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fireworks

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Fireworks & Pyro Projects

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CAUTION

The experimentation with and use of pyrotechnic materials can be dangerous. It is important for the reader to be duly cautioned. Making fireworks is inherently dangerous. Serious injury or even death can result from any number of causes, sometimes beyond the user's control. Before proceeding with these projects, be sure that you are willing to undertake these risks.

About the Cover

One evening in November 2009, Tom Handel and I were about to watch a display of Maltese style shells lovingly created over a two year period by members of the Florida Pyrotechnic Arts Guild (FPAG). He and I are both long time members of that club, and had a pretty good idea that we were about to see something very rare and spectacular. Even the artwork on the *outside* of those shells was unlike anything we had seen before.

Shells Prepared for the 2009 FPAG Maltese Fireworks Show

In November in that part of Florida, the leaves have fallen from the trees. And there is this one particular pecan tree which I have habitually stood behind and watched that club’s extraordinary fireworks creations. That is because in November it is cold at night in North Florida, and there are always two things near that tree that are necessary for me: a good sized campfire and the cook tent.

The cook tent is the center of the universe at that weekend-long fireworks event, and is where the coolers of beer, corn squeezin's, and unspeakably good food are all located. So standing by the fire, looking out into the field where the fireworks are launched, you are confronted by this big, Spanish-moss draped pecan tree, and a decision.

At first, I tried to watch the fireworks from in front of the tree. The view is fine, but it’s cold, too far from the campfire and its built-in camaraderie, and too far from the food.

So, over the past dozen or so years, I got used to watching some of the best fireworks in the world through that particular tree. And it grew on me. And after awhile, I came to actually prefer the pyrotechnic decorations that adorned the silhouette of the pecan tree.

So, this particular evening, Tom shows up with his camera and his tripod, and a chair and parks himself ready to photograph the show. And somehow I prevailed upon him to try shooting these Maltese shells, which we knew would be simply incredible, from behind the tree.

He balked for a moment, and then gave in.

A few days later, he sent me a link to the pictures he took, and I was just blown away. I love fireworks photos, but these were in a class by themselves. And the pecan tree was the star of the show.

The cover of this book is a composite of several of Tom's photographs from that night. Our enduring thanks to Tom for letting us use that spectacular image, and to Rob Secades for creating the composite.

Tom was also gracious enough to allow us to include the whole collection of his shots from that night. I call it:

"Tom's Tree."

You can see them all in the Shells and Stars sections of this book. Tom's pictures are copyrighted, but if you would like to use one or more of them, acquire copies, or have any questions about them, you can contact him at tom.handel.photography@gmail.com.

Enjoy.

Harry Gilliam
March 4, 2010

Note to Readers

This book is a compilation of fireworks-making projects previously published by Skylighter beginning in the late 1990's, mostly in its newsletter, *Fireworks Tips*.

At first, Skylighter's projects were published as text-only articles. Over time, we added photographs, and eventually video to the projects. Graphical styles and the visual presentation of the different projects changed over the years, as well. Throughout this book, you will find some projects with no photography or illustration, and in general those were the earliest ones.

The projects presented here have been changed in some respects from the original ones published in *Fireworks Tips*. They have been proofread for errors and corrected extensively. There has also been some editing of the material, when I felt there were areas where we could describe something more clearly. The projects have been re-organized into topical groupings. Finally, the collection of projects has been graphically redesigned into a consistent, more attractive, and we feel, a more utilitarian look and feel.

It is a challenge to write usable articles on making fireworks. The writer always has to remember that fireworkers who read the article will be of varying skill levels. The challenge is writing instructions clear enough for a beginner to understand and interesting enough for everyone. It was my observation 15 years ago when I started reading the fireworks instructional material that was available, that much of it was over my head. I was a novice then (and still am), and I noticed that most fireworks writers assumed way too much about the knowledge and skill set of their readers.

So, creating these projects has always been a process where the writer sent a draft to me, and I attempted to edit it in such a way that readers of every level of pyrotechnic proficiency would be able to not only understand and use the material, but to survive the project intact. As this book came together I noticed that that work never ceases for me. A distance of 5 or 10 years after the initial creation of a fireworks project often makes it possible to see a clearer way to present a thing.

Many authors contributed material to Skylighter over the years. We are deeply indebted to all of them. Over the years the material they created for us has gotten stronger and stronger.

The quality of our projects took a big leap forward when John Werner started writing for us and illustrated his articles with excellent and detailed photography. John is a master fireworks maker and designer and has spent many years in the commercial fireworks arena. His projects reflect not only his decades-long knowledge of pyro, but the practicalities of commercial fireworks manufacture.

The next giant leap in project quality came when Ned Gorski started writing for us in 2008. We have been blessed with an incredible array of projects from Ned. In my view Ned brings four gifts to the table: First, he is a true fireworks expert, and his credentials in that arena are unmatched by many. He is a naturally excellent instructor; Ned inherently understands what a person will need to know in order to successfully create a particular firework. Best of all, he can write that in a way that anyone can understand. His instructive talents extend to his photos and videos;

again he knows exactly what needs to be shown, and he gets that done very well photographically and increasingly in video. Perhaps most importantly, to me, anyway, he is an absolute delight to work with.

It is a privilege to be able to capture the good works of so many expert pyros and keep that work alive to share with you and those who come later. There is a great deal of pyrotechnic literature in existence, but most of it is never seen by the current crop of fireworks makers. Some information may be old and out of print. Or it may have been an excellent project written for a fireworks club newsletter, to which the current members no longer have access.

What is in this book is just the tip of the iceberg in pyro literature. It is by no means complete. If you are serious about making fireworks, I encourage you to read everything you can get your hands on.

There are many ways to make fireworks successfully. This book presents a cross-section of just a few of those methods. Do not ever think these projects represent the definitive methods. Far from it. They simply represent the preferences of each writer and what he or she may be doing at one point in time.

That being said, if you are new to making fireworks, we strongly encourage you to start by using the methods contained here. My own bias is that you learn by copying what others have learned the hard way. Do not ever forget that you can kill yourself making fireworks. No matter how independent you are, or how much satisfaction you derive from reinventing wheels, keep this in mind: much of what you read here was earned in the hardest, dearest way possible.

Build your competency on the shoulders of those who came before you, some of whom died or were severely injured in their own learning process. There will be plenty of opportunity for you to experiment, but I strongly suggest that you learn how to do one particular thing at a time, using the instructions given to you by others. Once you know you’re competent, and when you want to accomplish something new, or need to solve a particular pyro problem, then by all means, experiment.

But remember, the art, science, and craft of fireworks making is now quite old. Much of what we practice today was being done 100, even 200 years ago. If there is something you want to do, it is quite likely that somebody else has probably done it already. So I strongly suggest you dig around a bit before you try something entirely new to you.

I personally want to thank the following individuals for their work on this book: Sid Stepp has to be credited with both the idea for this book and for reformatting every article in it to give us all the look and feel that it has today; Brian Paonessa and Jess Ralph for their help in working with the original material when it was first posted on the Skylighter.com website; Tom Handel for his editing skills and wisdom in applying them; Rob Secades for his cover design and visual inspiration; to all the authors of the projects in this book; and to the thousands of customers of Skylighter’s who have continued to support us over the years and who finance the creation of everything we do at Skylighter.

Although every attempt has been made to find and correct typos and mistakes in this book, if we missed any, please let us know. We welcome your suggestions and critiques as well.

Harry Gilliam
Publisher

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Contents

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Rockets

World's Smallest Flying Fish Fuse Rocket

By Harry Gilliam

Learn how to make a small rocket using flying fish fuse.

Materials Needed

- Dried grass stalk
- Flying fish fuse
- Launch tube, small
- Scissors
- Scotch Tape

One night I was sitting on Ken Musgrave's back deck playing with silver flying fish fuse. We were lighting little one-inch long pieces of the flying fish fuse and throwing them out into the night sky.

After throwing several thousand or so pieces of flying fish fuse Ken says, "Look at this." He had a piece of dried grass stalk lying on the table. Using scissors, he snipped a piece about 2 inches long to make his rocket stick.

Then he cut a length of silver flying fish fuse the same length as the width of the Scotch Tape he had on the table, about 3/4 inch. Using a really short length of Scotch Tape, perhaps 1/4 long or less, he taped the piece of flying fish fuse to the top end of the rocket stick.

He then stood the rocket up in a hollow drift from a 6-pound stinger missile rocket tool kit. You light it from the bottom, of course. Et voila! You have the world's smallest rocket.

Tips: The grass stalk was really thin, a millimeter or less. It was brown, not green, and lightweight. It may take some experimenting to get the right length rocket stick. Make it too long and your rocket will do a kamikaze dive.

The flying fish fuse was totally covered by the tape, creating a quick match fuse kind of sleeve. Without the "sleeve," the rockets didn't fly. We didn't leave any flying fish fuse sticking out at all, and just kind of touched the flame to the bottom of the tape sleeve.

The 6-pound stinger missile rocket drift made an excellent rocket launch tube. Plastic straws also make good cheap rocket launch tubes, but they will melt a little.

Visco Fuse Rockets

By John Werner

A while back I received samples of some of Skylighter's fabulous new Chinese-made fuse products: fast yellow visco, green visco, thin (cross-match) visco, and paper firecracker fuse. Noting the substantial flame spit from the visco fuse, I decided to try making some simple miniature rockets using the normal green visco. As hoped, the rockets worked great, were lots of fun, and requiring no special tools, were extremely easy to make. The rocket engine is roughly the size of a common bottle rocket and if carefully made will go a hundred feet or more in the air. Here's how to make the basic model.

Materials and Tools Needed to Make Visco Rockets

Green Chinese Visco Fuse, 3/32 Inch Diameter

- Chinese visco fuse
- 1 inch wide masking tape
- Typing paper, 8-1/2 x 11 inches (preferably 24 lb.)
- Hot melt gun and glue
- Glue stick (not hot melt)
- Bamboo skewers

- Thin, strong string
- Scissors
- Utility knife
- 1/4 inch I.D. x 12 inches long thin-walled brass tubing or equivalent to use as a launch tube
- 5/16 inch O.D. x 1 inch long wood dowel
- 1/8 inch drill bit

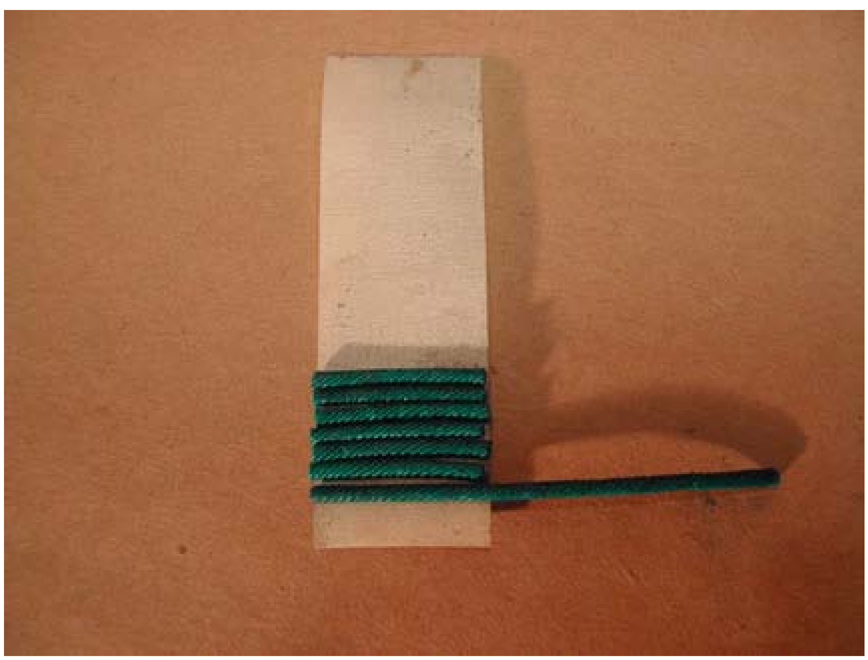
How to Make the Rocket

Cut six pieces of visco fuse, each 1-inch long (Skylighter Chinese green visco must be used; American made visco does not have the necessary burn characteristics).

