motion, which will cause the powder to move into the stars rather than the stars moving into the space left by the canulle wall. A little more powder than will equal the height of the stars is used, so that it spills over the center just slightly when the tube is removed. Finally, coarse rough powder is filled over the stars and powder until the top of the break is level. This final addition of rough powder itself is often then tamped until the corners of stars just begin to appear through it. The FFA core in the center should still be a distinct entity, and it is tamped also. At this point the shell should be filled such that an appropriate amount of paper (somewhat less than half the casing's inner diameter) extends beyond the fill level, to be pleated in toward the fuse at the center of the top inside disc.

Top discs with spolette, made as described elsewhere, should be readily available as shells are filled. The disc is pushed down onto the powder and stars in the shell casings, and settled firmly into place by tamping with a wooden rod. This must never be done hard enough to break the stars. After the disc has been tamped down, it is held down with one hand while the case is felt all around; it should be firm all over with no soft spots.

The paper extending beyond the disc is then folded down toward the center of the shell, i.e., toward the fuse. If everything has been well calculated, when this paper is folded into place, it will fall just short of the shell fuse, just barely touching it. Another disc, pierced to receive the fuse, is pushed down over the fuse onto

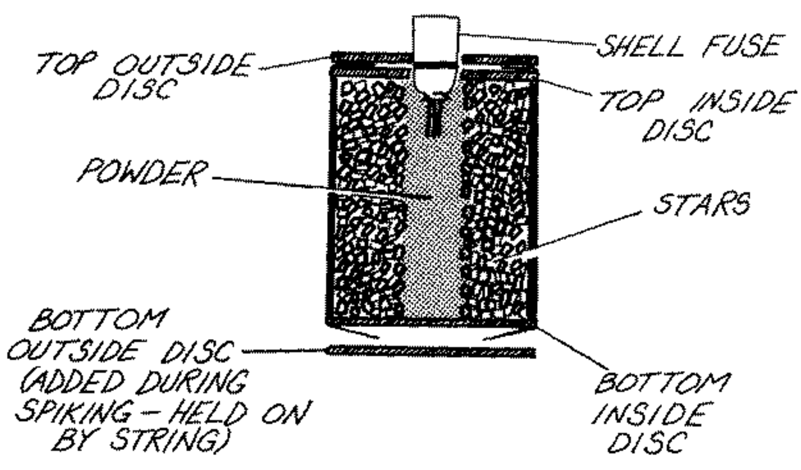



*Figure 13. Cross-section of filled shell case.*

the folds of paper, settled into place by tamping with a wooden stick. If desired, some makers apply glue around the spolette between the two discs. Finally, the shell is marked as to its contents and set aside. Figure 13 is a cross-sectional view of the filled shell casing.

When filling shells, attention must be paid that the proper size of star is chosen to fill a particular size of shell. Because stars differ so broadly in burning characteristics, it might seem that this question cannot be addressed without reviewing every star composition individually. In a sense this is true, and of course every experienced shell maker becomes aware of, and adjusts for, these variations in making stars. However, smaller stars are usually used in smaller shells and larger stars in larger shells. The reasons for this are two-fold:

1) Aesthetic considerations — The density and symmetry of effect produced are affected by the size of stars used. Large shells obviously have more volume, spread wider, and so the burning time of the stars can be proportionately longer than for small stars. Thus the stars can be larger. On the other hand, a small shell filled with large stars seems sparse in its burst, because so few stars fit into a smaller casing; and they normally burn too long, destroying the symmetry of the burst and leaving a "hole" in the center. Stars too small for a large shell burn out before the shell burst spreads to its ideal diameter, and the effect of the shell is disappointingly short-lived.
2) Structural considerations — The ratio of interstitial spaces between stars to the space occupied by the stars themselves must be small and relatively constant from size to size. Large interstices damage the shell's structural integrity; such a shell may collapse under the pressure of the lift charge. A shell derives its rigidity from the contents of its casing, and one *must* have the stars settle into a compact, stable configuration. It is difficult to do this if the stars are too large for the size of the case. This quickly becomes apparent on trying to fill a 3″ casing with ¾″ cut stars! Table 9 provides a very general guide to average star sizes for use in various sizes of shells.

The color stars are here presumed to be made with potassium chlorate, which is still overwhelmingly used in the display fireworks industry. Potassium and ammonium perchlorate stars generally burn slower and accordingly must be cut still smaller. Insofar as most such stars have a smaller flame size than could be obtained with chlorate stars of comparable size, this results in a tendency for perchlorate shell bursts to look sparse. Furthermore, perchlorate stars have a greater tendency

**Table 9. Corresponding shell and star sizes.**

| Size of shell | Cut color stars | Cut tailed stars |
|---|---|---|
| 3″ | ¼″ or smaller | ¼″ - ⅜″ |
| 4″ | ¼″ - ⅜″ | ⅜″ - ½″ |
| 5″ | ⅜″ - ½″ | ½″ - ⅝″ |
| 6″ | ⅜″ - ½″ | ½″ - ⅝″ or ¾″ |
| 8″* | ½″ or larger | ⅝″ or larger |

*8″ not normally made with plain cut stars.

to be blown blind, although this problem can be solved usually by heavy priming. Problems associated with the perchlorates can doubtless be overcome with careful formulation and experimentation, but they are not yet rectified, which, along with the higher cost of the perchlorates, accounts for the industry's continued dependence upon chlorate-based colors for the type of shells here being described.

The problem of sparse-appearing breaks may to some extent be solved by mixing tailed stars with the color. An inexpensive charcoal mixture of saltpeter, charcoal in excess, sulfur, sometimes lampblack, and dextrine can be cut to about the same size as the color stars, and mixed with them in a ratio of about 3:1 or 4:1, color:charcoal. The charcoal composition produces a low light output and the stars are not perceived as a separate effect when the shell bursts, being overpowered by the color, but they "fill in the space" and give the impression of a fuller burst. Flitter and electric stars, cut to normal size and mixed with color stars in about the same ratio as the charcoal stars, also have a "filling" effect, but are perceived as an *added* effect, and generally look most admirable.

Various types of tailed stars (charcoal, flitter, electric, etc.) may need to be cut larger than color stars because they usually burn faster, and also because they leave a spark trail. Tailed stars make a full-looking burst when fired from a shell by themselves, and less attention to cutting them small (to preserve burst density) is required. Sometimes tailed stars are deliberately cut smaller to give a pseudo-double ring effect with the larger color stars.

**Variant methods of case construction and filling**

Although the method described above is usual, two variations in case rolling and filling techniques are worthy of mention. In rolling the case, some fireworkers find it advantageous to begin with a turn or two of thin chipboard or index, of a width equal to the height of the shell wall. The heavier paper is centered on the outer


*Figure 14. Case rolled with inner liner.*

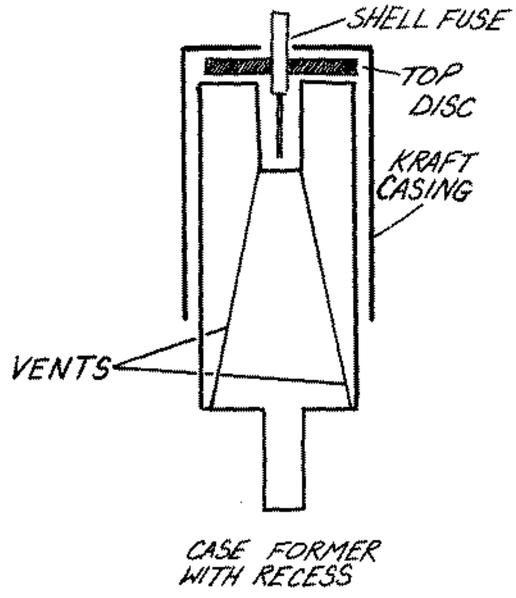



*Fig. 15.1*

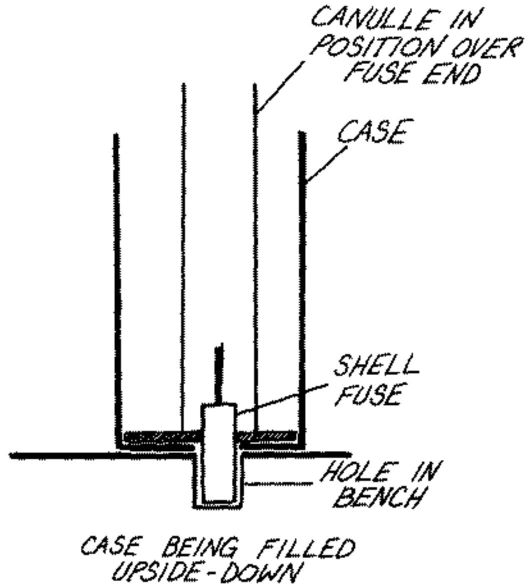



*Fig. 15.2*

*Figure 15. Making shell case "upside-down."*

kraft, and the case rolled up; or, the case is rolled in the normal fashion, its end folded in, and then the chipboard or index band is rolled up by hand and inserted into the casing (see Figure 14).

The claimed advantage of this technique is that it adds rigidity to the shell wall, making it possible to use fewer turns of kraft for the outer casing; the overlapping ends on the top and bottom are thus easier to pleat down. Furthermore, the chipboard establishes a uniform "fill level," as the case is always filled so its contents are just level with the top edge of the chipboard liner. Since having a level top is especially important with multiple-break shells, the liner is often used in making casings for breaks of such shells.

The other variant in technique requires that a hole or recess be made in the end of the case former to accommodate a shell fuse. After the kraft tube is rolled, the end disc with fuse in place is pushed into the end of the former, the inside end of the fuse fitting in the former recess; the extending paper is folded down onto this disc, and the outside disc fitted over the fuse and folded-down paper. The casing with fused disc is removed from the former, set over a hole in the workbench that accommodates the shell fuse, and filled, in effect, "upside down." The shell is then closed as usual, except that the bottom disc is used to close it (see Figure 15).

This technique is particularly adapted for single-break shells made with spolettes, as the matched and nosed end of the spolette fits up into the canulle, the powder settles around it without force; rather than being forced into the powder core as it is in the usual method, possibly breaking the match and causing its powder coating to flake away. Indeed, some makers use this method in making shells with spun Bickford or "tape" style fuses as well.

In order to prevent difficulty in removing the case from the former, the former is often "vented" with long narrow holes as depicted in Figure 15. Also, in lieu of making a hole in the workbench to accommodate the shell fuse, two pieces of lumber may be laid parallel on the bench or table, supporting the shells while allowing room for the shell fuses between them. In this manner, many such cases may be set out for filling at one time.

## SPIKING (STRINGING) SHELLS

After the inner cases of shells are filled with stars, or other garniture, and burst powder, they are reinforced by longitudinal and circumferential (vertical and horizontal) windings of string, which produce a pattern resembling latticework on the ends and walls of the shell (see Figure 16). This process, known as "spiking," requires considerable attention, as the string latticework must be both regularly-spaced and evenly-tensioned in order to produce the desired results. An inadequate amount of string will result in the shell bursting through the opposite sides ("side splitting") or, if the case is thick enough, blowing out the ends ("bow tie" break). It is instead desired to cause all the side walls to blow out, this being the aim of the longitudinal windings. String irregularly spaced will cause one side or the other to blow out, causing stars to be ejected from a hole in the side wall, like water squirting out of a hose. This is the so-called "hose break."

String may be taken directly from the ball or cone, tied to the shell fuse, and tightly wound onto the shell by hand, with tension being applied by pulling on the string with the hands. This procedure, however, is defective in several respects: it generates an irritating friction against the flesh, which can be remedied only by wearing heavy and clumsy gloves; it is quickly fatiguing, causing an irregularity of results if many shells are to be made at one time; and finally, it effectively precludes treatment of the string with tar or paste, which treatment offers many advantages both in ease of manipulation and in the quality of the product. As a consequence, it is preferable to apply string to the shells by one of several methods, in which string is fastened securely to a stationary binding point, and tension is applied by pulling on the shell as it is turned in the hands, winding the taut string upon it.