Cut one piece of visco fuse, 2-½ inches long

Cut one piece of 1 inch wide masking tape, 3 inches long

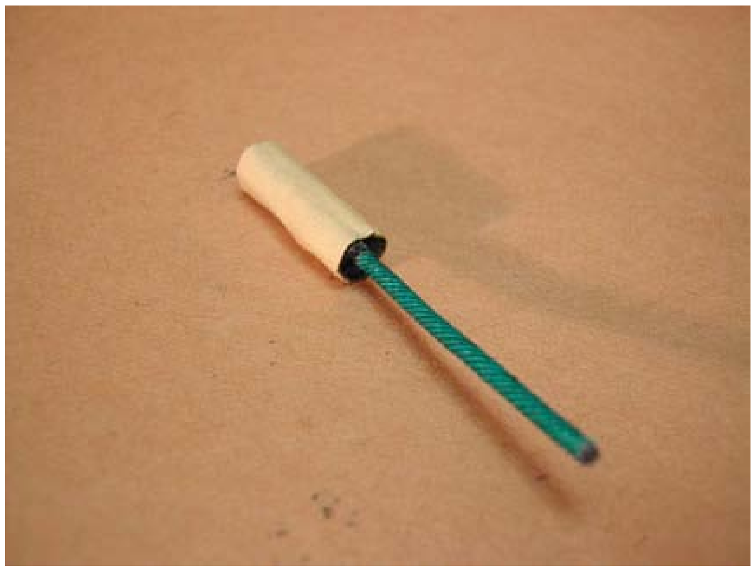
With the tape sticky side up and oriented vertically on the work table in front of you, place the 2-1/2 inch long piece of visco perpendicular to the tape, about 1/4 inch up from the bottom edge, with the left end of the visco aligned with the left edge of the tape, forming an "L" shape.



Precut Visco Attached to Sticky Side of Masking Tape

Stick the six 1-inch pieces of visco down onto the tape beside and just above the 2-1/2 inch piece. These pieces should also align with the left edge of the tape and just reach to the right hand side if they have been cut to the correct length. The pieces of visco should be touching each other.

Fold the bottom 1/4 inch flap of tape up over the pieces of fuse, and continue rolling up the tape/fuse combination as tightly as possible. When done correctly, the end result will be a long piece of visco surrounded by six short pieces of visco, tightly bundled together and held by the tape. On one end of the bundle, all fuse ends will be exactly even and on the other end, the six short pieces will be even, with the longer visco piece protruding 1-1/2 inches.



Rolled Up Fuse & Masking Tape

It will look like a tiny cartoon version of a bundle of dynamite. This may take a bit of practice to get a nice tight roll, but it is important for good performance.

From the typing paper, cut a strip 1-3/4 inches by 8-1/2 inches, and lay the strip on the worktable vertically. Apply glue from the glue stick to the entire surface. Just a quick coat will do; it is not necessary to be very thorough with the glue application, except at each end.

Fuse Roll Ready for Engine Casing

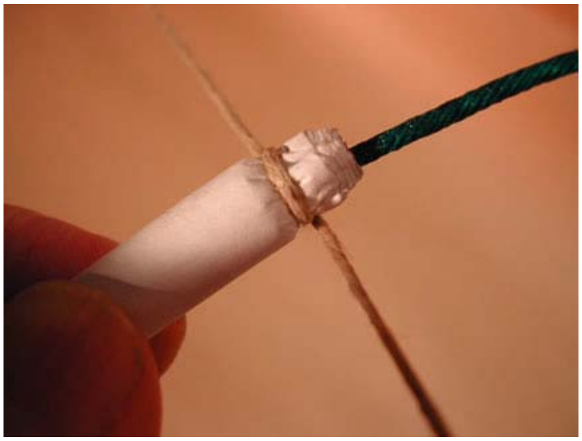
Place the fuse/tape bundle at the bottom of the paper strip, in preparation for rolling up the engine casing. Place the end of the fuse bundle with all fuse ends being even, 1/4 inch in from the left side of the paper strip.

Carefully, and as tightly as possible, roll up the fuse bundle in the paper strip. If done correctly, the result will be a small rocket engine with a ¼ inch deep cavity at one end and a ½ inch deep cavity at the other end, with a piece of visco sticking out. The fuse bundle should sit securely and should not be able to slide out of the paper casing. Set aside for a few minutes to dry.

Top of Rocket Casing Filled with Hot Melt Glue

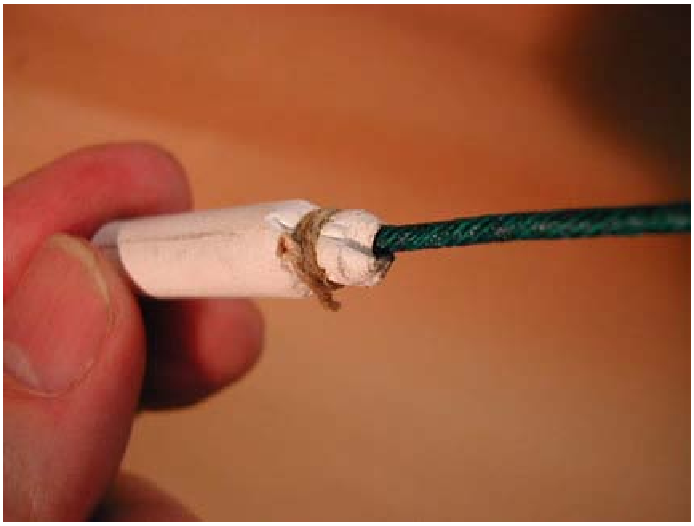
Completely fill the 1/4 inch cavity with hot melt adhesive. Let cool.

Choke down the 1/2 inch cavity end of the tube around the protruding single piece of visco fuse, using the string to constrict the tube.



Tying the Choke

A clove hitch and a few extra turns of string are applied to form and maintain the choke tightly around the visco fuse; this completes the rocket engine.

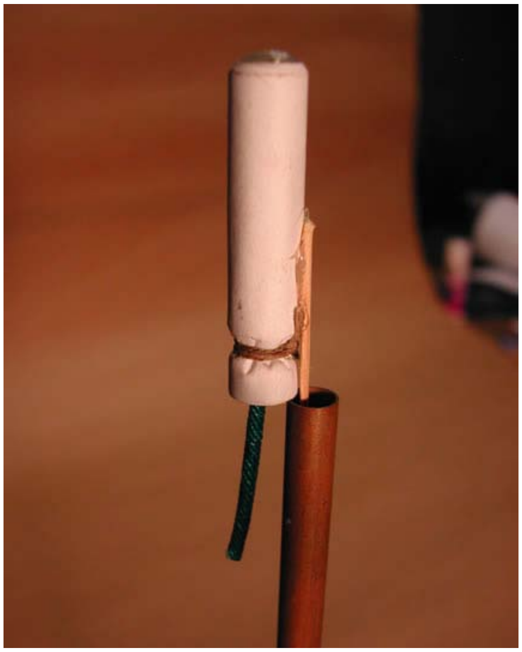


The Choked Rocket Engine

Static test an engine first by poking an engine headfirst into the ground and lighting it. It should burn nicely for several seconds. The nozzle end should not burn through or burn off. If it does, the paper is probably too thin and you may need a few extra turns.

Rocket Glued to Skewer Using Hot Melt

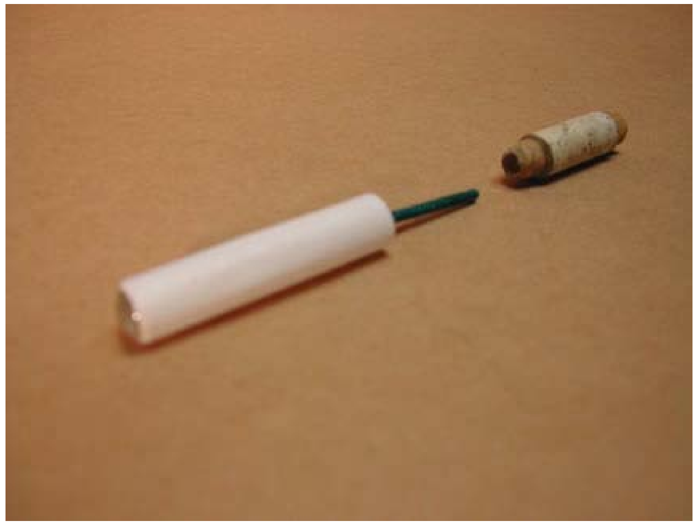
After determining that there is no burn-through and that your construction technique is sound, attach a 7-inch long bamboo skewer to the side of another completed engine with hot melt. To save weight and make your rocket fly higher, the skewer should first be split lengthwise with a sharp utility knife. The end of the skewer should be about 1/3 of the way down from the glue-filled cavity end of the engine (which means that the fuse points down the length of the skewer).



Rocket in Launch Tube

To launch your miniature rocket, place the thin-wall tubing approximately 3 inches into the ground so that the tube is stable, and pointing straight up or at a very slight angle. Place the rocket in the tube, light, and enjoy!

Improvements and Variations

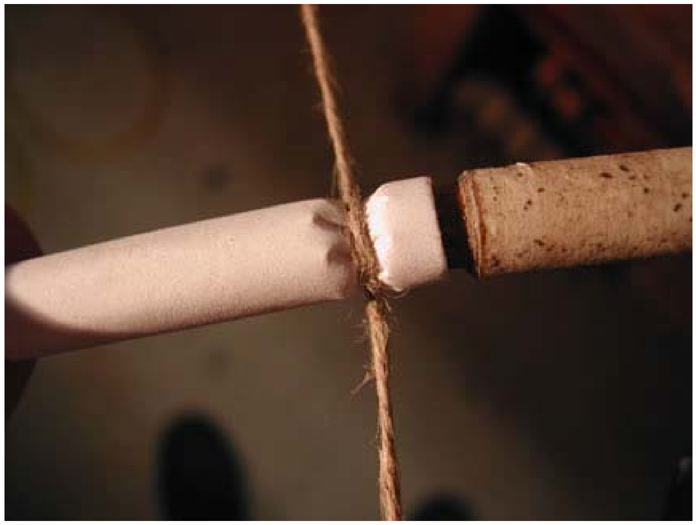


Rocket with Hollow Dowel Crimping Tool (on Right)

A very nicely crimped nozzle can be made using the 5/16-inch diameter X 1-inch long wooden dowel. First drill a 1/8-inch diameter centered hole from one end of the dowel all the way through to the other. Round over one end of the dowel just slightly and check to see if it slides down over the visco fuse and into the ½ inch cavity on the engine.

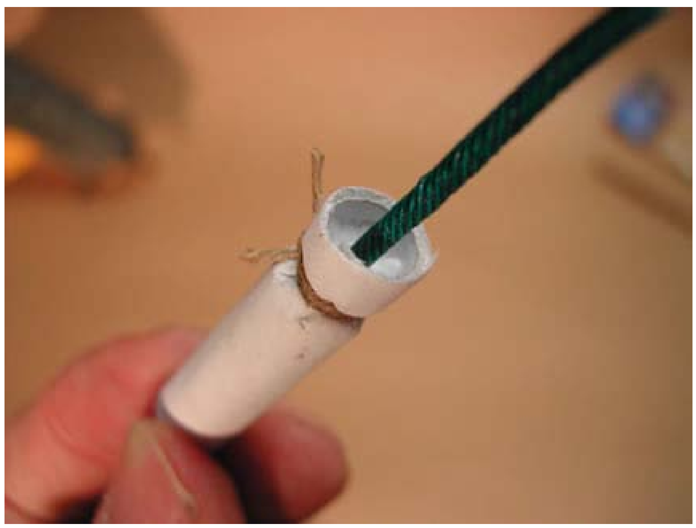
Wrap some tape around the dowel, back about 3/8 inch from the rounded end. This acts as a stop collar to prevent the dowel from bottoming out in the cavity, so make sure there is space for tying the string between the end of the dowel and the six short pieces of visco fuse.

Now secure the string around a stationary object. Wrap the string around the engine tube to be crimped and apply pressure with the string and with the dowel in place.



Rolling the String to Tighten and Form Nozzle

Rolling the engine back and forth as pressure is slowly applied produces a beautifully crimped nozzle.



Professionally crimped nozzle

Secure crimped area with string. This traditional method of making a crimped choke is described more thoroughly in Weingart or Lancaster.

Longer flight duration can be obtained by using wider masking tape and correspondingly longer visco fuse.

Before rolling up the visco fuse in the tape, sprinkle in small amounts of titanium (any of them) for some silver spark trails.

A slightly enlarged cavity at the head of the engine can be used for a simple lightweight, flash heading.

Questions and Answers

Q: Can I use any other of Skylighter's fuses to make these rockets?

A: I have used colored flying fish and crackling flying fish fuses. The crackling makes a neat crackle when it rises. I have not had good luck using the fast yellow visco with engines, as it burns too fast.

Q: This method seems like it could lend itself to making all sorts of miniature fireworks for us pyros who have very limited work areas?

A: Correct! It avoids any messy mixing, requires almost no tools, is safe and won't annoy the neighbors.

How to Cut Your Own Homemade Rocket Sticks

By John Werner

Learn how to cut your own rocket sticks from a length of wood using a table saw.

Materials Needed

- Table saw
- Wood, lightweight

Making your own rockets is an extremely satisfying project for both beginner and advanced firework makers. Getting your rockets to fly straight is an essential part of the process, and wooden rocket sticks are the simplest and most common form of guidance.

Although wooden dowels can easily be bought in three or four-foot lengths at the local home improvement store and used as rocket sticks, having the ability to cut and make your own custom size rocket sticks can be a real advantage.

However, a good quality table saw fitted with the proper blade is essential if this is to be done safely. Here are a number of suggestions for cutting your own sticks:

Table Saw - Use a quality, brand name saw such as Delta, Powermatic, Ryobi, Jet or DeWalt, fitted with a 10" blade. A high quality fence that is accurate and stays locked in position parallel to the blade is absolutely essential since you will be making narrow cuts with the fence set close to the blade. Many older or cheap table saws have poor, flimsy fences that should be avoided.

Blades - When buying saw blades there are no bargains and you get what you pay for. Get the best blade you can afford. Home improvement stores often do not carry top quality blades. A better place to buy is from woodworker catalogs or online. My personal favorites are blades made by Freud.

There are basically three main types of blades available for table saws: crosscut, rip and combination. Crosscut blades produce an extremely smooth, fine cut when cutting boards across the grain and are mainly used for fine furniture making and therefore are not needed by the average woodworker (or fireworks maker).

Rip blades are used only for cutting a board along its length, as in cutting rocket sticks. A rip blade should not be used for making crosscuts. Combination blades are designed to function both as a crosscut and a rip blade. A top quality combination blade (about 50.00 to 60.00 dollars) works pretty well as intended in both roles. However, if you intend to do a lot of ripping cuts, I recommend getting both a combination and a rip blade. Although it means changing blades, a rip blade will glide through the wood with much less effort.

Push Sticks - When making cuts any time the fence is located close to the blade, a push stick is mandatory for pushing the tail end of the board past the blade. You may be familiar with push sticks that are basically a straight stick about 8" to 12" long with a notch on the front end that hooks over the back end of the board, enabling you to push the board.

This is a most common type of push stick that is sometimes recommended in woodworking books and magazines. Unfortunately it is not a good design, especially when cutting thin, narrow strips like rocket sticks, as it can slip off the back of the board easily and does not keep the wood from chattering as it is being cut. A much better shape is made from a piece of 3/4" plywood cut in an "L" shape that has a low "heel" on the bottom to hook the wood.

The vertical portion of the "L" is the handhold and should be about 2" wide and about 8" high. The horizontal portion should be roughly 6" to 8" long. The "heel" extends down from the bottom of the horizontal portion about 1/4" and is about 3/4" long. Imagine a tall, thin boot shape with a small, low heel.

The push stick is used by resting the sole of the stick on top of the board being cut and with the "heel" hanging off the back edge of the board. Push sticks should always be used to push the portion of wood that is between the blade and the fence, never the piece that is outside the blade. Since the rocket sticks are going to be narrower than the width of the push stick (3/4"), the saw blade will cut a groove in the sole of the push stick. Therefore the push stick needs to be made of wood so as not to damage the saw blade.

Suitable Wood - Any straight-grain, knot-free wood can be used for rocket sticks. Heavy, dense woods such as oak should be avoided, since they will add unnecessary weight to your finished rockets. At home improvement stores, clear pine or poplar are about the only choices available.

Start with 3/4" thick boards rather than 1 1/2" thick material until you gain more experience cutting narrow strips, and especially if your saw is under powered or you do not have a good, sharp saw blade. Scrap wood from old furniture such as tabletops can frequently be found being thrown out and is usually high quality, straight grain material. Watch out for nails and screws if you intend to use "recycled" wood.

Procedure

Determine the length of rocket sticks needed and crosscut your raw boards to that length first. It is much easier to rip boards that are three feet long rather than ones eight feet long. However, do not try to rip anything less than about one foot in length. Next, switch your saw blade to a rip blade (if you have one) and set the fence to the desired width of the rocket stick.

Set the height of the blade so that it is about 3/8" higher than the thickness of the material being cut. Spray-on saw blade lubricants are highly recommended when cutting and really make a big difference. Wearing safety glasses and a dust mask, cut the board into strips.

Remember to use your new push stick tight up against the fence. After you have cut your boards into strips, the strips are rotated 90° and cut into the final square cross-section rocket sticks. Lower the saw blade so the teeth are just barely above the thin dimension of the strips and run the strips through the saw to produce the final product. Do not try to cut sticks thinner than about 5/16"x 5/16".

Recommendations

Know how to use a table saw safely before attempting this project. This is not a project for a beginner unfamiliar with the use of a table saw.

Make sure your blade is sharp and that the fence can be set accurately.

Make a push stick from good quality 3/4" plywood and understand how to use it. The project should not be attempted without a properly made push stick.

Use good quality, knot-free wood for your sticks.

At no time during the cutting process should it feel like you have to force the material through the blade

Wear a dust mask and safety glasses.

Use a paste wax on the table saw top and fence, to help the wood glide through the cut.

Be aware of where your fingers are. Except for the hand on the push stick, your fingers should never extend past or over the edge of the blade of the saw. Do not try to pull the wood through the blade from the backside of the saw.

How to Make End-Burner Rockets

By Ned Gorski

Materials Needed

- Black powder, ball milled
- End-burner rocket tooling
- Nozzle mix
- Rocket sticks
- 1 lb. Rocket tube, ¾" ID X 7.5" long
- Tube supports

There are three common types of simple, black powder, charcoal-tailed, rocket motors: cored, nozzle-less, and end-burner.

A cored rocket motor is the traditional motor, typically with a clay nozzle and a hollow core going up through the nozzle and into the fuel grain for some distance. This is how the typical skyrocket is constructed. If you take the nosing off the bottom of a commercial skyrocket and look up into the end of it, you'll see about a half-inch thick ring of clay, which forms the nozzle, and then a longer core going up into the black fuel grain.

A nozzle-less motor is a fairly recent development as far as I know, and it has no clay nozzle, but does still have the core going up into the fuel grain. It uses a hotter fuel than the cored rocket motor.

An end-burning motor has a clay nozzle, but no core going up into the fuel grain. The fuel burns only from its end, and this type of motor typically uses a hot fuel and has a smaller hole, or aperture, in the clay nozzle than does a cored motor.

Often, full strength 75/15/10 (potassium nitrate, charcoal, sulfur) black powder is used as the fuel in end burner motors, and typically the diameter of the nozzle aperture is one quarter of the inside diameter of the motor tube (3/16" nozzle aperture for a 3/4" ID rocket tube).

I intend to use this end-burner rocket motor to test the power of fuels made with 5 different charcoals in an upcoming article, Some Notes on Experiments with Various Charcoals.

The nice thing about these motors is that they burn for a fairly long time, up to about 10 seconds, with a constant amount of thrust. That thrust varies considerably from one charcoal to another, in my past experiences.

Below is a shot of a motor that I carefully sliced in half with a hacksaw, outdoors. You can see how solidly the fuel packs when dampened just a bit, with no visible separation between fuel increments. You can also see how the top of the nozzle is shaped to direct the flow of the burning gasses smoothly out of the hole.

End Burner Rocket Motor

End burning motors are useful for more than just rockets, though. They can be used as short duration fountains (or gerbs, pronounced like the first part of "gerbil"), or as drivers on wheels or girandolas (horizontal flying wheels). When I want metal sparks in the motor's exhaust, I add 6% fine ferro-titanium or spherical titanium powder to the fuel.

End Burning Gerbs Using Ferro-Titanium (Photos by Nancy Stewart)

Girandola Using End Burner Drivers

Wheel Using End Burner Drivers

The methods for making end-burner rocket motors are very similar to the ones for making regular gerbs and less powerful wheel drivers. Those devices typically are made on a larger diameter spindle, and their fuels are less powerful than the rocket motors'.

Making End-Burning Motors

For the fuel, I've made 75/15/10 black powder ball-mill-dust using each of 5 charcoals (See Ball Milling 101 for details), and now I'm going to make 3 end-burning rocket motors using each type of mill-dust.

After milling, I add 1-3% water by weight to my mill-dust fuel, and screen it in well, to minimize dust during the ramming process, and to produce a very hard, solid fuel grain. Most folks do not dampen their fuel prior to making rockets. Some just use the mill-dust as-is. Some dampen it, then granulate it through a screen and then allow the granules to dry, thereby cutting down on the dust.

During the dampening process, I find a bit of difference when it comes to how much moisture each type of fuel needs to dampen it a bit. The willow and commercial hardwood mill dusts each required 1.5% or so. Whereas the other 3 charcoals required about twice as much water to achieve the same degree of moisturization. I know the fuel has enough water in it when it stops being dusty and free-flowing.

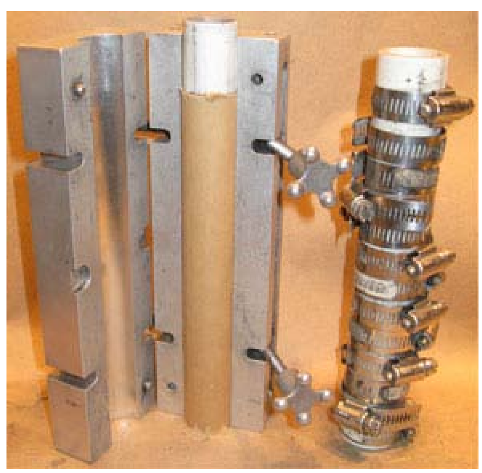
I press my motors in standard, 7.5" long 1 lb. (3/4" ID) parallel wound rocket tubes. If I am using full-strength, hot black powder I use tag board-walled tubes made by New England Paper Tube Company. These tubes are very strong and resist side burn-through. For weaker powder, I can use Skylighter's standard 1 lb. rocket tubes. During the pressing I find that each motor requires 3 oz. of fuel for all the charcoal mill dusts, except the whitewood charcoal, which only needed 2.75 oz. of fuel to fill the tube.

Here's a quickie tutorial on pressing end-burning motors. We covered Making Nozzle Mix in Skylighter Fireworks Tips #89. Here are some end-burner spindles and rammers from Steve LaDuke and Rich Wolter.

Tools for Ramming End-Burning Motors

The tapered-end rammer with the hole in it is for pressing the nozzle, and the flat end rammer is used to press the fuel.

There are various types of tube supports which can be used when ramming or pressing motors, but I don't find them to be necessary when using a mallet to hand ram these motors. I do use a support when pressing motors on a hydraulic press. (See notes on presses in Nice Shells in 2 1/2 Days, Part 2). Here are two types of commonly used tube supports. Supports are used to prevent the paper tube from splitting under the extreme pressures of hydraulic pressing used with these motors.



Two Types of Motor Tube Supports: Wolter Aluminum Clamshell and PVC Pipe and Hose Clamps

Before I ram the nozzle, I plug the hole in the spindle with the end of a bamboo skewer, and then install the tube onto the spindle.

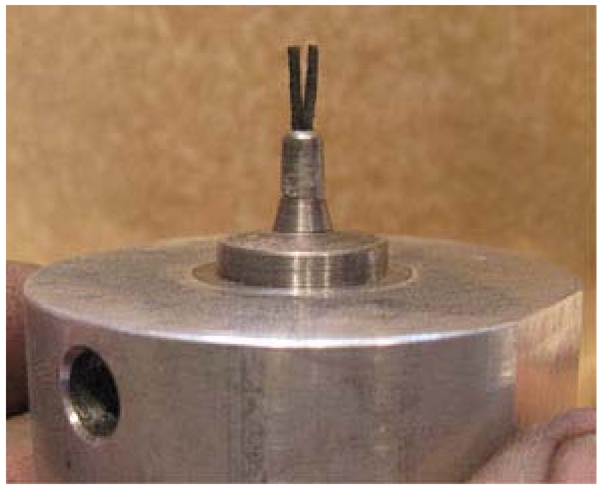
Spindle with Hole Plugged for Nozzle Ramming

Then I ram the nozzle using 1/2 tablespoon of the nozzle mix, with 8-12 good blows with my rawhide mallet. Each time I add an increment of fuel, I ram with the same number of blows from my mallet, using approximately the same force each time. It is important to keep the hole in the tapered rammer cleaned out.