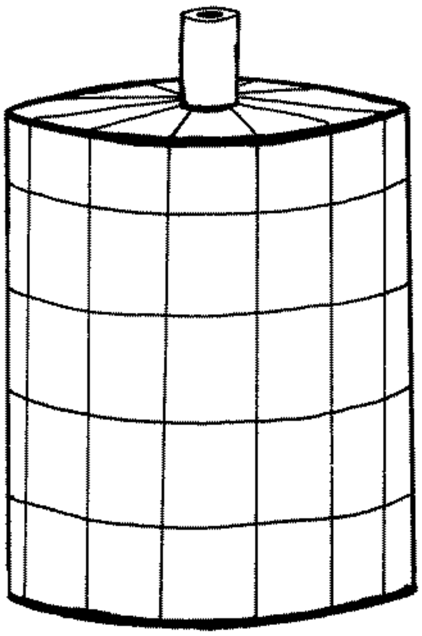


*Figure 16. Spiked shell.*

Perhaps the simplest and oldest device used in applying string to shells is called the *spiking horse*. It consists of two pegs (they may be bolts, spikes, dowels or whatever is sturdy and convenient) fixed upright in a board or bench. Between these rods the string is stretched preparatory to winding it up onto the shell (see Figure 17).[1]

In use, the spiking horse is "loaded" with string, beginning by tying at one of the pegs and looping in back and around the opposite one, then looping in back of the other peg, and so forth until all the string has been put on the horse, with the string crossing in the center ("figure 8" fashion) so that tension may be applied against either of the two pegs. Loading starts low against the bed of the horse and builds solidly upward and outward to prevent the load from slipping or giving slack. It is recommended that the workbench on which the spiking horse is mounted be firmly secured to the floor or wall.

It may be noted that a major difference in practice among pyrotechnists lies in whether or not to use paste on the string. It is, of course, faster to use dry string as the step of applying the paste is eliminated; however, pasted string adheres more closely to the shell walls, "bites" into the paper as it is wound on (if adequate pressure is applied), and thus is less likely to slip from its position. Pasted string dries very tightly adhering to the shell, which is especially important with multiple break shells in which the breaks are held together with string.

Paste may be applied to string in two ways: (1) make thick paste, take a handful and pull the string through the hand while putting it on the horse; (2) load the horse with dry string and paint a thin paste liberally

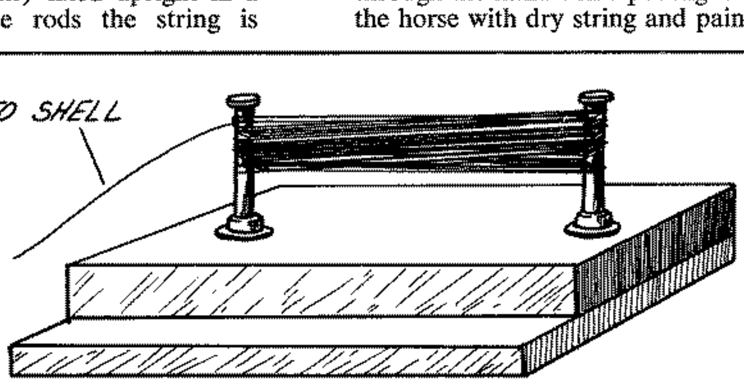



*Figure 17. Spiking horse.*

[1] A simple spiking horse may be made with: one piece of 2 x 4 (nominal; actual 1½" x 3½") lumber 32" long; one piece of 1 x 6 (nominal; actual ¾" x 5½") lumber 32" long; two ½" carriage bolts, 8" or 10" long, with approximately 2½" of thread or more; four ½" washers; and four ½" nuts to fit the carriage bolts; in addition, one half-dozen 8d nails or better, 2" x No. 8 flat head wood screws. Tools needed are a ½" and a 1¼" wood bit; a bit brace or power drill; a couple of C-clamps; a hammer and screwdriver.

Measure in 1¾" from the edge of the 2 x 4 at two points, close to the ends. Draw a line, using a straight edge, between these two points; the line will then bisect the 3½" width. Then measure in from the ends, along this line, four inches from either end. Mark these points, and at them, center the ½" bit to drill a hole at each. The result will be a 2 x 4 with two ½" holes, centered on 24", and centered on the width of the 2 x 4. Now, measure in 1¾" from one edge of the 1 x 6 at two points, close to the ends; draw a line between these two points. Measure in 4" from each end of the 1 x 6 along the line just drawn, mark these points, and at them center the 1¼" bit to drill a hole at each. The result will be a 1 x 6 with two 1¼" holes, centered on 24", with the centers 1¾" in from one edge. As is apparent, the centers of the 1¼" holes in the 1 x 6 will thus line up with the centers of the ½" holes in the 2 x 4, when the 2 x 4 is aligned flush with the edge of the 1 x 6 and flush with the ends.

Clamp the two pieces, 1 x 6 and 2 x 4, together with the pair of C-clamps, one at each end. At this point, one should either drill and countersink holes for the half-dozen screws (boring through the 1 x 6 and into the 2 x 4), or nail the two pieces of wood together, making sure that the holes in each piece align with each other. Remove the clamps and give the resultant assembly two coats of polyurethane varnish (this will help to protect it against paste sticking to the wood).

Now, put one of the nuts onto each of the carriage bolts, screwing it on about 2½", and over each bolt slip a washer. These bolts may then be seated through the ½" holes in the 2 x 4, from the top. Underneath (where the bolt protrudes into the recess made by the 1¼" hole in the 1 x 6), slip another washer on over each bolt, and screw a nut onto each bolt just so that all of the threads are engaged. Tighten the *top* nuts down onto the 2 x 4 firmly.

The steps described are illustrated in Figure 18. If properly followed, the result will be a compact and portable spiking horse that will sit flat on top of a workbench (as the ends of bolts on the bottom, their nuts and washers, are accommodated by the 1¼" holes in the 1 x 6); the two-inch "lip" made where the 1 x 6 extends beyond the 2 x 4 can be clamped firmly to the workbench with C-clamps; and when not in use, the horse may be removed and stored, freeing the workbench for other uses.

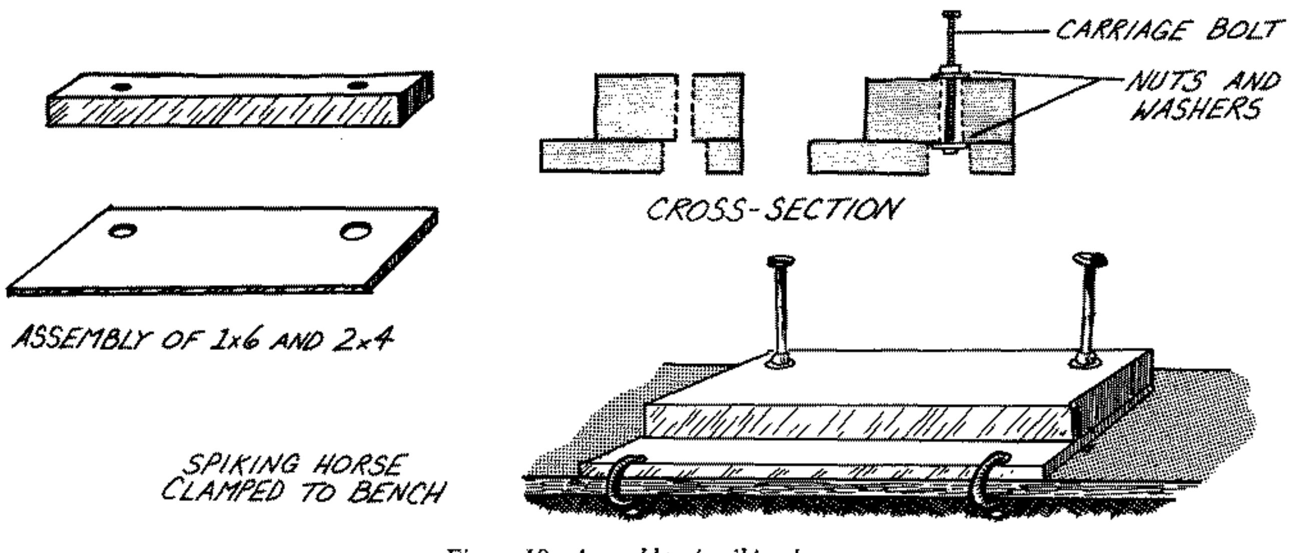



*Figure 18. Assembly of spiking horse.*

onto the string, making sure all is thoroughly wet. A wallpaper paste brush is useful for this purpose.

In order to begin spiking a shell, unloop a length of string from the spiking horse. The string is tied with a clove hitch to the fuse of the shell, and longitudinal winding is begun. With the first longitudinal wrap, the bottom outside end disc is centered on the bottom of the shell, over the folds of paper, and spiked on. The string passes around the bottom of the shell, up to the top, passing the fuse, and the shell is turned at right angles and another longitudinal wrap wound on; the strings divide the circumference of the cylinder into quarters, forming a cross in the center of the bottom of the shell. The quarters are then subdivided according to the number of final strings desired. It is very important that the operator keep the tension applied to the string constant as it is laid on (either as much tension as the string will bear, or, barring that, as much as the operator can apply steadily). The table below lists typical spiking patterns. It is to be understood that "side strings" here refers to the number of vertical passes on the side walls of the shell, dividing the cylinder's circumference, regardless of whether one, two or three strands of string be used in each pass.

It should be noted that in addition to the 8-ply and 10-ply cotton string most often recommended, varieties of flax twines, polyester or polyester/cotton blends, and hard-laid cotton strings are frequently found; further, that much less string is often found on cheaper shells made with an eye to quick mass-production techniques. The table above is a guideline, based largely on traditional practice.

Assuming a 3″ shell with twelve strings, each quarter (formed as described above) is further divided into three sections; ideally, a third is taken out of the first pair of quarters, then a third is taken out of the other pair of quarters 90° away from the first, and finally the other thirds are taken — resulting in three right angle crosses being applied to the shell bottom. The string passes the shell fuse on opposite sides with each wrap — i.e., the first time it passes on the right; the second, on the left; the third time on the right; and so on. For a 4″ shell with sixteen strings, the quarters would be

**Table 10. Typical spiking patterns.**

| Size of shell | No. side strings/No. strands each | Material |
|---|---|---|
| 3″ | 12/2 | 8-ply cotton |
| 4″ | 16/2 | 8-ply or 10-ply cotton |
| 5″ | 24/2 | 8-ply or 10-ply cotton |
| 6″ | 32/2 | 8-ply or 10-ply cotton |
| 8″ | 48/2 or 48/3 | 8-ply or 10-ply cotton |

turned to eighths, and then to sixteenths, again with superimposed right angle crosses, the string being placed 90° away from the previous wrap to keep the tension even. It is to be noted that the practice implied in some books, in which the windings are said to be advanced "ten degrees with each winding" or the like, in what might be termed a "clockwise" fashion, will result in both uneven tension over the shell, and also unevenness of spacing of the strings. It is much less easy for the spiker to gauge what (e.g.) 1/24 or 1/32 of the shell's circumference might be (unless end discs were actually marked for string placement before spiking), than for him to see that he has formed a right angle as here described. In any event, the patterns for longitudinal spiking of 5″, 6″, and 8″ shells follow the same scheme.

When the operator has completed the longitudinal spiking, he is ready to begin spiking circumferentially. The last longitudinal or vertical string passes the fuse and continues over the edge of the top disc as though an additional vertical string were to be added, but is instead run diagonally around the shell until it is running at right angles to the vertical strings — i.e., circumferentially around the shell at the bottom edge. The string should run in a circle around the bottom of the shell, crossing itself and pinioning all the vertical strings which were previously spiked. After making this ring around the bottom of the shell, the string should start up the side in a spiral, spaced so as to form squares as it intersects the vertical strings. The spiral continues to the top, where another circle is formed to pinion the vertical strings at the top of the shell. The string is then formed into a loop by the hand and a half-hitch thrown around the circumference of the shell and pulled tight (if the string is pasted, it will hold tightly after the string has been cut; the loose end should be smoothed down with the fingers, using a little paste).

A consequence of the crossing of all the longitudinal strings on the center of the bottom of the shell, particularly to be met with larger sizes of shells, is the formation of a "lump" of string which may make it difficult to paste in solidly due to air pockets where the pastewrap bridges over the string. A solution to this problem sometimes adopted is a style of off-center longitudinal spiking producing the sort of pattern illustrated in Figure 19, which shows the bottom of a 4″ shell.

## PASTING-IN

After shells have been filled and spiked, they are ready for pasting-in (pastewrapping), the process by which the walls and ends of the shell are covered with paper that has been thoroughly impregnated with wheat paste. This pasted paper wrap, when dry, becomes hard (contributing some rigidity to the shell) and acts to seal the shell from the influx of hot powder gases given off by the burning of the lift charge, which might otherwise cause the shell contents to ignite prematurely ("flowerpot" or mortar burst).

Materials needed for pastewrapping include kraft paper, wheat paste (wallpaper paste), and a large, flat surface that can easily be cleaned of residual paste when the work is finished. A formica-topped table is ideal, as it can be sponged off with liberal amounts of water, and if any paste should dry on the surface, it may be chipped away cleanly with a metal straight edge.

Paper for pasting-in shells again follows the rule of thumb that the number of turns equals the nominal diameter of the shell in inches; save that, for large special effect or multiple-break shells, the number of turns is often more. Table 11 lists typical paste wrap for single-break shells.