Cleaning Clay Out of Hollow Ram

I then pull the spindle out of the tube, remove the bamboo, insert a doubled piece of thin black match which projects out of the spindle 3/8", and re-insert the spindle into the motor-tube to ram the fuel.

You might notice that in the photo of the different spindles above, there are two types of spindles which are identical except one type has holes in them, and one does not. If you have several tools like this, you can press the nozzle with the solid spindle, remove it, insert the other spindle with the black match inserted in it, and then press the fuel. This eliminates the need for the bamboo plug.



Spindle with Black Match Prior to Loading Fuel

The black match gets embedded into the fuel grain for a very reliable ignition priming system. This is a piece of one of the five strands of thin black match that can be found in flat quick match.

The fuel is rammed, about a tablespoon at a time, to within 1/2" of the end of the tube, and then a clay bulkhead is rammed on top of the fuel.

Ramming Fuel in Tube

Rod Pushing Fuel through Funnel into Tube for Final Increments


Inserting Clay into Tube, and Clay Bulkhead Mix Rammed in Tube

If a header is going to be installed on the rocket, a drill bit is hand-twisted into the clay bulkhead mix to create a "passfire" hole. The passfire simply directs fire from the burning rocket motor to the contents of your header. A header can be a star shell, or any other pyrotechnic effect that you can get your rocket to lift.


Drilling Passfire Hole in Rocket Motor Bulkhead

A simple rocket heading can be made with some aluminum-foil duct-tape, 1/2 teaspoon of FFg black powder, and some stars.

Making a Simple Starburst Rocket Heading

I like to use two sticks on a rocket for balance. Home Depot sells some nice 1/4" x 3/4" pine lattice which works well for these little motors. Sticks are necessary, because without them, the rocket will not fly in any particular direction. Sticks act like a kite-tail. They help your rocket fly straight.

Rocket Stabilizing Sticks

Black Match Embedded in Nozzle after Spindle Is Removed

The last step is to add some visco fuse to your finished rocket. Just cut a 4-5-inch length and insert it in past the black match all the way into the nozzle. Your fuse should fit into that hole snugly and not fall out.

"Dialing In" the Motors and Fuel

For years, these motors performed very consistently for me. Then, while making and testing the motors for this article, some of them started to blow up on me. Obviously they were exerting too much pressure in the motor tubes.

Well, "Dang It." I had changed something: either the potassium nitrate I was using, or the charcoal, or the darn alignment of the stars in the heavens. But something had changed and now my new batch of fuel was too hot, too powerful.

This is an all-too-common experience in fireworking. It can be minimized by consistent manufacturing techniques, and the use of consistent quality and type of chemicals. Unfortunately, we hobbyists do not usually buy large quantities of chemicals, so as we resupply, variations can be introduced resulting in the type of problem above. (You can reduce this problem by shopping with reputable vendors who carry the same grades of materials for years.)

This ends up requiring and cultivating diligence, persistence, flexibility, patience, and carefulness in the budding fireworker, as we recognize and work to solve these problems. Meticulous note-taking will help you reproduce successful results. Unless you record everything you do, it will be next to impossible for you to achieve success repeatedly.

The fuel that is currently too hot for my motor tubes was made from ball milled black powder using a combination of willow and pine charcoals. I have milled up quite a few batches of this fuel and now have a 5 gallon bucket of the fuel, which has been thoroughly mixed so it is consistent throughout.

I know that fuel made with commercial airfloat charcoal is less powerful than the above fuel, so I mill 2 batches of it. My plan is to make up some fuels which are mixtures of the above two fuels, until I hit on a proportion of the two which results in a high-performance motor which does not blow the tube to smithereens.

I have an electronic scale I use to measure rocket thrust, to be detailed in a forthcoming article, Some Notes on Experiments with Various Charcoals. I also time the motor-burn with a stopwatch.

I have found in the past that a reliable, powerful motor burns for 9-10 seconds with 1.3-1.5 pounds of thrust. Beyond those parameters, the motors start to blow up.

I ram a motor, made with fuel containing only commercial airfloat charcoal. It burned for 12.3 seconds and produced .9 pounds of thrust on average. This is better performance than I've had in the past with this fuel, so apparently this new batch of potassium nitrate that I'm using results in a more powerful BP.

Next I ram a motor with 3 parts of the weaker, commercial charcoal fuel, above, and 1 part of the hot fuel containing the pine/willow charcoal. This motor burns for 11.5 seconds with 1.15 pounds of thrust.

The next motor has 50/50 of the two fuels, and it burns for 10.8 seconds, at 1.3 pounds of thrust. We're gettin' somewhere. This motor, with this amount of thrust is usable for a driver or girandola motor.

I want to end up with nice, consistent, high-thrust motors, but not have them at the edge of blowing up with some of them failing. I have a 40-motor, 36" girandola planned for this summer. I'm going to enter it in the competition at the Pyrotechnics Guild International's annual convention in Gillette, Wyoming. I don't want it to fail because some of the motors blow up.

I decide to try one hotter motor, stepping up to 1 part of the slow fuel, and 2 parts of the fast fuel. This motor burned for 10.5 seconds and had a bit over 1.4 pounds of thrust. It also had that "sound" of a motor being on the edge of blowing up.

I'm going to back off to the 50/50 ratio of the fuels, press up 9 motors with ferro-titanium in them as I would with girandola motors, let them dry out for 2-3 days, and then re-test them to make sure they are working consistently with that fuel mixture.

When these motors were dry, I took them out to my testing grounds and burned all of them. Three of them, mounted on the digital-scale test stand, burned for 10.5 seconds, with an average of 1.2 pounds of thrust, and they were all consistent.

Then I launched the rest of the rockets with and without headers, and with sticks of various lengths on them, so that they each had different weight payloads. Typically these motors fly well when their thrust is 2.5 to 3 times the total weight of the rocket.

For a 1.2 pound thrust (19.2 ounces), then, a rocket ought to weigh in the 6.4 - 7.7 ounce range. This is also the way to calculate how much a girandola ought to weigh, depending on how many drivers are on it.

For the above girandola example, with 40 of these drivers, the total thrust will need to be 40 x 19.2 = 768 ounces. The final 'dola ought to weigh between 256 and 307 ounces, or 16-19 pounds. The lighter it is, the faster it will climb and the higher it'll fly.

Of the sample rockets in this current batch that I launched, all flew well when their total weight was 6 -7.75 ounces, and they failed to fly well when their weight was 8 ounces or more. The above calculations would have predicted that.

I think that these motors, rammed with 50/50 cool/hot fuel have enough thrust, but are not near the "edge" where there is a risk of a percentage of them blowing up.

In the next article, I'll be using these end-burning rocket motors to test black powders made with the 5 different charcoals.

How to Make Engines for Estes Rockets

By Ned Gorski

Why make your own Estes-type black powder rocket engines?

"Let me tell ya all a story about a man named Ned,
His grandson Jake called, and this is what he said,
Pap, I've got an Estes rocket and a question for you,
Can you make a motor for it, with a homemade fuel?"

Swimmin' pools, movie stars...

. . .Oops, this isn't exactly on topic and it is certainly a bad takeoff on a 1960s TV show.

I have to admit something right off the bat. I led a deprived childhood. I never had an Estes model rocket to play with. This might explain many things about my personality. But, I digress.

I've often heard fellow fireworkers point to their first childhood Estes rockets as one of the major influences that got them moving on their lifelong path playing with pyro. It sounds like a good, safe, socially acceptable point of departure for such a journey.

But, such was not my fate. My first experiments were much less commercially marketable. Now, I have to admit something else. I'm a die-hard do-it-yourselfer. I've built complete houses, and when my water main broke this spring, down 10 feet underground, I rented a backhoe, refreshed my memory on how to operate it, dug a huge hole, and repaired the plastic water line. I much prefer to do things myself.

So, the thought of buying packages of reloadable black powder motors for model rockets sort of rubs me the wrong way. To me, the heart and soul of a rocket is its motor. If I'm going to make a model rocket, I want to be able to make the rocket engine myself.

Indeed, a few weeks ago, my grandson Jake did call me. He asked if I knew how to make motors for his Estes rocket. I told him that since I knew how to make end-burning, black-powder rocket motors, I was confident that we could figure out how to make one to power his model rocket.

That conversation spurred me on into this next phase of the second childhood I'm currently living: making motors for Estes rockets. If I was going to show Jake how to make them, I'd better figure out how to do it myself first.

How to Make a Model Rocket Engine

I'll be using the high quality, Skylighter TU1066, 3/4-inch ID rocket tubes for these rocket motors. I have tooling for making end-burner rockets, similar to TL1270, which works well with these tubes. It would be possible to use homemade tooling similar to that which was shown in Fireworks Tips #108, Making Gerbs.

Based on this starting point, I went to the website, http://www.hobbylinc.com/prods/tc_est.htm, and researched the specifications of some common Estes rocket motors. There are a couple of common sizes, D12-5 and E9-6 for example, which are spec'd at 1-inch OD, like the rocket engine tubes I want to use for the homemade models.

Estes' rocket motor nomenclature has three values in it. The letters A through E refer to the "total impulse" of the motor, or the total power of the rocket. Each succeeding letter, B, C, D, E, indicates an approximate doubling of total rocket engine power. So, the E rocket motor referred to above would have twice the total power of the model D rocket engine. That means that an E rocket engine should fly about twice as high as an Estes D rocket engine.

This "total impulse" or total rocket power combines the rocket engine's average thrust with the amount of time that it burns. If two rocket engines have the same average thrust, but one burns for twice as long as the other, the longer-burning engine would have twice the total power as the one which burns for less time, even though each had the same average thrust.

This average thrust of an Estes rocket engine is indicated by the number after the letter. The D12-5 motor has an average thrust of 12 Newtons (4.45 Newtons equals 1 pound). The E9-6 rocket motor would have an average thrust of 9 Newtons. The E rocket engine is longer than the D motor, so even though it has a lower average thrust, it has twice the total power since it burns longer than the D.

The number after the "dash," for instance the 5 in D12-5, means that after the thrust burn of the rocket engine, there will be a 5 second delay before the parachute ejection charge activates.

The info on those rocket engines led me to model rocket bodies which use them, and I settled on using an Estes "Eliminator" which comes mostly pre-assembled. This rocket body can use any of these model engines: D12-5, D12-7, E9-6, or E9-8.

Estes "Eliminator" Model Rocket

I bought a couple of the model rockets with the idea that I'd use one to fire store-bought Estes rocket engines, and I'd modify the other one as necessary to experiment with my homemade engines.

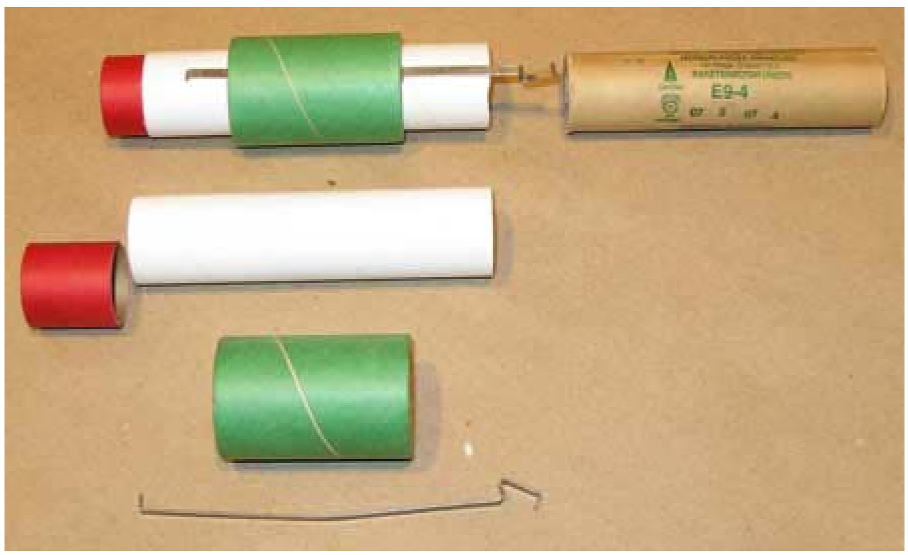
In addition to the rocket bodies, I also purchased some Estes D12-5 and E9-6 rocket engines. These motors employ the same type of high-quality paper tubes I'll be using. The Estes D engines are 2.75 inches long, and the E's are 3.75 inches long.

But, alas, the Estes model rocket engine tubes were not the 1-inch outside diameter specified at the website listed above. They are actually only about 15/16-inch OD. This is going to require me to make a modified motor mounting system in order to use my slightly larger, 1-inch OD tubes and motors.

Modifying the Standard Estes Rocket Engine Mount

Normally step 1 of my Eliminator model rocket's assembly instructions would have me assembling the stock Estes engine mount. But since my rocket engine tubes are slightly larger than the OD of the stock Estes rocket engine tubes, I will have to modify the Estes engine mount. The stock Estes model rocket engine assembly and parts are shown in the photo below.

Notice that there are basically two mounting tubes, the long white tube, and the short green tube. The E size Estes rocket motor shown is inserted into the white tube until it is held in by the metal clip. As you can see, normally the white tube fits inside of the green tube, and the whole assembly fits into the tail of the plastic model rocket body.



Eliminator Model Rocket's Stock Engine Mount, and E9-4 Estes Engine

The total weight of the model rocket engine mount and engine is 91.5 grams (3.2 ounces), of which 69.5 grams (2.45 ounces) is the weight of the motor, and 22 grams (0.8 ounce) is the weight of the mount. I've learned, after playing with girandolas and black powder rockets for a while, that their weight is critical.

The total weight of a black powder rocket will determine whether or not it will fly, and if it does, how high it will go. Also, the weight of the rocket engine and mount contributes to the aerodynamic balance of the flying rocket. So I'll want my homemade motor and mount to weigh about the same as the stock versions.

In the stock rocket engine mount, the engine slides into the white tube and forward until it hits the part of the metal clip, which is projecting through the wall of the white tube. The motor is held in with the other end of the metal clip, and this becomes critical when the parachute ejection charge ignites. That ignition will pressurize the rocket body, and "try" to eject not only the nosecone and parachute out its front, but also the motor out its back. The clip is what prevents the motor from being ejected.

The red tube at the front of the motor mount also helps hold the model rocket engine in place during the thrust and coast phases. It is hollow to allow the ejection charge gasses to burst forward into the rocket body tube and eject the parachute.

So, since my homemade motor tubes have different dimensions than Estes' rocket tubes, I have to find some way to hold my 1-inch OD motors in place, front and back, and keep the front of the motor mount hollow so that the parachute can be ejected.

First, I eliminate the white mounting tube altogether. And it appears that if I slightly modify the ID of the green tube, I can make everything fit. I was able to peel some layers off from the inside of the stock green motor mount tube, so that my homemade motor will slide into it.

I also have some Skylighter TU1065 and TU1068 paper rocket tubes, which have an OD of 1.25-inches, the same OD as the green tube. The ID of these tubes is 3/4-inch, which will allow my parachute ejection gasses to pass through. That ID is small enough that the rocket motor can slide up against it and serve as a "stop" to prevent the rocket engine from pushing forward during thrust. So, I cut a 3/4-inch long piece of TU1065, and use it to replace the stock red tube that Estes supplies as part of its motor mount.

The design of my modified mount to accommodate my homemade motors is shown below. The metal clip will end up sandwiched between the green tube and the rocket body tube once the green tube gets glued into the rocket body. I have bent the clip slightly, so it will clip onto the end of the motor when it's inserted. Both tube sections will be glued in place inside the rocket body tube.

For some tips on cutting paper tubes for model rocket engines, please refer to Fireworks Tips #107, Cutting and Treating Paper Tubes.

Custom Motor Mount and Tube for Homemade Estes Rocket Engine

This custom motor mount assembly weighs 20 grams, which is just about the same as the stock one. So far, so good.

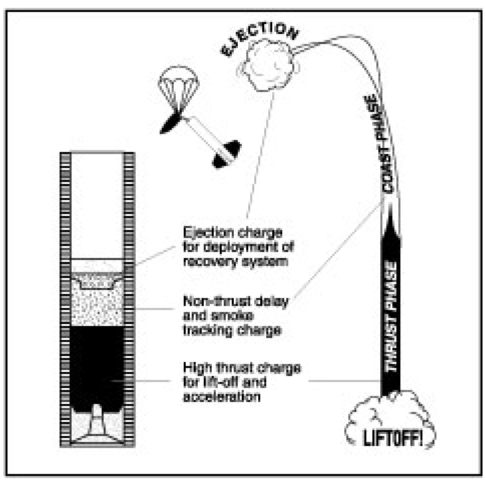
Whether I'm installing the stock or the custom motor mount, I glue them in place per the instructions, so that the end of the motor projects out past the end of the rocket body tube 1/4-inch when the motor is fully inserted.

I'm now confident that with a bit of creativity, any type of stock Estes rocket engine mount can be modified and adapted to accommodate a homemade motor.

I went ahead and completed the rest of the rocket assembly per the original Estes model rocket instructions. The final flying weight of the rocket was 170 grams (6 ounces) with the stock motor installed.

Dissecting an Estes Model Rocket Engine

The following diagram is from the Estes "Rocketry 101" educational information, available at the http://www.esteseducator.com website. It shows the various sections of an Estes model rocket engine and how each section performs during flight.



Estes Rocket Engine Diagram

This is a relatively typical end-burning model rocket engine construction, where a clay nozzle is rammed in the end of the tube, and a solid black powder rocket fuel grain is then rammed above the nozzle. There is no hollow core going up into the black powder grain, therefore the name "end-burner."

Estes uses two types of black powder rocket fuels in the motor diagrammed above: a powerful "thrust" rocket fuel, and a less powerful "delay" fuel. These two sections of rocket fuel are topped off by a powerful ejection charge, which produces volumes of gasses quickly in order to eject the nosecone and parachute.

A dissected stock E motor shows the various sections of the motor.

A Dissected Estes E9-6 Model Rocket Engine

In this motor, the nozzle was about 1/2-inch thick, weighed 5.5 grams, and had a 5/32-inch "aperture," or hole. The 2.5-inch long, 38-gram rocket fuel grain was extremely solid and hard, like one single cylinder of rocket fuel. When tapped with a metal rod, the rocket fuel grain "tinks" like a piece of fired clay dish.

The nozzle hole projected another 1/8 inch into the model rocket fuel grain. I test-burned a chip of the thrust-fuel grain; it burned instantaneously as one would expect full-strength black powder to do.

Surprisingly, the delay fuel was only about 1/2 inch thick, and was a medium gray in color. I expected it to be black and to occupy more space, since it burns for so long. A bit of the delay fuel burned very slowly, and it produced a small amount of white smoke as it burned.

Embedded in the top of the delay fuel was a 1/8-inch layer of granular black powder ejection charge. When scraped away from the rocket engine's delay fuel grain, this ejection charge weighed 0.5 grams.

On top of the ejection granules was a thin layer of clay, which I imagine pops off easily when the column of fire inside the motor hits the ejection charge. This will allow the gasses from the charge to eject the parachute.

The most important data on this motor is its thrust. Thrust is what powers the rocket skyward. I'll need to make homemade rocket engines having close to the same amount of power, if I want rocket flights equaling the altitude I get with stock motors.

I have a scale, which has a load cell platform and a remote digital readout console. I use this scale to test my rocket engines and record the digital readout of the thrust/power from rocket engines.

An E9-4 rocket engine's thrust phase lasted for 3 seconds and produced about 2 pounds of thrust on average. The delay fuel burned for 4 seconds and produced no thrust.

Estes E9-4 Rocket Engine's Thrust Measured with a Digital Scale

(Click Image to Play Video)

This Estes Eliminator rocket will fly highest with an E motor. A D rocket engine will result in a lower altitude, and is recommended for first flights. When I tested a D engine on the test stand, the thrust phase lasted for 2 seconds and produced about 1.8 pounds of thrust (rocket power).

How to Make a Homemade Estes Rocket Engine

Tips on making rocket nozzles, and the clay mix they are made from, can be found in Fireworks Tips # 89 in the Making Nozzle Mix article. Additionally, some basic information on how to make an end-burner rocket engine and the tooling used to make them can be found in Fireworks Tips #95.

I'll be using one-pound (3/4-inch ID) end-burner rocket tooling, similar to Skylighter TL1270 tooling.

Skylighter TL1270 End-Burner Rocket Tooling

I'll be making the motors using the methods in the article cited above, with some slight exceptions: I will not be dampening the black powder rocket fuel immediately prior to use. I also will not be pressing these rocket engines with a hydraulic press, but hand-ramming them instead with a rawhide mallet. No tube support is needed when the motors are made this way.

First, I want to try the simplest-to-make black powder rocket fuel, a screened 75/15/10, potassium nitrate/airfloat charcoal/sulfur mix. So I screen 15 ounces/3 ounces/2 ounces of each chemical respectively through a 100-mesh screen, using commercial, hardwood airfloat charcoal from Skylighter.

If any of the potassium nitrate won't pass through this screen, I grind it more finely in a coffee mill per the instructions and cautions contained in Fireworks Tips #112.

I rammed a rocket engine with a 2.25-inch long fuel grain using the simple, screened, black powder fuel. This motor burned for 7 seconds and only produced between 0.2 and 0.25 pounds of thrust. When it burned,

Well, I suspect I have a ways to go before I can make a motor that will get this model rocket up and flying. There are a couple of ways to increase the power of a rocket motor like this.

I can switch from commercial, hardwood airfloat charcoal to a homemade charcoal. For tips on making homemade charcoal, see Fireworks Tips #90. I have some homemade spruce/pine charcoal, which I know makes more powerful black powder than does commercial hardwood airfloat.

I like using homemade charcoal, and I could pass that skill along to Jake as we work on this project. So, I think I'll try the same procedure as my initial one, but substitute homemade spruce/pine airfloat for the commercial charcoal.

This second rocket engine burned for 6 seconds, with a thrust of 0.25 - 0.27 pounds. I'm heading in the right direction, but have a long way to go yet.

With a 6-ounce black powder rocket, based on my past experience using end-burner motors on girandolas, I'm guessing that I'll need at least 0.75 lbs of thrust to even start to lift the rocket, and more like 1.2 pounds to really get her to fly.

Another way to speed up black powder is to ball mill it. For information on ball milling, see Fireworks Tips #91. I'm going to ball mill both batches of rocket fuel for two hours to see how significantly that increases its power.

While those batches were being ball milled, I went ahead and pressed a rocket engine using some finely granulated, commercial Meal-D black powder that I had on hand. I wanted to see what sort of thrust a known, good, powerful black powder fuel would create when hand-rammed in one of these homemade rocket engine configurations.

That motor burned for 3 seconds and produced 1.5 pounds of thrust, and I'm confident that it could have enough power to lift the rocket.

Once my two fuels had been milled, I made rocket engines using them and burned them on the test stand.

The motor made using the milled spruce/pine charcoal black powder burned for 3 seconds and produced about 1.3 pounds of thrust on average. Now we're getting somewhere. The ball milling made a huge difference.

The rocket engine made using the milled, commercial airfloat charcoal black powder burned for 3.5 seconds with an average thrust of 1 pound. Even this motor sounded and "felt" as though it might send the rocket into flight.

Note: When I use the term "commercial hardwood airfloat charcoal," I am of course referring to what I have on hand. Who knows what wood this was actually made from at the charcoal factory? My store-bought charcoal may be quite different from your store-bought charcoal, depending on what wood was used to make them on the day of the week it was made. So, your results may vary from mine.

Okee-doke. Switching to the homemade spruce/pine airfloat charcoal increased the engine's thrust a bit, and ball milling the fuels made a huge difference.

Another way to increase the power of the rocket is to decrease the diameter of the engine's nozzle aperture. The tooling I'm using creates a 3/16-inch nozzle hole. I could try going down to a 1/8-inch hole, but doing so would necessitate ramming a solid nozzle and drilling the hole, as I described in Making Gerbs, Fireworks Tips #108. I'd rather keep this project simple for Jake, and continue to use my stock rocket tooling.

One additional procedure that may increase the power of the black powder fuel is to slightly dampen it, screen the comp several times to thoroughly integrate the water, and dry it. I used this method when making the rocket fuel for the one-pound black powder rockets that I wrote about in Fireworks Tips #113.

Another significant advantage to using fuel that has been dampened, screened, and dried is that the fuel is slightly granulated instead of being finely powdered and fluffy. This makes ramming the powder into the motor tubes much less messy.