The width of the paper to be used of course varies with the height of the shell, but in general should be such that when the shell is wrapped up in it, the paper overhangs by anywhere from a little more than one-half the diameter of the spiked shell to almost a full diameter on each end. For example, suppose a 4″ single-break shell measuring 3¾″ from bottom end disc to top end disc, and having an outside diameter a little larger than 3½″; the sheets of paste wrap would measure anywhere from 7½″ to 10″ wide (depending upon preference) and 24″ long, with the grain running the short direction. Two such sheets would be required.

Mix the wheat paste according to directions on the container; the well-known brands such as "Golden Harvest" usually call for something like nine pints of water for every pound of the dry powdered paste. Wheat paste which includes the gluten of the flour is

**Table 11. Paste wraps for single-break shells.**

| Size of shell | No. of turns/ Weight of paper | Length of sheet |
|---|---|---|
| 3″ | 3 turns/30- or 40-lb. | 1 - 24″ sheet |
| 4″ | 4 turns/50-, 60- or 70-lb. | 2 - 24″ sheets |
| 5″ | 5 turns/60- or 70-lb. | 3 - 24″ sheets or 2 - 36″ sheets |
| 6″ | 6 turns/60- or 70-lb. | 4 - 24″ sheets or 2 - 48″ sheets |
| 8″ | 8 turns/70-lb. | 4 - 48″ sheets |

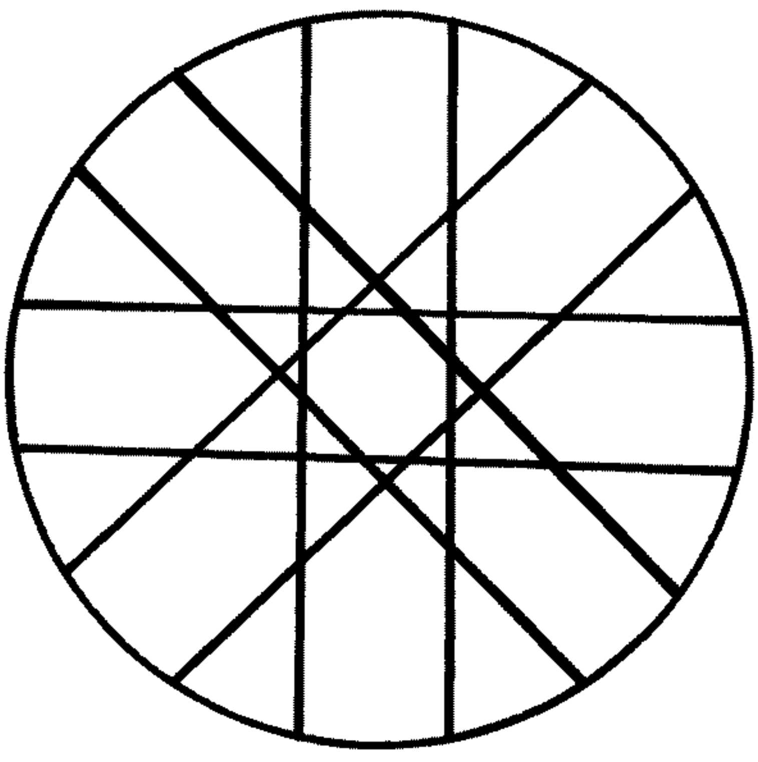


*Figure 19. Off-center spiking pattern for 4″ shell.*

preferable to paste based solely on starch, as it has less tendency to separate. Paste made according to package directions will usually suffice for all sizes of shells, though we like to think the ideal consistency is a little thicker than spaghetti sauce. Sometimes there is an advantage in using thinner paste on heavier papers, and thicker paste with lighter ones. When the paste is of a homogeneous consistency, the paper is "broken" or saturated thoroughly with it so that the paper is soaked through and through, and the grain is broken. A good method for achieving this is to take a handful of paste and smear it all over one side of the sheet; then double the sheet on itself (so the pasted side is folded back on itself) and smear both sides of the doubled sheet with more paste; then crumple the doubled pasted sheet into a ball. The purpose of this is to break the grain of the paper (making it more pliable) and help the paste to soak into the paper. Set this crumpled ball of pasted paper aside and repeat the operation until several have been done. At this point, the first one should be thoroughly soaked and ready to be used.

Unfold and smooth out one of the paper "balls" and fold it over on itself lengthwise a couple of times. At this point any excess paste may be wrung out of the paper by pulling it through the hand while squeezing it. Then it should be unfolded and laid out flat on the table and smoothed out. Place the shell on one end of the sheet, roughly centered on its width so that approximately equal portions overhang the shell ends. It is an aid in smoothing the paper down to the shell and making it adhere if the body of the shell is smeared with a little paste before rolling up the shell. Roll the shell up in the pasted paper, rubbing it down very firmly onto the shell body while rolling. The pattern of string on the sides of the shell should show through clearly after the paper has been well rubbed down. If more than one sheet be required, they are rolled on successively.

When the shell is rolled up in the paper, the overhanging edges are torn into strips (six or eight of them) and these are carefully smoothed down on the shell's ends, first on the bottom, then on the top. A "collar" on which to set the shell, fuse end down (with the fuse inside the "collar") may be made of a piece of pipe an inch or so smaller than the shell's diameter, and is a useful aid while smoothing the paper on the bottom of the shell. On the top of the shell, the paper should lap up onto the shell fuse and be pressed smoothly against it.

The width to which the paper for paste wrap is cut has much to do with the style of time fuse chosen for the shell. Where a spun Bickford or "tape" style fuse is in use, the paper may be cut to overhang a little more than half-a-diameter so that when smoothed down to the fuse it just touches it. This is necessary with such fuses as the thickness of the shell's top or "crown" is dictated by the distance between inside and outside cross-matchings; if the crown is too thick, it interferes with proper cross-matching. When a spolette is used, less attention to the thickness of the crown is required. Certain pyrotechnists, indeed, claim that a specially heavy crown is needed to seal and support the spolette in place. These workers will cut the paste wrap paper to overhang the shell's top by almost a full diameter. In tearing and smoothing down the strips of paper, the strips are first torn as usual, then each strip is torn halfway down the middle and rubbed down with the halves "forked" on either side of the spolette. Such a technique is quite time consuming, but it produces a heavy and almost conical crown around the spolette. Similarly, opinion differs on the proper amount of paper to overhang and smooth down on the shell bottom. Some operators believe a sufficient seal is obtained by having the strips meet in the center of the bottom; others, particularly with heavy and large shells, make it the full diameter of the shell and in pasting-in cause it to overlap. Particularly with very large shells having many turns of pasted paper, such a technique leads to almost hemispherical shell bottoms. Whatever technique is chosen, when tearing the overhanging paper, one stops just a tiny bit before reaching the body of the shell. This is done primarily to avoid "dog-ears" or rough corners on the top or bottom edges of the shell, but it is also claimed that "pin-holes" where hot gases from the exploding lift charge could permeate the paste wrap are thus avoided. Finally, rub the shell with the hands to express excess paste and to smooth the paper down firmly all over the top, bottom and sides.

Some pyrotechnists prefer, particularly on smaller shells, to fold the pasted paper down on the bottom of the shell while rolling, at the same time pleating or twisting the overhanging paper at the top around the shell fuse, one turn at a time, instead of tearing it into strips. This is particularly feasible when lighter paper is used for paste wrap, as on 3" shells. Other makers merely fold the inner layers of overlapping paper in on the shell, and tear the outer layer or two as usual. These methods afford speedier production (when employed by a practiced worker), and are also advocated as means of preventing "pin-hole" formation.

If more than three or four turns of heavy (60-, 70-lb.) paper are to be put on the shell, it is wise to paste in with two or three turns, let dry, then add two or three more turns, until all the paper has been pasted on that is required. In this way, the undesirable situation of having heavy masses of soggy pasted paper on the shell all at once can be avoided. Shells should be set to dry in a well-dehumidified, heated room with circulating air. Warm, breezy summer days are ideal for shell drying out of doors. Air current is more important than heat in drying; shells will dry faster at 70°F with a breeze than they will at 90°F when the air is stagnant. Wet shells should be dried on screens to assure air circulation above and below, or otherwise, turned frequently to give all surfaces equal opportunity to dry.

On shells with many turns of paper, particularly when time fuse is used and there is no desire for a heavy shell top or "crown," often a band of paper just covering the side walls of the shell is used. For example, a 6" shell might be pasted with a band (24" long, width equal to shell wall) and a sheet (24" long with 3" overhang on either end torn into strips and smoothed down on the ends), set to dry, then pasted with another band and another sheet. With a spolette, it is desirable to have a crown that is heavy and supports and seals around the tube. Thus all the paste wrap on such a shell should overhang the top and be smoothed down around the spolette, but it need not be built up with paper on the bottom; half the sheets can be cut to roll up flush with the bottom edge only, and the balance to be torn into strips and smoothed down (see Figure 20).

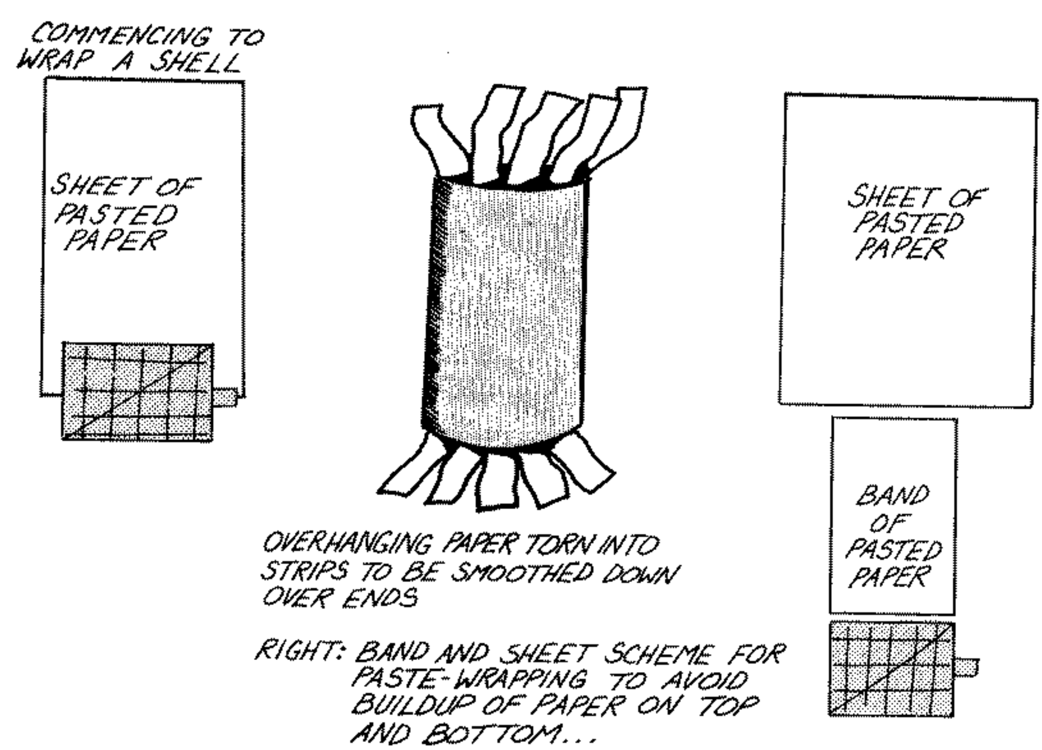



*Figure 20. Pastewrapping procedures.*

In some plants, where a need for economy makes it desirable to accomplish all the pastewrapping in one operation, larger shells are pasted in with lighter paper than is advised in Table 11. The same number of turns are used, but (e.g.) a 5″ shell might be wrapped in five turns of 40-lb. or even 30-lb. kraft. This expedient method produces shells faster, but with an offsetting decline in appearance, and (to a lesser extent), less quality of the product in performance. It is possible to get by with such cheapening of single-break shells without too much decline in reliability, but a poor paste job will have considerably more telling effect on a multiple-break shell.

It is easier to work paste into the lighter weights of paper, and when many small shells are to be pasted-in, it is usual to prepare many sheets of paper at once. To do so, using 30-lb. or 40-lb. paper, lay a sheet out on the table and brush or smear one side, then the other, with paste. On top of this sheet, lay another, with the edge staggered about ½″ in from that of the first sheet. Brush the top of this sheet with paste and lay yet another sheet atop it, again ½″ in from the edge of the sheet below; brush with paste, and repeat until a sufficient number of sheets have been laid out and pasted. It will be understood that the sheets of paper lie on the table in a "lapped" pile, like shingles on a roof or the slats of a Venetian blind. When the pile is complete, it is picked up as a unit and turned over, and brushed with paste on its bottom side. Then it may be broken by wringing it, rather as one wrings out a wet cloth, the narrow way (that is, against the grain); and after this, perhaps even crushed into a ball. When smoothed out it is laid flat on the table so that shell pasting can begin. The shells may be rolled up one after the other right from the pile of paper. This operation is illustrated in Figure 21. The paper may either be torn into strips and smoothed down on the shell ends, or folded and twisted, as preferred.