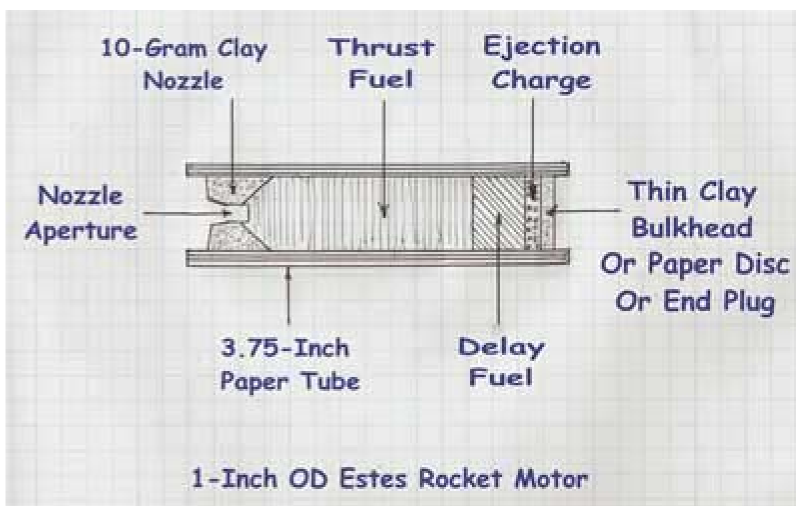
I went ahead and dampened 3 ounces of each rocket fuel with 10% water, screened it, and allowed it to dry overnight on kraft-paper lined trays.

A motor made with commercial-airfloat fuel, processed in this manner, burned for 3.4 seconds and its thrust averaged between 1 and 1.2 pounds.

A motor made with the spruce/pine charcoal fuel burned for 2.8 seconds and produced an average thrust of between 1.3 and 1.5 pounds.

So, processing the fuels with the water slightly increased their power. I'll make engines with these two processed rocket fuels, commercial-airfloat and homemade spruce/pine charcoal, ball milled, dampened/screened/dried, and see how the rocket flies with them.

This is the final rocket motor configuration I have in mind.



Cross-Section of Homemade Replacement Estes Model Rocket Engine

I'm going to use a simple Tiger-Tail Star composition for the delay fuel, eliminating any binder that would be used when making stars. This is a very slow-burning composition.

Tiger Tail Star Composition for Delay Fuel

Chemical	Percentage	4-ounce batch	115-gram batch
Airfloat charcoal	0.47	1.9 ounces	54 grams
Potassium nitrate	0.47	1.9 ounces	54 grams
Sulfur	0.06	0.25 ounces	7 grams

I simply screened this composition through a 40-mesh screen three times, slightly dampened it with water, as I did with the rocket fuel, and dried it.

For the ejection charge, I dampened some of the rocket thrust fuel with 5% water, and pressed thin black powder pucks with it. These pucks were dried and crushed, making black powder similar to what was made in Fireworks Tips #96. I'll use the black powder granules, which pass a 10-mesh screen, but won't pass a 20-mesh screen.

I can vary the duration of the thrust phase of the rocket engine by varying the length of that black powder fuel grain. 3/4 inch of the thrust fuel burns for about 1 second. So if I want, say, 2 seconds of thrust, I can ram 1.5 inches of that black powder fuel. Each 3/4 inch of that fuel weighs about 8 grams.

Similarly, the delay fuel burns for about 1 second per 3/16 inch of that fuel. So if I want 2 seconds of delay, I'll ram 3/8 inch of that fuel. Each 3/16 inch of the delay fuel requires about 2 grams of it.

In this way, I can adjust and fine-tune my model rocket flights for any altitude I want.

To make a motor, I rammed the clay nozzle using 10 grams of clay nozzle mix, with 12 whacks with my rawhide mallet. If I'm using a spindle that has a hole drilled in the center of it for black-match fusing, as I described in the end-burner article, I simply allow that hole to get filled with clay, which I'll remove with a drill bit at some later time. I'm not using the black-match fusing technique in this project.

Then I rammed the black powder thrust fuel in flat-teaspoonful increments and 8 hits of the mallet for each increment. Then I did the same with the delay fuel.

I poured in 2 grams (a heaping 1/4 teaspoonful) of my ejection charge and only lightly tamped that powder flat by hand-pushing the ram into the rocket engine.

I tried capping the ejection charge with a lightly tamped clay disc, with mixed results. During this research and development, my worst calamities occurred when the parachute did not deploy, seriously damaging the rockets.

I got the best parachute ejections when I capped the ejection charge off with a 3/4-inch paper disc, DK0600. I put the disc on a piece of masking tape, which was a bit larger than the disc. That way, when I pressed the disc in, the tape folded up on its edges and made it fit a bit more snugly--no gluing necessary. If I'd had 3/4-inch paper end plugs, PC0800, I would have used them by just pressing them into the rocket tube and using no glue.

Here's a photo and video of a test of a homemade model rocket engine, made with 3 seconds of thrust (24 grams of black powder fuel), and 3 seconds of delay fuel (6 grams).

Homemade Estes Rocket Engine

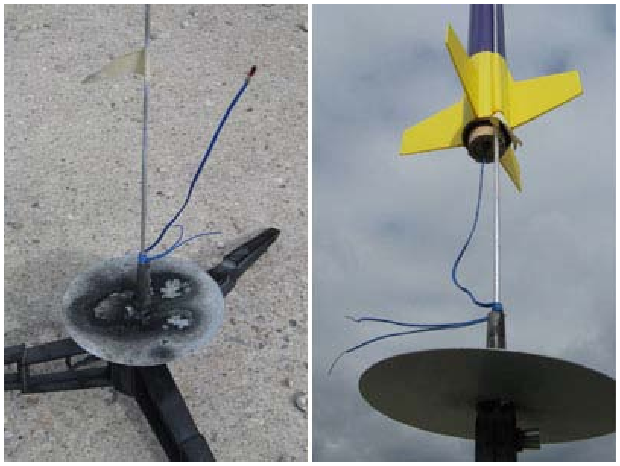
(Click Image to Play Video )

I now have stock Estes D and E model rocket engines, and homemade motors made with the two different charcoals. It's time to go out to the rocket range for some testing.

Flying My Homemade Estes Model Rockets

To launch these rockets, I purchased an Estes rocket launch pad. I want to fire them electrically. So, instead of Estes igniters I used homemade electric igniters made with GN5040 ematch blanks and the GN5050 electric match dip kit. A little tutorial on using these materials to make electric match igniters can be found in Fireworks Tips #102.

Here's how I rigged the ematch igniters: First I wrapped the ematch leads around the launch rod, pointing the ematch head straight up. Then I lowered the rocket down the rod until the igniter head inserted into the rocket-motor nozzle aperture. This is the one application where I do remove the electric match protection shroud.



Installing and Inserting Electric Igniter into Rocket Motor

I then extended the ematch wires about 6 feet over to my electric firing box. It's nice to be able to fire the rockets with a wireless remote control from 50 or 75 feet away, or to let the kids push the button.

One other homemade component of the rocket launch that I made was fireproofed wadding to go into the model rocket body tube between the engine and the parachute. Estes sells little packets of fireproofed toilet-paper squares for this purpose.

I sprayed some paper towels with Universal Fire-Shield, Paper Shield P-3000, available online at http://www.firechemicals.com. Once it dries, this product fireproofs porous materials like paper and string. I've sprayed it on the tissue paper I used for homemade sky lanterns.

A lightly balled-up wad of the treated paper towel stuffed into the rocket body-tube, followed by the parachute and rubber-band shock-cord (folded up in another piece of the paper towel), really protected the parachute, strings, and rubber band from the heat of the ejection charge.

Fireproof Wadding to Protect Parachute during Ejection

I went out to the approved rocket launch area in my local state park, and flew some of my model rockets. The Estes D engines propelled the Eliminator rocket a good 500-700 feet high, and the E engines really sent it up there, probably over 1000 feet high.

My homemade rocket engines made with the commercial airfloat charcoal fuel flew about 500 feet up. The spruce/pine charcoal fuel sent the rocket up another one or two hundred feet higher than that, comparing favorably with the stock Estes D motors.

Estes Rocket with Homemade Engine in Flight

(Click Image to Play Video)

All in all, I flew rockets with about a dozen Estes stock engines, and about the same number of my homemade motors.

Results

You can hear my glee in the final video. Flying the rockets was truly an enjoyable, child-like experience. Good fun.

And, any day spent learning something new is a good day in my book. I learned how Estes rockets work, and what goes into one of their motors.

I learned how to duplicate the performance of those stock motors with my own homemade motors. And now I know I can direct Jake as he makes his own motors for his rockets.

Finally, a good day at the rocket range is a day when the rocketeer brings the rocket back home in mostly one undamaged piece, ready to fly again another day. I got to do that today.

Have fun with your Estes rockets, your kids and grandchildren, and your "inner child."

How to Make Stinger Missiles

By Dan Williams

Learn how to make fireworks stinger missile stick-less black powder rockets using Skylighter stinger missile rocket firework tooling.

Materials Needed

- Bentonite clay (CH8078)
- Black powder, Meal D, rocket fuel
- Charcoal (CH8068)
- Delay composition
- Dextrin (CH8107)
- Funnel
- Hand drill and 1/8" bit
- Hydraulic press or wooden mallet (TL4040)
- Kyanite (CH8165)
- Masking tape
- Nitrocellulose lacquer (CH8198)
- Parlon (CH8210)
- Potassium nitrate (CH5300)
- Red Gum (CH8230, CH8231)
- Scoops, small
- Sodium silicate (CH8287)
- Soluble glutinous rice starch (CH8238)
- Stinger missile tooling
- Sulfur (CH8315)
- Table saw
- Toothpick
- Tubes, parallel, rocket

- Visco fuse (GN1000, GN1001, GN1004, GN1005)
- Wax

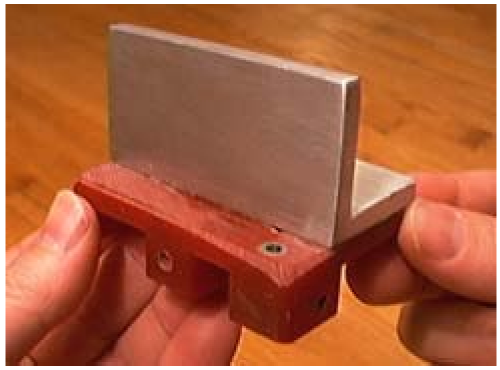
The name "stinger missile" seems to have become fairly common among pyro hobbyists to refer to the class of stick-less rockets which are spin stabilized. This means that the usual efforts to assure a predictable flight path of the rockets, which include body fins or a stick, can all be dispensed with for stinger missile rockets. Consequently, the spin stabilized stinger missile rockets are extremely easy to make. This is what makes stinger missiles so much fun.

The methods presented here closely follow those first described by Warren Klofkorn some 10 years ago. His article appears in "The Best of AFN II" on page 62 and has become the standard reference for stinger missile construction. A description of my personal experience with his instructions and a few other innovations, hints and tips are included here in the hope that they might make your stinger missile making experience more enjoyable.

Stinger Missile Rocket Tooling

Tools are usually the first consideration of any new rocket project. Since the tools for stinger missiles are fairly simple, it doesn't cost much to buy it from professional sources, like Skylighter.

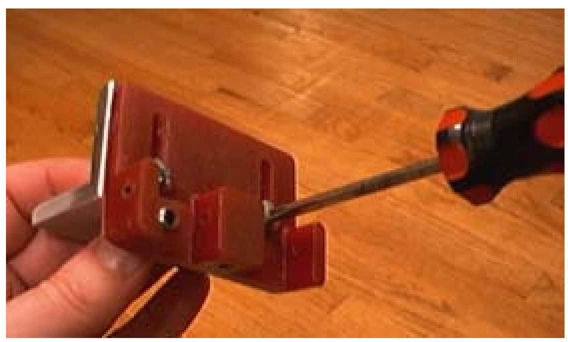
Shown in this picture, a machined aluminum spindle is mounted in a ramming base and held in place with a bolt through the bottom. The rammers consist of an aluminum rod with a hole in it for pressing the black powder rocket fuel around the spindle and a solid one for pressing the rocket fuel and delay composition above the spindle.



Stinger Missile Drill Guide

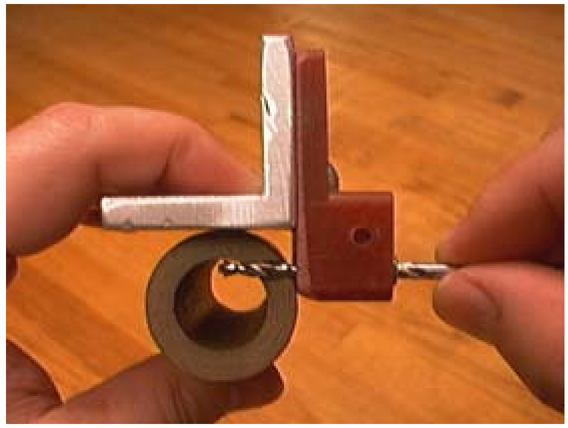
This is a close-up of the firework tool jig used to position the side vent hole in the stinger missile rocket body tube. This hole is used to create tangential thrust that will cause the stinger missiles to spin as they fly. The angular momentum of the spinning stinger missile is what stabilizes the rocket.

This jig helps to accurately position the rocket vent hole to consistently achieve a good spin. The desired location of this vent hole is just above the clay rocket nozzle and in a direction that is at a tangent to the inside surface of the rocket tube. This jig may look a little different from the present Skylighter product, but the function is identical.



Adjusting the Drill Guide

To adjust the firework tool jig for the size of stinger missile rocket you plan to make, you must first loosen the two screws until they allow the guide hole plate to slide relative to the angle piece. First adjust the screws to be slightly snug so that the two jig pieces aren't overly floppy, but will slide with a little effort.



Correct Drill Guide Alignment

Now get a piece of rocket tubing and hold it against the firework tool jig as shown. Place the 9/64 drill bit (provided with the stinger missile tool kit) in the guide hole and check the alignment as illustrated in the picture.

The drill bit should be positioned so that its side flutes are even with the inside wall of the stinger tube. If this verbal description is not clear, just look at the picture. Now, if your alignment isn't correct, just slide the jig pieces until it the angle is correct, and then tighten the screws. This alignment will assure that, when drilling the side vent hole for your stinger missile rocket, the drill bit will emerge at the right place on the inside surface of the rocket tube.

With the vent hole aligned correctly, you will achieve the best thrust angle to maximize spin and stability for your stinger. Be sure that your adjustment screws are in the same places in the two slots, assuring that the two firework tool jig pieces are parallel to each other. Another good tip to use at this point is to put a small piece of tape on the drill bit to mark the proper depth of insertion into the guide hole.

The proper depth is also shown in the picture. If the drill bit is allowed to go any further into the tube, it will begin to drill into the opposite wall of the tube, causing undesirable weakening at that point. With this done, the jig setup is complete and you're ready to get your hands dirty and have some real pyro fun.

Parallel Tubes in Various Lengths

Construction of the stinger missile rocket starts by preparing the rocket body tube. A typical 1 pound rocket tube may be used. The Skylighter TU1068 is a good example. It measures 3/4 inch ID, 1-1/4 inch OD and 7-1/2 inches long.

You can save money if you buy the longer TU1065 from which you can cut as many as 9 stinger missile rocket tubes, and have less tube cutoff waste. Either way, a stinger missile tube must be cut to a length that depends on what heading is planned for the payload of the stinger.

Cutting these heavy tubes is best accomplished by using a table or radial arm saw because a clean, square end is desirable for stingers. A length of 3 inches is typical for stingers which contain some colored firework star composition for delay.

Another option is to add a header extension filled with stars and some burst composition. When this option is chosen, the rocket body tube can be cut a little shorter, enabling three rockets to be made from a single 1 pound stinger missile rocket tube. The construction of these headers will be covered later.

Ramming the Clay Nozzle

With the rocket tube cut to the desired length, it is placed over the spindle on the spindle base and a carefully measured amount of nozzle clay is poured into the rocket tube. A small funnel of some sort, as shown on the floor in the picture, is very helpful in accomplishing this.

Klofkorn's original article advocated the use of 4.3 cc of powdered Hawthorne Bond clay for the stinger nozzle. I use a 60%/40% mix of bentonite clay and kyanite treated with an additional 5% of toilet seal wax dissolved in Coleman fuel. Instead of using a volume measurement for the nozzle clay, I recommend that you use a weight measurement so that a consistent nozzle length is achieved.

The importance of doing this will become evident shortly. Stay tuned. If you are not using a hydraulic press, the nozzle clay is compacted by administering about a dozen firm blows (this is called "ramming") with a mallet of some sort, as shown in this picture. Although a little bulge in the stinger tube wall can be desirable after ramming or pressing, be careful not to split the tube.

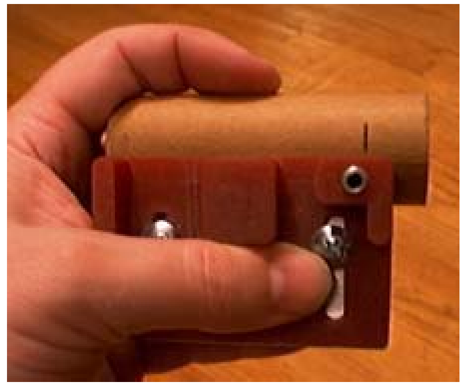
Marking Rammer for Side Vent Hole Position

Before drilling the side vent hole in the tube, a mark must be made on the outside of the rocket tube to indicate where the top of the rocket nozzle is located. Start by applying a piece of masking tape to the rammer so a mark can be easily made on it.

Then place the rammer in the tube until it seats against the rocket nozzle. Now make a mark on the masking tape, as shown. Of course, if you were really on the ball, you could do this right after you finished ramming the clay, in the step above.

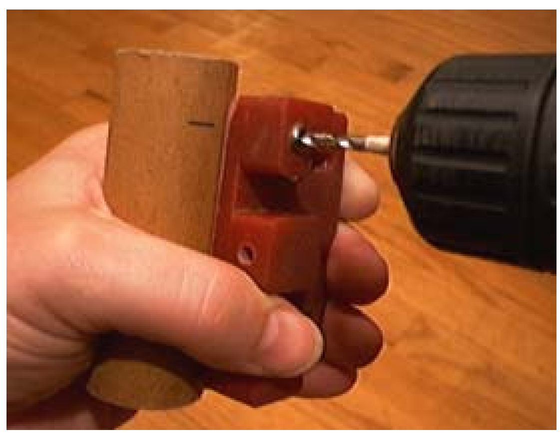
Marking Side Vent Hole Position on Tube

Next, remove the rammer from the tube and hold it against the outside of the rocket tube with the mark you just made even with the top of the rocket tube. Make a mark on the tube at the bottom of the rammer. This mark should now indicate where the top of the nozzle is inside the tube.



Positioning Drill Guide for Side Vent Hole

Now the tube is held in the drilling firework tool jig, as shown. The guide hole should be located so that the side vent hole will be drilled just above the nozzle. In case you haven't figured it out, you should remove the rocket tube from the spindle base before you drill the side vent hole.



Drilling Side Vent Hole in Tube

Hold the tube in the drilling jig in one hand, properly positioned as shown in this picture. Then the hole is slowly drilled with a hand drill, taking care to firmly grip the tube in the jig so that it doesn't move. Again, note the piece of tape on the drill bit, which indicates the proper depth for the drill bit in the guide hole.

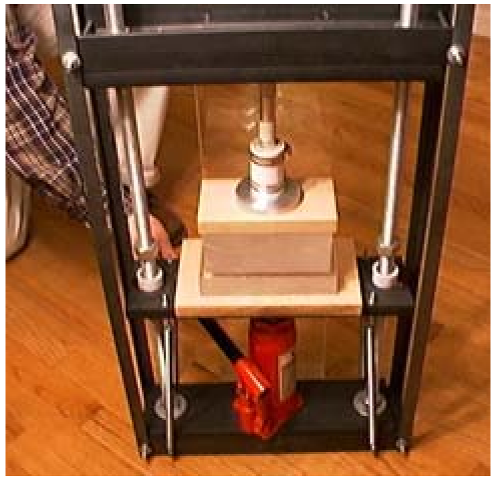
Now pay close attention. Here comes the nifty tip you've been waiting for. Once the location of the top of the nozzle has been established, it should be measured and preserved in your notebook. This measurement can be used in all future stingers with the assumption that it will always be accurate.

The assumption is a safe one to make if your nozzles are always made the same way with exactly the same compression and same amount of clay. The significance is that the side vent hole can be drilled before the rocket nozzle is rammed, eliminating the need to remove the tube from the spindle to locate the top of the nozzle and drill the hole after nozzle ramming. It's a nice little time saver.

Treating Side Vent Hole to Reduce Erosion

The vent hole can be made more impervious to hot exhaust gasses by treating it with a few drops of sodium silicate solution, as shown in this picture. An eye dropper is used to put the silicate into the hole.

A toothpick or small nail is then used to spread it around in the hole and prevent blockage or constriction of the hole. Some of my impatient pyro friends skip this step to avoid waiting for the required 20 minutes for the silicate to dry in the vent hole. Their stinger missiles still seem to fly just fine, albeit possibly not quite as high.



Using Hydraulic Press to Press Nozzle & Fuel

This picture illustrates the use of a typical rocket press to form the nozzle and load the black powder fuel. When a hydraulic press is used instead of a mallet, a reinforcing sleeve is a good idea to avoid deforming the rocket tube. Whichever method is used to load the black powder fuel, a little scoop, as shown in the hand ramming picture above, is handy for measuring out the black powder fuel for each pressed increment. I made mine by hot gluing the bottom section of a film canister to a small garden marker stick.

The black powder fuel must be compacted in the tube in about 4 or 5 increments, each of which should be no longer than the inside diameter of your tube. For the black powder fuel, I use the same milled meal that I use to make a good lift powder. It contains willow charcoal to make a very hot stinger fuel. This fuel would be too hot for a standard 1 pound rocket, but for stinger missiles it works very well because the stinger core is considerably shorter.

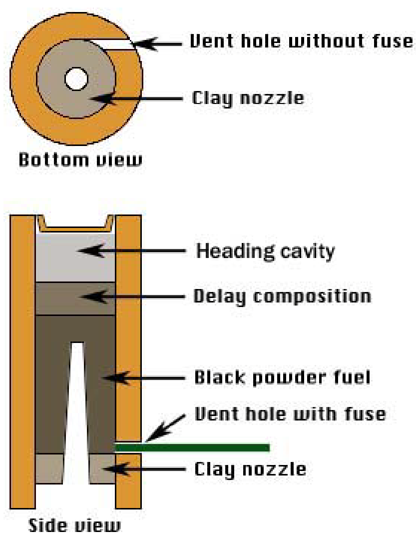
I have noticed, however, that in the case of the larger 3 pound stingers, my home-made black powder is a little too hot. I experienced a few explosions immediately upon ignition until I cooled the black powder fuel down a little with a few percent of mineral oil. As with most black powder based rockets, you may need to experiment a little to dial in the proper burn rate for your stingers.

After the rockets have been charged with their black powder rocket propellant, some delay composition should be loaded above it to allow the rockets to reach their apogee. Otherwise, your stingers will activate their payloads at very low altitudes because the actual thrust burn only lasts about 1 second. The following slow black powder composition is suggested as a safe and compatible delay element:

Ingredient	Percentage
Potassium nitrate	45%
Charcoal	50%
Dextrin	5%

Somewhere between 6 cc and 9 cc of this composition, dampened with a sparing amount of alcohol, is pressed into the top of the tube using moderate pressure only. It is a good idea to give this delay composition a little drying time before adding the final heading to the rocket.

The diagram shows the internal structure of the stinger missile after a heading composition has been installed.



There is nothing sacred about this particular way of making a delay. A totally different delay composition can be used for your stingers. I am a little partial to some of the glitter formulas, myself, such as Winokur #39.

Finished Stinger Missiles with Headings

Now we are ready to talk about the various heading options for our stingers. After all, what's the point of making a stinger missile that just spins as it flies if it doesn't do something cool at the end of its flight? An easy firework shell header with stars can be constructed using a 1-1/2 inch length of Kraft paper tube whose inside dimension is 1-1/4 inches. This tube is glued to the top of the tube with a 1/2 inch overlap.

The expanded cavity now has more room to accommodate a larger payload of stars and burst. The payload space needs to be filled completely and firmly packed so that no asymmetries can be created when the rocket spins. The cavity can be closed in a variety of ways.

A typical end plug or cap will do the trick, but if you want to maximize your payload space, a molded nose cone can be used. The nose cone shown in the picture is molded from Kraft paper pulp bound with CMC binder.

An example of each of these header options is shown in the picture. Again, whatever header is chosen, care must be taken to avoid asymmetries, and not make them too long, or your stinger missiles will wobble all over the sky and fly off at undesirable angles.

Installing Fuse in Side Vent Hole

Now a visco fuse piece is added to the side vent hole. A 1/8 inch drill bit (1/64th smaller than the one used to drill the hole in the rocket tube to start with) is inserted into the hole and twisted gently by hand to open a small cavity in the black powder fuel grain.

A glob of Meal D wetted with nitrocellulose lacquer is placed on the end of a 3-inch length of visco fuse. The globbed end is inserted into the vent hole as far as it will go. The nitrocellulose lacquer will dry shortly and secure the visco fuse in place.