The effect of the quality of the paste wrap and the amount and weight of the paper used on the appearance of the break is uncertain.[2] A heavy paste wrap will certainly lead to higher pressures within the shell before it breaks, and thus presumably to better ignition of the garniture, and to a harder, more symmetrical burst. It is the present writer's opinion, however, that symmetry of burst is primarily a function of spiking in a traditional shell with black powder burst. The importance of paste wrap is more in serving to seal the contents of the shell from hot powder gases, and as a reinforcement to hold the shell together as it is propelled violently from the mortar. That this is so is proven by the existence of an alternative traditional technique, called *rinfasciature* or *dry pasting*[3], in which paste wrap is dispensed with entirely, but excellent, symmetrical breaks may yet be accomplished.

When the paste wrap has dried on the shells, they will feel dry and rock-hard all over. Progress of drying may be checked by pressing with the fingernail around the shell fuse (this is where drying takes longest). Once dry, shells are ready to be equipped with lift and leader.

## FINISHING (LIFT AND LEADER)

The shell, following pastewrapping, is essentially complete as a projectile, but (as opposed to some current Oriental practice, and much earlier Occidental practice) is always equipped with its own self-contained lift

[2] No detailed published studies have been done on this problem for traditional Italian-style cylindrical shells, although Shimizu (1976) investigates this problem with spherical shells in depth. — ED.

[3] This technique will be described in Part II of this work.

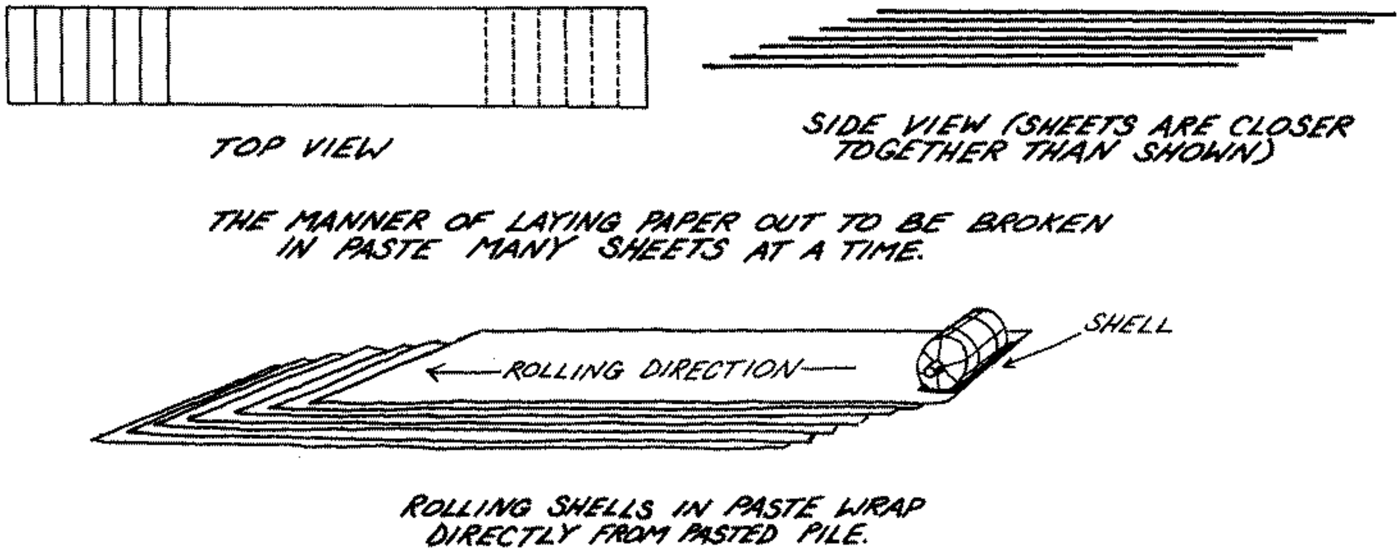



*Figure 21. Procedure for pasting-in many small shells at once.*

charge (propellent) powder, and a long quickmatch leader which will project from the mouth of the mortar after the shell has been loaded, and by which both shell fuse and lift powder may be ignited. The process of finishing a shell with lift and leader is more complicated than it might seem, and is worthy of special attention because it is crucial to the success of every shell.

Required for shell finishing are black match, FFA black powder (sometimes 4FA powder is used for smaller shells), various sizes of match pipes, 30- or 40-lb. kraft paper, string and paste. Although the techniques for making black match itself vary widely, and are outside the concern of this discussion, the match pipes to be used are of special concern. Two types of piped match are used in shells: *leaders,* i.e., the match, typically two to three feet in length, by which the shell is fired, and *passfires,* the match that (as the name implies) passes fire from the top of the shell (where it is tied in with the leader and the shell fuse) to the bottom (where the lift charge is located).

**Leaders**

Leader pipe should be ¼" - ⅜" in diameter, and sized to fit the shell and the mortar for which it is intended. A 24" or even 18" leader is ample for 3" single-break shells, while larger shells have 30", 36", or longer leaders. However, on a long multiple-break shell, the top of which may stand only a foot from the mortar muzzle, a shorter leader may be used. Some pyrotechnists use mass-produced bundled match for shell leaders, but this is not commended; such machine made match is expensive, and furthermore hand-rolled leader pipes are stronger, better withstanding the abuse that shell leaders must take.

Many techniques are in use for making leader pipe; a simple one is as follows. First, strips of 30-lb. kraft paper should be cut the length of the finished match pipe, with the grain running the long way, and about four to five inches wide. A straight rolling rod of the desired diameter, preferably made of smoothly finished metal, is also necessary. Paste one edge of the paper with a strip of paste about ½" wide; lay the rod on the paper about an inch in from the opposite edge. Bring that edge of the paper strip up over the rod and push it down with the fingers as the rod is rolled forward. The hands, with the fingers against the paper, are moved outwards longitudinally to the rod. The edge of the paper strip is thus trapped between the rod and that part of the paper which is yet unrolled, forming a loop. The outward movement of the fingers draws the loop of paper taut; the advancing rod mashes the loop into a flat crease, which with a little practice is quite straight (see Figure 22). Finish rolling up the pipe and tighten it by continuing to roll for several revolutions, smoothing the pasted edge with the hands. Finally, remove the rod carefully and repeat the operations until sufficient pipes are rolled. Practiced workers usually fan out many strips (perhaps 100), paste all the edges at once, and roll up the pipes very quickly.

If the technique described cannot be mastered, an alternative method is to fold over about an inch of paper along the length of each strip in advance, then turn the paper over so that the folded-over part lies facing the work surface, and paste the opposite edge with a ½" strip of paste. Bringing the folded edge over and around the rod, tuck the fold under the rod, and roll up the pipe.

*Fuse caps* are also necessary in assembling the *heads* (as leaders not yet attached to shells are called). Some pyrotechnists simply cut up ordinary leader pipes into pieces 6" - 8" long, folding, tying, or twisting one end of each piece shut. Others prefer to roll special pipe on a rod about 1/16" larger in diameter than that used for the leader pipe itself. Often, white or a bright colored paper is used for the fuse caps, to distinguish them in the dim light along the mortar line from the leader pipes rolled of brown kraft. Some makers use lance tubes for fuse caps.

Also roll on a ¾" or 1" rod a large sort of pipe of 1½ - 2 turns of light paper. This should be cut into bands or rings of about ½" width with which to bind up the folded heads.

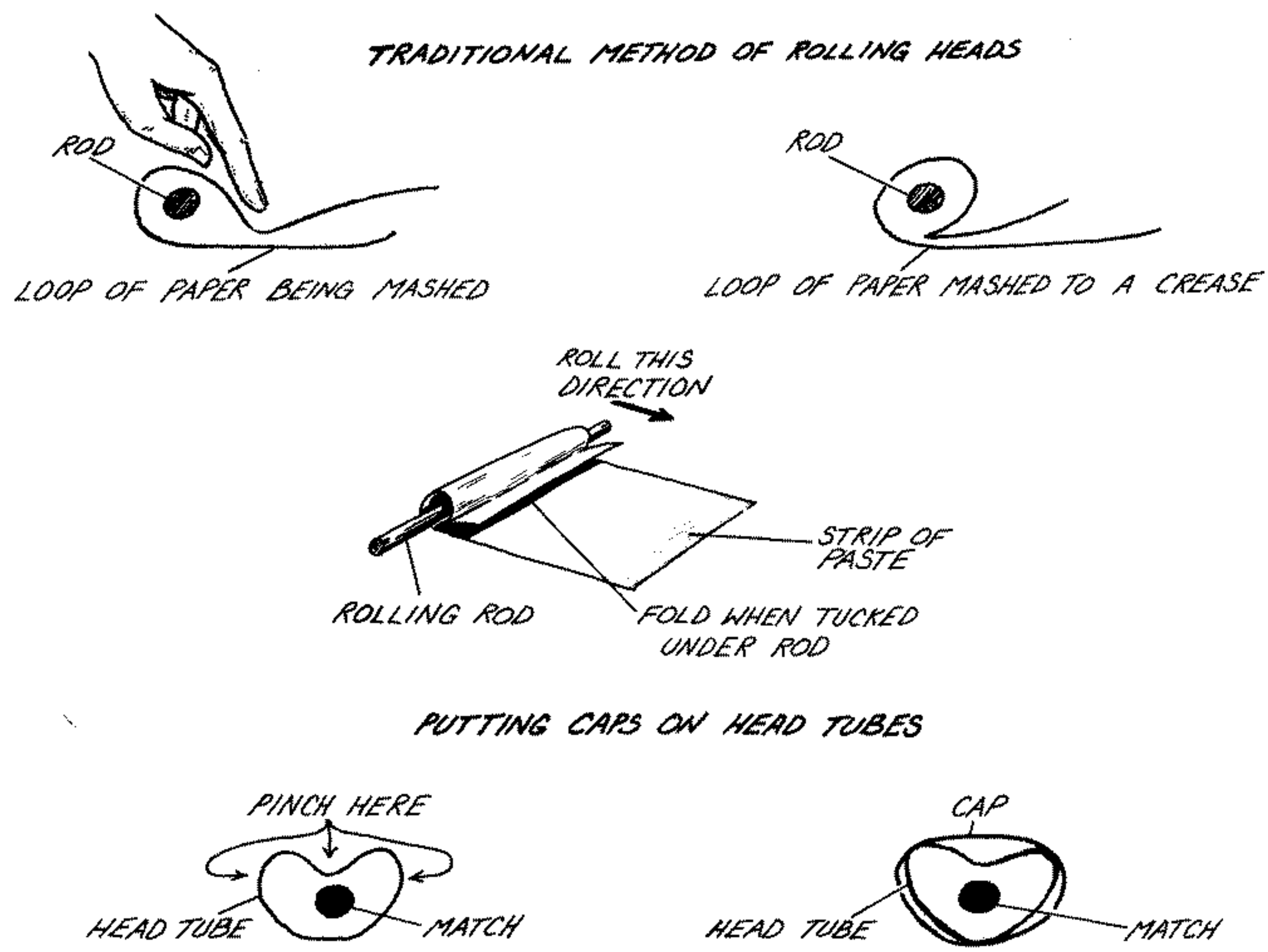



*Figure 22. Match pipe rolling operations.*

The black match should be cut perhaps 6″ longer than the leader pipe, and threaded through the pipes so that about 4″ protrudes from one end, and 2″ from the other. Place the fuse caps over the 4″ ends (pinching the leader pipes to enable the caps to slip over them), and fold all but about a foot of the leaders up in bundles perhaps 6″ wide, and slip the bands over the bundled match to bind the finished heads, as illustrated in Figure 23.

**Passfires and Buckets**

Also necessary for shell-finishing are *passfire pipes.* Passfire pipes may be rolled on a ⅜″ or even ½″ rod, since these big pipes usually carry two or even three lengths of match, usually 6- or 8-strands of cotton per length. These pipes are usually rolled in lengths of two or more feet and cut to the size needed.

*Buckets* must also be rolled for the spolettes of shells. These should be about 3″ long, of three to four turns of 40- or 50-lb. kraft, and of a diameter to fit over the spolette and the passfire (as will be shown later); ¾″ for small shells, and even 1″ for big shells with big spolettes.

Cut the passfire pipes to such a length that the pipe will run from the top of the spolette (with which it will be flush), down the side of the spolette, over the top of the shell, and down its side to about 1″ below the bottom of the shell. Now, cut match about 2″ - 3″

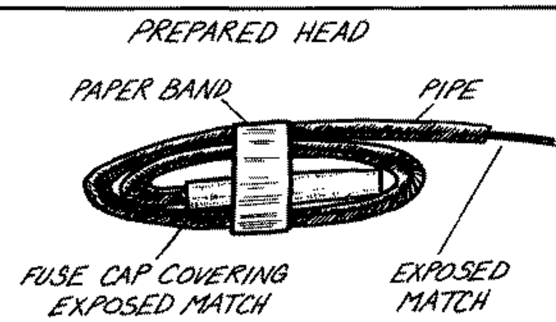



*Figure 23. Prepared head.*

longer than the passfire pipe (two pieces for small or short shells, three pieces for big or long ones) and thread it through the pipe so about ¾″ extends from the end that will be tied to the spolette, and about 1½″ - 2″ from the bottom end which will communicate fire to the lift charge. Some makers prefer to flatten the passfire pipe by rubbing it flat on the work surface prior to inserting the match. Be sure that the match lies flat, side-by-side, and does not cross or twist in the pipe. The resultant assembly is a complete passfire.

Bend the exposed ends of match on the top end of the passfire over the top of the spolette, which has previously been prepared by scraping or scratching it to expose a fresh surface of powder, removing any paste that may have covered it during spiking or pasting-in.

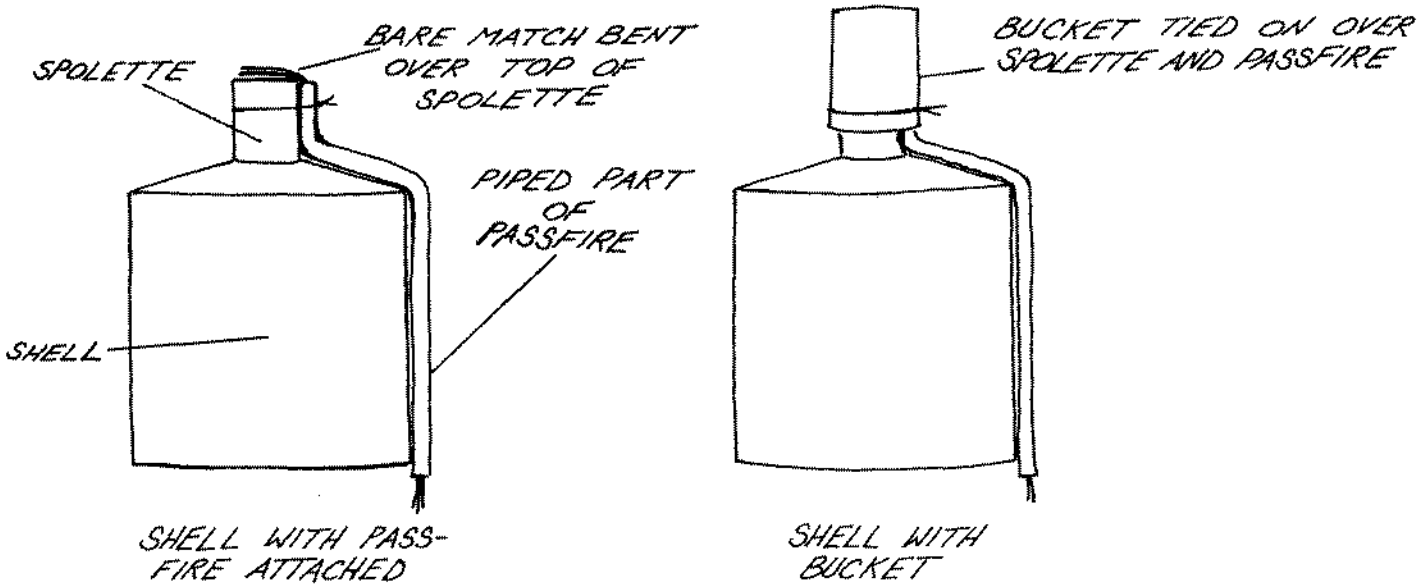



*Figure 24. Attaching passfire and bucket to shell.*

Tie the match in this position with a clove hitch around the spolette and the passfire down the side of the spolette. The presence of double or triple pieces of match usually suffices to insure that the tie will not choke off the passage of fire as it would if only one piece of match were used; however, it is a matter of practice and experience to learn the appropriate firmness with which to tie — tightly enough to prevent slipping, but not so tightly as to strangle the passfire completely. Bend the passfire down along the crown of the shell, then down the side, securing on the side wall with a piece of pasted paper or paper tape (see Figure 24).

Next, smear the sides of the spolette with white glue, being careful not to get it on the exposed match on top of the spolette. Slide a bucket tube carefully over the spolette and passfire — if the bucket tube is of the proper diameter, it will fit snugly without being forced. Rotate the tube on the spolette to insure a good glue contact, and tie firmly over the bucket tube at the base of the spolette, with a clove hitch of strong twine.

Some workers are able, with a bit of dexterity, to eliminate entirely the step of tying the passfire to the spolette prior to fitting the bucket. The passfire is bent in place and the bucket slipped over it and the spolette, then the bucket is tied as usual.

**Lift wrap**

The shell is now ready to receive its *lift wrap*. Cut 30-lb. kraft paper (heavier paper is often used for the larger shells) sufficient in length to go two turns around the shell, and about twice the diameter of the shell *former* (i.e., 2½″ × 2 = 5″ strip for 3″ shells; 3½″ × 2 = 7″ strip for 4″ shells, etc.). The grain should run the width of the paper, i.e., parallel to the direction the shell will be oriented as it is rolled up.

Paste half the width of a strip on one side with a paste brush. Lay the shell on the strip at one end, with the passfire down the side, such that the pasted portion is in line with the shell, with the unpasted portion overlapping (see Figure 25). Roll the shell up in the paper, making sure it goes on tightly. Shells so wrapped may be set to dry and the paper will shrink down tightly on the shell walls and over the passfire. The overlapping ends of *un*pasted paper form the bag for the lift charge.

**Lift charge**

When the pasted-on lift wrap is dry, the lift charge of FFA blasting powder may be measured (see Table 12) and dumped into the lift bag, as the shell is held in an inverted position. If the pasting has been done well, the paper will adhere to the shell walls, and powder will not sift down between the paper and the wall of the shell. The inner turn of paper may be folded down over the powder, making sure that the passfire end is bent over into the powder first. The outer turn is then gathered, sack-style, into the center of the bottom, and firmly tied with a clove hitch of strong twine. The gathered paper may be trimmed close to the knot with tinsnips or a knife. A well-sharpened, serrated knife works well, as it has a sawing action.

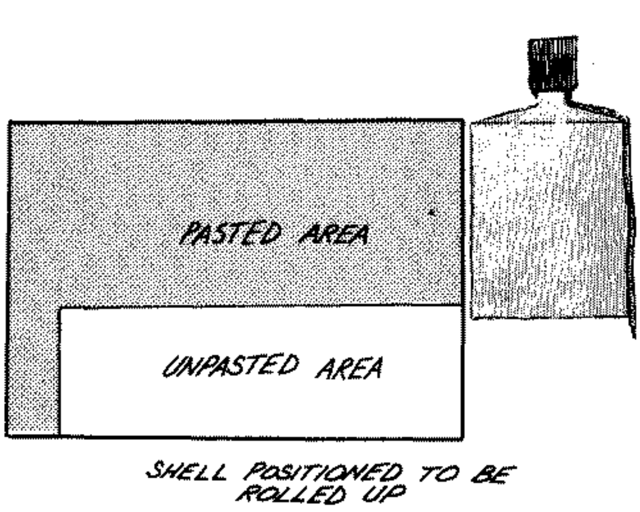



*Figure 25. Shell ready for lift wrapping.*

**Table 12. Typical lift charges for 3" - 8" single break shells.**

| Shell size | Description | Weight of FFA for lift |
|---|---|---|
| 3" | 1-break color or salute | 1 oz. |
| | Color and special garnitures (whistles, serpents, saettines, etc.) | 1¼ - 1½ oz. |
| 4" | 1-break color or salute | 2 oz. |
| | Color and special garnitures | 2½ oz. |
| 5" | 1-break color or salute | 3 - 3½ oz. |
| | Color and special garnitures | 4 - 5 oz. |
| 6" | 1-break color or salute | 4 - 5 oz. |
| | Color and special garnitures | 4½ - 6 oz. |
| 8" | 1-break color | 8 - 12 oz. |

NOTE TO TABLE:

The above table indicates lift charges for the simpler shells described in this first part of the present work. Appropriate charges for more elaborate and heavier shells will be suggested in the second part, which will treat the manufacture of such shells. It is impossible to list the entire variety of shells that it is possible to make, so ultimately it will be necessary for the pyrotechnist to arrive at lift charges for his large and special shells by experience.

A rule of thumb often used is to allow 1 oz. of FFA for each pound of shell weight up to 10 lbs., and ½ oz. for each pound in excess of 10 lbs. Especially with very large shells, such factors as the fit of a shell in the mortar, the mortar length, and the length of the shell, assume importance which they do not have in the case of smaller and more routine shells.

The shell is turned upright, with the bucket on top; the head (previously prepared) should at this point have an extra piece of black match (perhaps 3" - 4" long) inserted into its open end, and that end then thrust into the bucket (contacting the match from the passfire on the top of the spolette), and the bucket gathered around the pipe, and firmly tied with a clove hitch. At this point, it is usual to smear a little white glue over the knots at the bottom of the shell, at the bottom of the spolette where the bucket is tied on, and at the top where the bucket is choked onto the leader. As previously mentioned, the doubling of the match (where it is tied into the bucket) is insurance against failure, as a single length of match tied too firmly in its pipe may be delayed, or even choked off in burning. The shell is now complete and ready to fire.

Table 13 describes the dimensions of mortars suitable for firing cylindrical shells of usual dimensions and lift charges as prescribed in Table 12.

**Table 13. Mortar lengths for cylindrical shells.**

| Diameter | Length |
|---|---|
| 3" | 18" for single-break color or salutes only<br>24" for all uses |
| 4" | 30" |
| 5" | 30" |
| 6" | 36" |
| 8" | 48" |

### Variations in finishing

The method described above is an old, traditional one that makes shells which slide smoothly down the mortar and leave few glowing embers in the mortar after firing. Often the method described is further elaborated. Instead of gathering in and tying the lift bag at the bottom, it is sometimes folded over, and then covered with a sheet of pasted 30- or 40-lb. kraft to hold the folds shut and make a flat bottom. The walls of the shell are then covered with a band of thin paper (completely pasted on both sides), perhaps 1½ turns of 30-lb. kraft, sometimes ordinary brown paper, but often colored kraft or even Christmas wrapping paper. Such a finish is ordinarily reserved for large and elaborate shells.

A much more common finish for shells is for the shell to be handled as described, up to the point where the passfire is tied to the spolette. Instead of merely bending the match over the end of the spolette (as shown in Figure 24.1), the match is cut somewhat longer, so that it can be bent down the opposite side of the spolette and tied as illustrated in Figure 26.

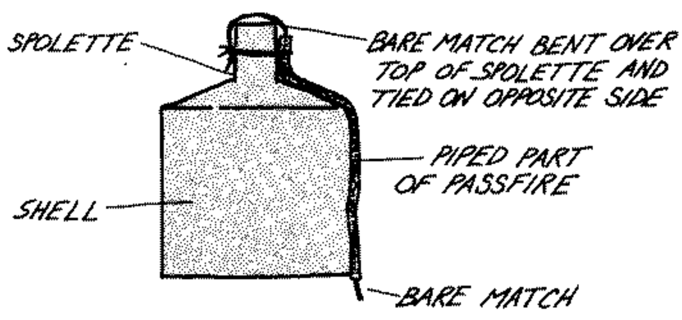
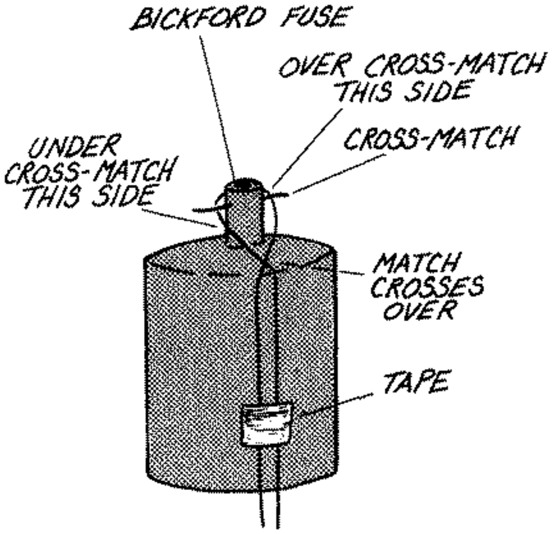



*Figure 26. Shell prepared for dry-wrap finish.*

The shell is then wrapped up in a sheet of dry paper, pasted onto the body of the shell only at its edge, long enough for two or three turns around the shell body, and extending several inches beyond either end of the shell. The wrap is then gathered in around the base of the spolette and tied, the shell inverted and the lift powder put into the "cup" formed by the paper extending beyond its bottom. This paper is then tied off close, and the shell is completed by tying the leader in at the top, treating the extended gatherings of paper sticking up around the spolette (from the place where tied at its base) as a sort of "bucket." In dealing with a shell with a spun type fuse, this method is the only one suitable to use, because it is impossible to have a separate bucket for the timer fuse.

On 3" finale shells, it is possible to dispense entirely with the passfire pipe, making passfires with naked match. The confinement afforded by the tight turns of lift wrap suffices in lieu of a pipe. Cut lengths of good match, perhaps three times the height of the shell. Holding the shell in one hand, lay the match along the side so that perhaps one inch protrudes beyond the bottom. Bring the match up *over* the cross-matching of the time fuse, around it in back, *under* it on the other side, doubling back and crossing over the match where it runs along the top, and *down* the side parallel to the first strand. Secure with a square of paper tape; roll up the shell in a couple of turns of 30-lb. kraft, extending perhaps 3" - 4" beyond either end of the shell. Empty the lift charge into the bottom and close the lift wrap with a clove hitch; invert the shell, insert the head (with doubled match) and tie once above the timer fuse. Figure 27 shows this expedient method of making a passfire.




Shell (ready for lift wrap)

*Figure 27. Finale shell with passfire of naked match.*

It is usual to use a passfire pipe on larger shells made with timer fuse, with the match extending from the end "forked" under the cross-matching, as shown in Figure 28. The outer lift wrap is essentially similar to that described for the small shells. Sometimes, when using a dry paper wrap, powder from the lift charge will sift up between the wrap and the side walls of the shell, particularly if the wrap has been put on loosely. Some shell makers tie a ligature around the bottom of the shell (or just below it) to prevent this. This in effect chokes the lift wrap and prevents powder migration (see Figure 29).

In summarizing the advantages and drawbacks of the dry lift wrap (as opposed to the pasted lift wrap as previously discussed), it is obvious that the dry wrap

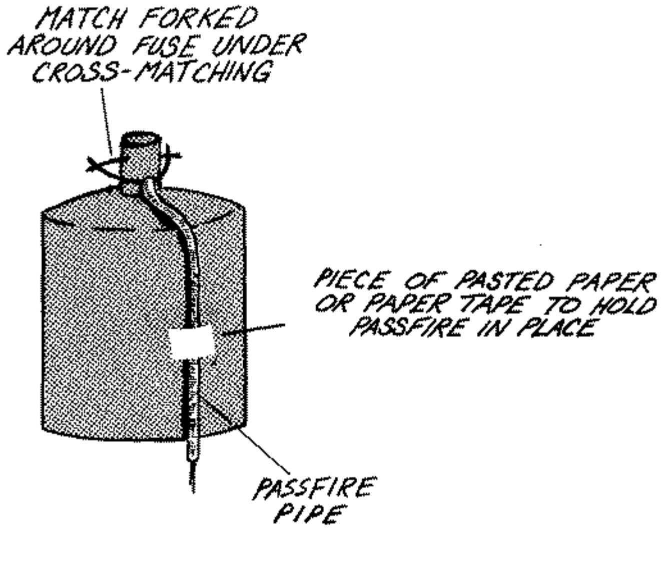



*Figure 28. "Forked match" on large shells using timer fuse.*

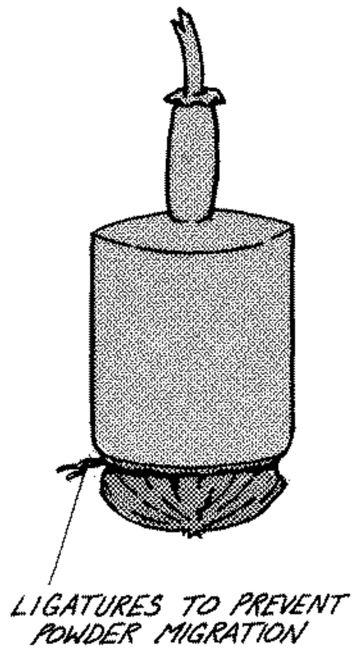



*Figure 29. Shell tied off with ligature.*

is more expeditious, and thus less costly; but burning detritus is blown into the air, posing a hazard to operators and materials in the area around the mortar. Furthermore, remnants of these wrappings often remain, glowing or burning, in the mortar, and must be removed periodically. This is why the dry wrap is used by the fastidious pyrotechnist only for finale shells or in situations (e.g., electric firing) where each mortar is used only once during the display and will not need to be reloaded or repeatedly approached by the display operator.

## SINGLE BREAK SHELLS WITH SPECIAL GARNITURES

The successful achievement of consistently-performing single break shells of cut stars may logically be followed with efforts including various special garnitures other than cut stars, or shells containing cut stars in combination with such garnitures. The list of these garnitures is lengthy, and only some of the simpler types are described here (other, more complex garnitures will be described in Part II).

### Comets

Comets are large pumped stars, usually ranging from ¾" to 1¼" in diameter, but they may be even larger in large shells or where some special effect is sought. Generally they are of a tailed composition, such as charcoal, flitter, or electric types, but on occasion they may be of a colored or fancy "colored electric" type.

Large pumped stars such as these must be pumped with heavier pressure than can be applied by hand. Ordinarily, they are rammed by means of a heavy mallet applied to the pump's plunger. In order to assure that they are of uniform size, so that they will stack properly inside the shell, normally they are rammed somewhat longer than usual and then the excess is cut off with a small knife or spatula. If the pump is of the type equipped with a pin or stud on the side, and a slot to accommodate this in the sleeve, the procedure is as follows: holding the pump with the pin perhaps ½″ - 1″ above the top of the sleeve, fill the pump with the damp composition, and place the bottom of the pump on a smooth surface sturdily supported on the floor. With the mallet, ram until the composition is thoroughly compacted. At this point the pin should stand maybe ¼″ above the top of the sleeve. The plunger is pushed until the pin contacts the top of the sleeve, and the excess composition protruding from the sleeve is cut off, falling back into the tub of damp composition. Finally the plunger is turned until the pin engages the slot, and the comet is pumped out and set to dry. Pumps may be made without the pin and slot, and in this case an index mark is made on the plunger to serve a similar purpose; the composition is rammed, and the excess ejected by pushing the plunger into the sleeve until the index mark registers with the top of the sleeve; finally, the excess is cut off and the comet ejected.

Comets are laid in the shell casing so that they form a circle around the periphery of the case. The comets touch the case on its inside wall, and touch each other; the circle or ring of comets should fit snugly in the case. If the circle fits loosely, a chipboard liner rolled up and inserted inside the case may be used to reduce its diameter to tighten the fit. On the other hand, if it should arise than an extra comet could be made to fit by slightly enlarging the inside diameter of the case, this may be done by rolling a turn or two of chipboard on the former prior to rolling the kraft on it. After finishing the case in the usual fashion, the chipboard is removed, leaving a case with a circumference just enough larger that the extra comet may be added, making a snugly fitting ring of comets. Each pyrotechnist has his own preferences, which depend upon the choice of compositions and their burning properties, as well as on the effect desired. However, the following schemes in Table 14 suggest typical patterns:

**Table 14. Patterns for comet rings in shells.**

| Size of shell | No. of comets per ring | Comet diameter |
|---|---|---|
| 5″ | 10 | 1″ |
| 5″ | 9 | 1⅛″ |
| 5″ | 8 | 1¼″ |
| 6″ | 12 | 1⅛″ |
| 6″ | 10 | 1¼″ |
| 8″ | 14 (loose) | 1¼″ |
| 8″ | 15 (tight) | 1¼″ |

The careful pyrotechnist may have pumps made to make comets of special sizes to fit snugly in his shells, or may have case formers of slightly smaller or larger diameter than standard to make comets of standard sizes fit. If a slightly larger former than usual is used to make the shell casings, or if the technique of rolling on chipboard, then removing it after the case is rolled, to achieve a slightly larger shell case, is employed, then it should be ascertained that the resultant shell will still fit in the mortar of appropriate size after it is finished. The table given above is for use with comets and shell casings of standard size.

A small, roughly triangular space is left between the inside shell wall and each pair of comets (see Figure 30.1). After each ring of comets is laid in place, the spaces must be filled with either rough powder or an inert filler such as sawdust, so that no empty air spaces jeopardize the integrity of the shell wall. Whatever filler is chosen (rough powder and sawdust each have advocates among experienced fireworkers), it must be sifted down into these spaces and then rammed with a small stick. Some makers have found it of advantage to carve a special, roughly triangular, tool to fit on the end of the rod employed for this purpose. Lacking such, however, an ordinary dowel serves quite adequately.

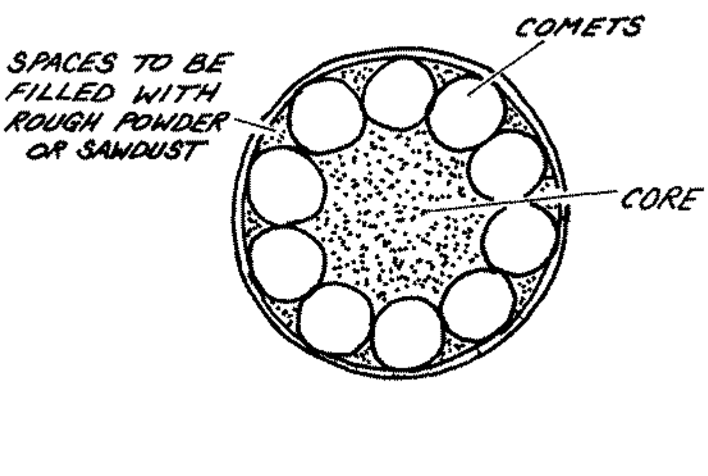



*Figure 30.1. Top view of comet shell.*

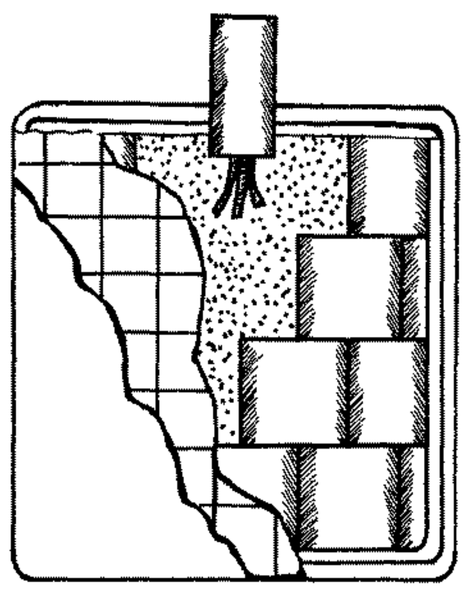


*Figure 30.2. Side view of comets as stacked in shell.*

*Figure 30. Comet shell details.*

Having laid the first ring of comets, and rammed the spaces with rough powder or sawdust, the next ring must be added. This ring is staggered by half the diameter of the comets, so that when viewed from the side, the stacked rings of comets have the appearance of a brick wall laid in "running bond." Normally at least three rings, and perhaps four or five (depending upon the size of the comets and the size of the shell) are used, and the height of the comets is so determined that when the desired number of rings or layers are laid in place, the shell is more or less the same height as its diameter. As each ring is laid in place, the empty spaces are rammed with rough powder or sawdust and the next ring added, and so forth until all have been put in place (see Figure 30.2).

When all comets have been put in place, the entire central space is filled with FFA powder until it is level with the top of the topmost ring of comets. The shell is then closed with a fused end disc, the excess paper pleated down, and another disc added over the folds as usual. Spiking, pasting-in, and finishing with lift and leader all follow as for a shell of cut stars. Variations sometimes observed are: (1) In the spiking, a closer pattern is occasionally used; typically, the number of side strings employed is increased to that normally used on the next larger size of shell. For example, a 5″ comet shell might be spiked with 32 side strings (the pattern ordinarily used for a 6″ shell) instead of 24. Circumferential spiking is also closer, to match the closer vertical spiking, making small squares on the side walls. (2) Because comet shells are sometimes heavier than plain star shells, and also because the comets may be longer-burning than cut stars, the lift charge must often be increased to account for these factors. Such alteration is a matter of experience with the effects in question.

A *double-ring effect* may be procured by filling the shell case with comets as described, but rather than filling the central space or core entirely with FFA powder, centering a canulle in this space and filling around it, between the comets and the canulle, with small cut stars. The canulle should then be filled with powder as in making a cut-star shell, and withdrawn. The top of the shell is made level with rough powder, and it is closed, spiked, pasted-in, and finished as usual. The success of such effects is greatly dependent upon the compositions chosen for the comets and the cut stars, both in terms of color contrast and relative burning speed. Ideally, the comets, being larger, are thrown out the farthest by the shell burst, while the small stars stay closer to the center of the burst; the appearance made is of a large outer "ring" made by the comets, with a contrasting dense center made by the small cut stars. Figure 31 depicts the cross-section of a double-ring shell.

**Serpents, whistles, and other tubular garnitures**

Serpents, whistles, and similar garnitures consisting of composition rammed in paper tubes are well described elsewhere and detailed instructions for their manufacture need not be given here. The possibilities for variation are almost endless and for purposes of shell-filling, all such garnitures are treated the same. Typically, they are rammed in ⅜″ to ½″ i.d. tubes and are anywhere from 2½″ to 5″ long depending upon the effect. All must be carefully matched and nosed prior to being put in shells.

The effect desired when such garnitures are used in shells is that of a symmetrical break of color, like that obtained from a normal shell of cut stars; the garnitures appear to fall from the center of the color break. To begin, a long shell case must be rolled, to allow for the height of the garnitures and above them, the usual amount of colored stars that would be used in a star-shell of the given size. For example, presuming a 3″ color and whistle shell using whistles 2½″ long, the paper should be cut to allow a finished shell wall height of approximately 5″ (2½″ for the whistles, 2½″ for the color). The normal number of turns of paper used for any shell of the given size are used, as previously described.

Having rolled the shell case, proceed to arrange the garnitures, matched end up, in a ring around the bottom of the shell case. They should fit snugly, touching the inside shell wall and each other. If for some reason they do not, an empty tube, flattened by laying it on the floor and stepping on it, may be inserted in the ring and this will generally tighten the fit. Now, rough powder should be added to fill the entire central space or core, and shaken down to fill the spaces between the garnitures and the shell wall. A small rod is useful to consolidate the rough powder in these interstices. The rough powder must be filled to a level just above the mouths of the cases.

Place the canulle of the appropriate size for the shell in the normal central position, its bottom resting on the rough powder already filled. As for a regular star shell, fill cut stars around the canulle to the proper depth, then fill the canulle with FFA powder and remove it; consolidate the stars as usual by shaking, patting,

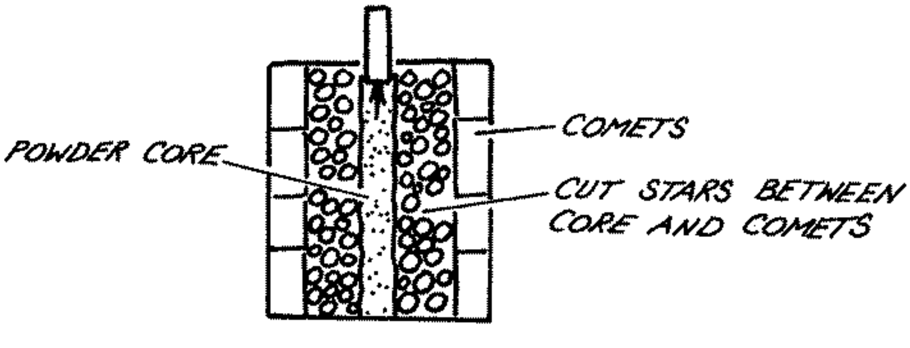



*Figure 31. Double-ring shell.*

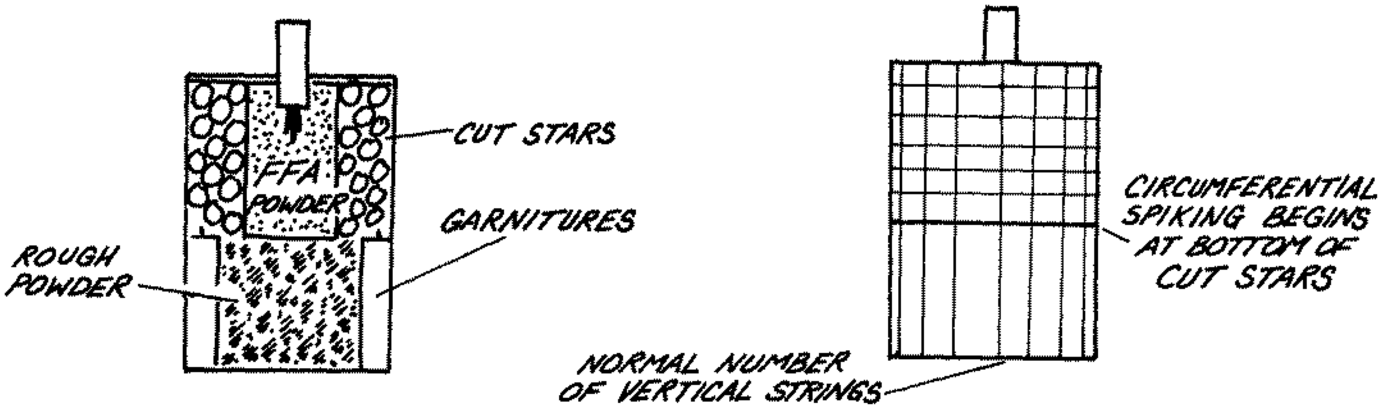



*Figure 32.1. Cross-section of shell.*

*Figure 32.2. Spiking pattern of shell.*

*Figure 32. Shells with tubular garnitures.*

and so forth. Level the top of the case off with coarse rough powder and close as usual with a fused disc, pleat the overhanging paper down on the top of the shell, and add another disc over the folds.

When spiking the filled and closed shells, a variation from the normal practice is observed. The longitudinal or vertical strings are put on as usual, spiking the outside bottom disc on in ordinary fashion with the first wrap; the number of strings is that prescribed for a normal shell of the size in question. However, when all vertical spiking is finished, the string is run diagonally not to the bottom of the break (as in a plain star shell), but only to the bottom of that area where the color stars are filled; i.e., just above the mouths of the garniture tubes. Circumferential spiking proceeds upward from this zone in the usual fashion, making a pattern of squares with the vertical strings, and finally the vertical strings are pinioned at the top of the shell and the usual half-hitch loop thrown around the top to tie off the string.

The spiked shells are then ready to be pasted-in with the normal number of turns and weight of paper for a shell of the given size. Finally, they should be finished with the lift charge and leader as usual. Figure 32 depicts a sectional view of the shell alongside a view showing the spiking pattern on the shell walls.

**Saettines (siatenes, citeens) or lambetti**

A favorite shell is a break of color and saettines or lambetti. These are a variety of small insert reports typically made only for shells (although they may be shot from small mortars by themselves or used as ground reports). Their identifying characteristic is that they are fused with black match, around which bran or sawdust is rammed to provide a delay. The explosive effect is furnished by a flash powder or dark report composition, the case being very light in construction. The sizes may vary widely, but the most common sizes are ¾″ and 1″ diameters by 1½″ or 2″ long. Described here is the manufacture of the 1″ size.

Paper to roll cases for saettines is cut from sheets of 22½ x 34½ chipboard, .018″, .022″, or .026″ in caliper (depending upon preference), and 24 x 36 30- or 40-lb. kraft. Cut the chipboard into pieces 7½″ long by 2″ wide, cutting the 7½″ into the 22½″ and the 2″ into the 34½″ dimensions. This results in 51 pieces from each sheet. Cut the brown kraft into pieces 12″ long by 4″ wide, cutting the 12″ into the 24″ dimension, and the 4″ into the 36″ dimension, giving 18 pieces from each sheet. Thus, to make (for example) 1000 saettines, 20 sheets of chipboard and 56 sheets of brown kraft are needed. The grain of the paper is customarily in the long dimension, thus cutting in accordance with the above instructions will result in the grain running parallel to the short dimension of the pieces, or parallel with the former during rolling.

Using an inch dowel as a former, first lay the 2″ wide strip of chipboard on the 4″ width of the kraft sheet, centered on its width and flush with one of its

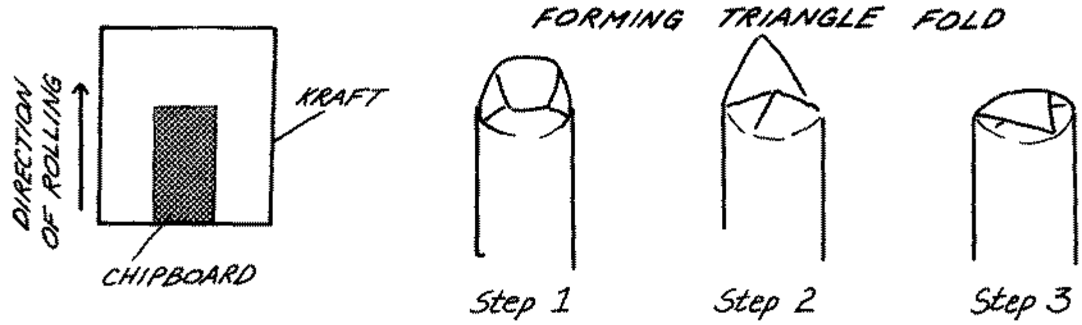



*Figure 33. Saettine case rolling and closing.*

ends; roll the two up together, pasting only the edge of the kraft (see Figure 33). Slip the tube thus formed up over the end of the former so that the edge of the chipboard is flush with the end of the former, with only the 1″ width of kraft overhanging. Fold this down with the "triangle fold," i.e., beginning by folding one side in with the thumb or fingers, then the other side so as to form a sort of triangular tongue which is folded down last. The folds are secured by beating with a mallet or by jolting the former, folded end of the case down, on the work surface. The complete case may then be slipped off of the former, and another rolled and closed (see Figure 33).

In order to fill the cases thus formed, first select a scoop of sufficient capacity that when charged into the case, the flash powder fills it about half full. Any "hot" flash powder, generally made without filler (i.e., bran or sawdust) may be used.[4] Having filled the cases half full with flash or other report composition, introduce the pieces of match. One or two pieces are normally used, according to the preference of the pyrotechnist. Two pieces will result in a shorter delay, insuring ignition in any event.

In one technique, the pieces of match lie close to the side wall of the case. Enough bran or sawdust is next introduced, so that it fills the case to almost overflowing the top edge of the kraft. A dowel, or even the forefinger, is then used to ram the bran or sawdust down to the level of the chipboard liner; the cases are then closed by folding the overlapping kraft paper down, making the triangle fold with the pieces of match protruding from the points of the triangles (see Figure 34).

In another technique, the match is centered in the casing as it is filled with bran or sawdust. A rod with a central hollow to accommodate the match, or even a sturdy paper tube (such as a wheel pusher case), may then be used to compact the filler material down to the level of the chipboard liner. Finally, the match is bent over to the side of the case, and the triangle fold formed with the match sticking out the point of the triangle as before. Figure 34 illustrates this alternative method.

It is important to note that the pressure necessary to ram down the bran or sawdust is one of the factors in establishing the delay — the more pressure used, the longer the delay. Some workers prefer bran, others sawdust; and the wide variance in grades of either material makes some trial and error necessary to procure just the desired delay. Some makers forgo ramming the filler material entirely, merely filling the bran or sawdust slightly higher than the chipboard inner liner, and relying on the pressure of folding the ends in to compact it. This very light compaction results in very short delays.

A final variant in the filling of saettines is worth noting. This is the practice of filling a small amount of bran or sawdust on the bottom of the casing, before adding the flash powder. The reasoning behind this is that while the triangle fold, if properly made, should be gas-tight, the layer of filler protects against premature explosion of the saettine if a hastily, imperfectly formed fold allows fire to penetrate.

After the cases have been filled with flash and filler material, matched, tamped, and the overlapping paper closed with the triangle fold, they must be tied. Using a spiking horse to hold and dispense the string, paste the string well and unloop a length of it. Some makers prefer to lay a length of string underneath the top triangle flap, then cast a half-hitch over the flap around the length of the casing, then another half-hitch, finally tying the ends with an overhand knot (actually, this procedure results in a clove hitch secured by an overhand knot). Others simply tie a clove hitch around the length of the saettine, and secure by tying on the side, rather than the end, of the case. In either instance, the result must be a knot that holds the flaps shut on both ends of the case and that does not slip off. Figure 34 illustrates the general appearance of the finished and tied saettine.

It is desirable that the position of the apices of the triangles be opposed on the top and bottom of the saettine, so that viewed, as it were, from the top or bottom of the case, they would, if superimposed, form the Star of David. This configuration makes the casing assume a shape from which it is less easy for the string to slip than if the points of the triangles were aligned.

Suitable string for tying saettines must be strong, not too thick, and able to take paste easily. The Belgian flax twine works well, as also do 8- or 10-ply cotton. A single strand is sufficient, although some like to use two strands running together for extra strength. When the paste is dry on the string, the saettines are ready to be loaded into shells.

Saettines are filled in shells in a manner much like other tubular shaped garnitures. They are arranged in a ring around the shell wall at the bottom of the case. In a 3″ shell, only three 1″ diameter saettines fit and these leave no central space to speak of. In a 4″ shell, six 1″ saettines fit in a more usual sort of ring. The match is pointed inward toward the center of the case. Rough powder may be used to fill around the saettines in the spaces between them and the shell wall; often, sawdust is used. In the 4″ and larger sizes, the central space or core is filled with rough powder. Three inch shells do not allow this, but it does not seem important with saettines to have a central burst core in the saettine section. When the shell opens with color, the bottom of the case "peels" open like a banana, and the saettines drop out of the center of the break. The desired effect is for the saettines to explode just as the color has reached its full spread. If they explode just as the shell is opening, or if they hang fire for a prolonged period, the saettines are not functioning correctly.

Whether sawdust or rough powder is chosen to be rammed in the interstices, after the saettines and rough powder core (if any) are in place, a little more rough powder is added just to cover over the saettine match, the canulle lowered into its central place, cut stars filled around it to their customary depth, the canulle filled with FFA powder and withdrawn; the stars and powder consolidated as usual during the filling process, topped off with coarse rough powder and the shell closed with

Before aluminum powder was available, "dark" report composition was used (consisting of potassium chlorate, antimony sulphide, sulfur, and sometimes other ingredients) to give noise only, leading to the name of *saettine* ("little shot"). After aluminum flash powders were introduced, these articles began to be described as *lambetti* ("little lightning") because they gave both flash *and* sound. Today there is no real distinction, since the method of manufacture is the same, and "dark" report composition is rarely used. Some manufacturers call the item *saettine*, and others call it *lambetti*, depending upon their private custom.

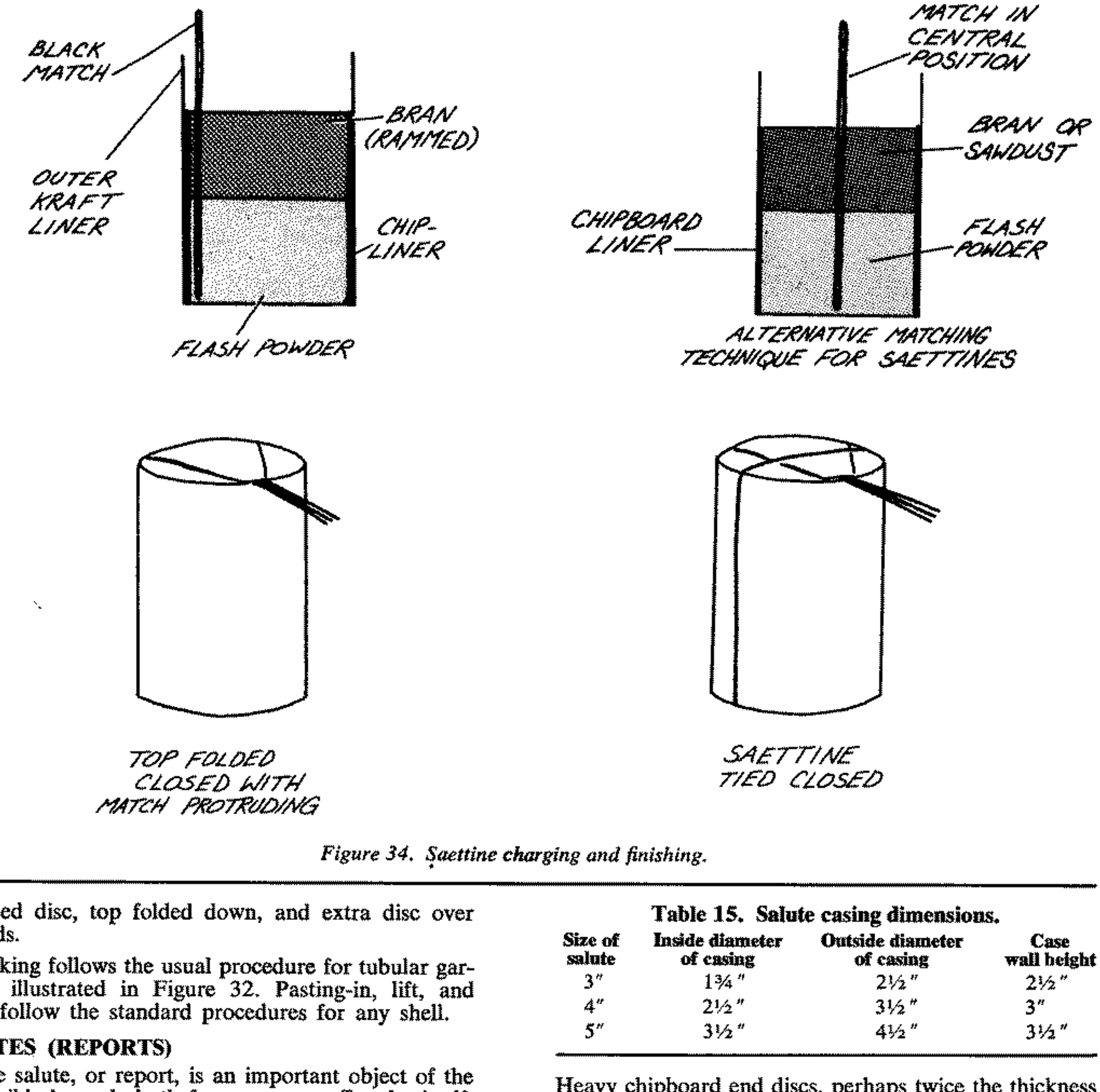



*Figure 34. Şaettine charging and finishing.*

the fused disc, top folded down, and extra disc over the folds.

Spiking follows the usual procedure for tubular garnitures illustrated in Figure 32. Pasting-in, lift, and leader follow the standard procedures for any shell.

## SALUTES (REPORTS)

The salute, or report, is an important object of the shell-builder's work, both for use as an effect by itself, and as a component in multiple-break shells. In construction, the salute is a special type of shell in which a heavy-walled case is used to contribute both rigidity to the projectile and confinement to the flash powder, which it contains in place of the usual shell contents of stars and powder. The cases may be either hand-rolled or machine-wound by the spiral-winding process. Handmade salutes are almost exclusively used as components ("bottom shots") in multiple-break shells, and will be discussed in Part II of this work. Single-fire salutes in smaller sizes are used in such quantities that they are most economically and speedily made with machine-wound cases. Techniques for using these are discussed here.

Spiral-wound casings may be purchased from a variety of manufacturers who furnish paper tubes for all uses. Dimensions typically called for are summarized in Table 15.

**Table 15. Salute casing dimensions.**

| Size of salute | Inside diameter of casing | Outside diameter of casing | Case wall height |
|---|---|---|---|
| 3″ | 1¾″ | 2½″ | 2½″ |
| 4″ | 2½″ | 3½″ | 3″ |
| 5″ | 3½″ | 4½″ | 3½″ |

Heavy chipboard end discs, perhaps twice the thickness employed for ordinary star shells, are also required. If such heavy end discs cannot be procured, two or more thinner discs may be glued together to form one thick disc. The discs are equal in diameter to the outside diameter of the salute casing, thus being the same in diameter as the discs called for in ordinary star shells of the given size. Two such thick discs, one solid for the bottom, the other pierced (in the usual manner for any shell) to receive a shell fuse, are required for each salute.

The casing may be loaded either from the top or the bottom, depending upon preference. If it is to be loaded from the top, the bottom (solid) disc should be cemented onto one end of the casing, using liberal amounts of white glue; if to be loaded from the bottom, the shell fuse is first well cemented into the top (pierced) disc, then the fused disc cemented onto the casing. A convenient way is to pour the glue into a shallow tray, and dip the ends of the casings into it; then to apply the discs.

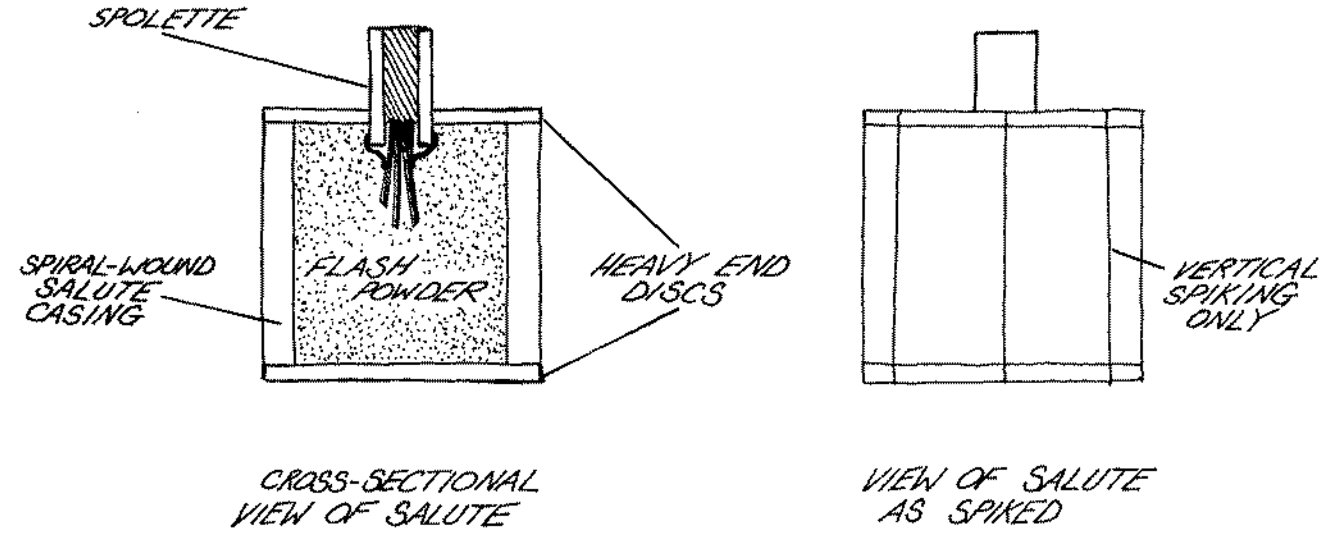



*Figure 35. Single-fire salute construction with machine-wound casings.*

After the glue has dried, flash powder is charged into the casings. If they are being filled from the bottom, it is convenient to set two pieces of lumber on the workbench a short distance apart, inverting the casings so that the fused disc is supported on the pieces of lumber, while the fuse is accommodated between them. Flash powder is dirty and has a tendency to become "airborne," so the charging must be managed so as to avoid spilling or getting the flash powder where it should not be — particularly avoiding getting it on the edge of the casing to which the remaining end disc is to be glued after filling. A wide-mouthed funnel, such as housewives use in canning preserves, is a useful tool in this operation — it is ideal if the mouth is just wide enough to fit neatly inside the casing. Flash powder should be filled into the casing until it is almost level with the edge; contrary to some published information, salutes are completely filled with flash powder.

Compositions for flash powder are many and varied, each maker having his own preferences for his own reasons. Several are shown in Table 16.

The first composition listed is of a variety much used with good effect in the past. Although thousands of pounds of such composition have been mixed annually without incident, mixtures of this kind are needlessly sensitive and their use has resulted in loss of life and property. The perchlorate compositions, nos. 2, 3, and 4, are capable of making quite loud reports and are recommended. For a silver cloud effect in conjunction with the loud report, 5 - 10% additional coarse titanium sponge or turnings may be added to any of the above compositions.

Flash powder for salutes is generally diluted with bran, sawdust, or other bulking filler, in volume ratios 3:1 or 4:1, flash powder:filler. This not only cheapens the mixture, but prevents it from becoming caked or packed, thus serving the valuable purpose of propagating the explosion faster.

The filled casings are at last closed with an end disc. Plenty of white glue to cement it in place should be applied to the edge of the casing. After the glue has dried, some workers prefer to seal around the joints of the discs to casing, top and bottom, with a band of pasted paper; others proceed directly to spiking.

Salutes are spiked with the same number of vertical strings as for any shell of the given size, i.e., 12 strings for a 3″ salute, 16 for a 4″, 24 for a 5″, and so forth. The purpose of spiking is not, as it is with a star shell, to apply equal reinforcement over the entire shell wall, but is simply to hold the end discs on and afford greater confinement to the explosion (making it louder). Accordingly, the string may be tied off on the fuse after all vertical spiking is in place; or a couple of turns may be taken round the side walls merely to pinion the vertical spiking, and the string tied off with the customary half-hitch loop. Figure 35 illustrates salute construction steps through spiking, using the machine-wound casings as discussed here.

The spiked reports are finally pasted-in with the appropriate number of turns of paper of the proper weight, as for any shell of the given size. Finishing with lift and leader follows the procedure for any shell. Great attention must be paid to sound and precise construction of salutes, as malfunctions lead to serious accidents.

END OF PART I

**Table 16. Flash powder compositions.**

| | 1 | | 2 | | 3 | | 4 | |
|---|---|---|---|---|---|---|---|---|
| | **Parts** | **%** | **Parts** | **%** | **Parts** | **%** | **Parts** | **%** |
| Potassium chlorate | 8 | 61.5 | — | — | — | — | — | — |
| Potassium perchlorate | — | — | 4 | 66.7 | 8 | 66.7 | 7 | 70.0 |
| Dark pyro aluminum | 3 | 23.1 | 1 | 16.6 | 3 | 25.0 | 3 | 30.0 |
| Sulphur | 2 | 15.4 | 1 | 16.6 | 1 | 8.3 | — | — |