I don't bother to bend it against the rocket tube wall and affix it with tape, as recommended by Klofkorn. This practice has damaged the somewhat brittle visco fuse and has caused failure of ignition on some of my stingers. If you use a more flexible visco fuse, this may still be a good idea to make the visco fuse more secure during storage and transport.

Reinforced Exhaust Hole

A little bit of added stability at lift off can be achieved by gluing a custom reinforcement to the business end of the stinger missiles. This is accomplished by tracing a circle around a stinger tube on a piece of strong tissue paper.

A notebook paper hole reinforcement is then glued to the center of the circle. The circle is cut out and glued to the nozzle end of the rocket as shown in the picture. The launch spindle will be inserted through the hole of the reinforcement at launch time. The reinforcement helps the rocket spin about its central axis without wobbling.

Another possibility I have seen used for this purpose is a standard paper end plug with a hole punched in it. The end plug is not glued into place so it will easily be blown out when the rockets fly. These end plugs may usually be re-used a few times before they become too badly charred.

Stinger Missile Mounted on Launch Pin, Ready to Fire

Stinger missile rockets require a custom launch pin to support them prior to launch and during initial spin-up of the device. This can be as simple as a nail driven through a good sized piece of wood to give your rocket a solid footing during launch.

The last thing you want when your rocket starts spinning is for the launch stand to tip over and send an angry stinger into your terrified audience. The nail is rounded at the end by a file to provide a good pivot point at the top of your stinger's core.

This picture shows a typical launch stand with two launch pins, one supporting a finished stinger missile ready for launch. A little decorative paper has been added to give it a festive flair. All that remains is to light the visco fuse, retire to a safe distance and feel the rush these marvelous little stinger rockets give to their creator and his audience.

Tips and Suggestions for Further Enhancements

After a suggestion from Lindsay Greene, I tried adding 3% of 40-200 mesh spherical titanium or ferro-titanium to the black powder fuel. It creates a beautiful, cork screw trail of bright golden sparks as the stinger ascends. It is a very impressive effect with little extra effort. The only drawback is that the titanium causes a little extra wear on your firework tools and launch spindle.

You can also use this simple mix of black powder and titanium flake:

- Meal D or homemade, ball-milled black powder 88%
- Flake titanium 12%

Why do titanium flakes work so well? Flakes have edges. Edges take fire better than balls (spherical) or gravel (sponge). So the material burns more thoroughly, faster, and to my eye, brighter and richer.

Another possible time saver is to insert the visco fuse into the side vent hole before ramming the black powder. The black powder will compress around the visco fuse and help secure it in place. Care should be taken not to insert the visco fuse too far into your rocket, however, or it might shorten the spin-up time before the main rocket core ignites and sends it skyward.

The launch spindle must be long enough to suspend the stinger about ¼" above the launch base. If the bottom of the tube is touching the wooden base, it will interfere with the rocket's ability to spin on the spindle.

An exciting recent innovation is to use flying fish fuse in the header. A bundle of short lengths of flying fish fuse will ignite to make a swarm of little wigglies all over the sky. One end of each flying fish fuse is primed to aid ignition and the other end is coated to inhibit ignition. This special flying fish fuse can be purchased from Skylighter.

How to Make Black Powder Rockets

By John Werner

Learn how to make "core burner" black powder rockets using Skylighter 4 oz. rocket tooling.

Materials Needed

- Bentonite clay (CH8078)
- Charcoal, 80 mesh (CH8066)
- Charcoal, airfloat (CH8068)
- Funnel
- Gram scale
- Launch tube, metal or plastic tube, approximately 36" long x 1" inside diameter (I.D.)
- Mallet, preferably wooden, aluminum or brass
- Masking tape, 3/4" wide
- Mixing screen, 20 mesh (TL2002)
- Paper, 5" x 2-1/4"
- Potassium nitrate (CH5300)
- Brass or aluminum ramming sleeve, (see Tooling, section 2, for details)
- Rocket tooling, 4 oz. (TL1204)
- Scoop, 1-teaspoon size
- Sulfur (CH8315)
- Tag board file folder
- Tubes, 1/2" I.D. x 5" long (TU1028)
- Wood dowel, 1/4" diameter x 30" long

One of the most enjoyable pyrotechnic devices a person can make and become proficient at is the black powder rocket. Many reasons contribute to its attractiveness: it can be made and shot immediately, the chemicals used are cheap and relatively safe to work with, it is fun to tinker with, and most importantly, there is nothing more impressive than hearing and seeing a well made black powder rocket take off with its distinctive sound and long gold charcoal tail.

There are basically two types of black powder rocket engines. One type, the "end burner" rocket, uses a relatively fast-burning black powder propellant and often incorporates a high percentage of commercially made black powder in its formulation, or requires the black powder rocket propellant to be ball milled before it is loaded into the engine tube.

The term "end burner” is used to describe the way in which the propellant progressively burns from one end of the rocket tube to the other in a straight linear fashion. Typically, this type of engine produces a fairly short tail as the rocket rises into the sky.

This article will describe how to make and fly a second type of rocket engine, the "core burner." Core burning rocket engines are made by forming the black powder propellant around a thin metal core or spindle, which extends up through the center axis of the rocket tube.

Removing the spindle after the rocket engine is loaded results in the black powder rocket propellant having a long hollow cavity, which greatly increases the available surface area for burning. More surface area means that a slower burning black powder composition can be employed for the black powder rocket’s propellant and still provide adequate thrust.

Core burning rocket engines can now be made using only simple hand-mixed black powder compositions of potassium nitrate, charcoal and sulfur. As a bonus, core-burning rocket engines are characterized by having very long, beautiful golden tails and an impressive distinctive sound as they take off.

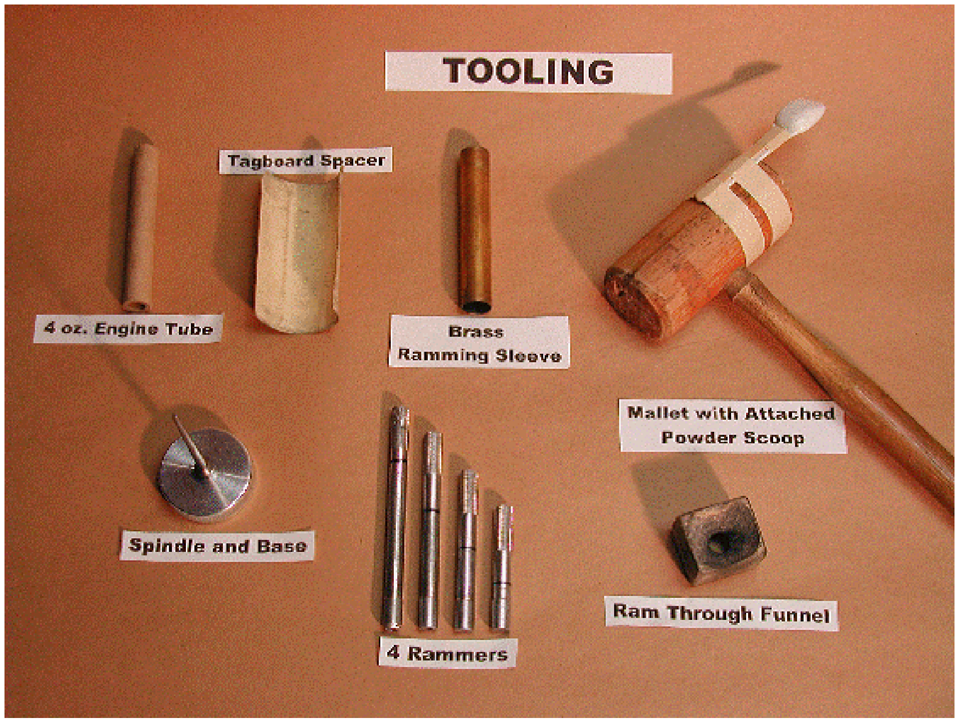
Before You Start

The best use of black powder rockets is firing them in groups or "flights," so this article is geared toward production techniques that allow lots of rocket engines to be made quickly and without machinery. I particularly like the methods used by the Latinos to make their rockets. It is straightforward and produces rockets that are reliable and consistent.

The Latinos produce thousands of hand-rammed black powder rockets for their displays and in my mind are the best rocket makers in the world today. My video "Fireworks From Mexico" (Skylighter #VD0300D) shows many of their rockets being fired.

This article is intended for beginners and is based on using 4-ounce rocket tooling available from Skylighter. No commercial black powder or ball milling of a black powder composition is required, and the black powder formulation is straight out of "Dictionary and Manual of Fireworks" by George Weingart (BK0025). The rocket engines are rammed instead of pressed and reviewing the article on hand-ramming "Basic Pyrotechnic Hand Ramming Technique" is suggested.

Tooling



Tools Needed to Make a Black Powder Rocket

Preparing Rocket Tooling

The 4-ounce rocket tooling available from Skylighter consists of a stainless steel spindle mounted on a large aluminum base and four varying length aluminum rammers (or "drifts" as they are sometimes called). Prior to using the rocket tooling the rammers need to be marked in conjunction with the rocket engine tube that will be used, in this case a 5" long tube (#TU1028).

Slip the rocket tube onto the spindle and base. Start by sliding the longest rammer into the rocket tube until it lightly bottoms out on the spindle shaft. Withdraw the rammer about 1/8" and place a mark with a felt tip pen on the shaft of the rammer where the top of the rocket engine tube falls.

The mark should be drawn as a ring around the shaft, so it is visible from all directions. Mark the other three rammers in a similar fashion. It is extremely important that the rammers are accurately marked in order to prevent them from striking the spindle when filling a rocket engine tube with black powder.

Use a Ramming Sleeve

The paper rocket tubes for this project do not have a wall thickness heavy enough to withstand the ramming process and require a metal sleeve be placed over the rocket engine tube while it is being rammed. The sleeve prevents the rocket engine tube from expanding and splitting and is removed after the rocket engine is completed.

I used a 5" section of brass tubing obtained from the McMaster Carr Company, No. 8950K721, with an I.D. of .811" and an O.D. of 7/8". Since the rocket engine tube O.D. is only 3/4" a spacer made from a 3-3/4" x 4-7/8" piece of file folder (tag board) is rolled around the rocket engine tube to increase its diameter and make it a sliding fit into the brass sleeve.

Make sure the brass tube ends are cut square and are beveled smoothly on the inside. Naturally, for those who have access to a metal lathe, a sleeve can be machined to an exact I.D. to accommodate the rocket engine tube without using the tag board spacer.

Funnels

A small plastic funnel is needed to neatly and easily load the clay and black powder into the rocket engine tube. Paper cone drinking cups work great as funnels too, just snip off the bottom to the correct size hole to fit the rocket tube.

A "ram-through funnel," though not absolutely necessary, is a nice addition to your rocket tooling. Since the funnel remains in place during the ramming process, you can save considerable time by not having to repeatedly insert and remove your funnel. The funnel is machined to sit snugly on top of the rocket engine tube and its throat is the same diameter as the I.D. of the rocket engine tube thus allowing the rammers to slide down through the funnel itself.

Don’t forget to mark the rammers as described earlier, taking into account the added height of the ram-through funnel if you decide to use this accessory.

Mixing the Black Powder

The formula for the black powder propellant is from the Weingart book Dictionary and Manual of Fireworks and is listed under "4 Oz. Rockets." I have converted the formula, which is in parts by weight, to percentages:

Weingart's 4 Ounce Rocket Fuel

Ingredient	Parts	Percentage
Potassium nitrate	16	55%
Airfloat charcoal	6	21%
80 Mesh charcoal	3	10%
Sulfur	4	14%

Make up a small batch of black powder formula for test purposes. Black powder core burning rockets can be pretty fussy about their exact formulation and much depends on the nature of the chemicals. Each rocket engine will require about 16 grams of black powder, so a small, 58-gram batch will allow you to make up 3 rocket engines.

An easy way to get 58 grams is to double each amount in the "parts" formula and then weigh out that amount of chemicals in grams. The total will be 58 grams. With these small amounts it is important that your scale can accurately weigh out the desired quantities.

Make sure all chemicals are free flowing, fine powder. You may need to grind the potassium nitrate if it is lumpy. After weighing out each finely powdered chemical, pass them through the 20-mesh stainless steel screen onto a clean sheet of paper.

Mix the black powder chemicals together by hand on the paper and then screen and mix two more times. At this point the black powder mix will be dusty and messy to work with. Later in this article, I'll show you how to granulate the black powder to make it more pleasant to deal with. First, however, it needs to be loaded into a rocket engine tube and fired before going to the trouble of granulating.

Charging the Rocket Engine Tube

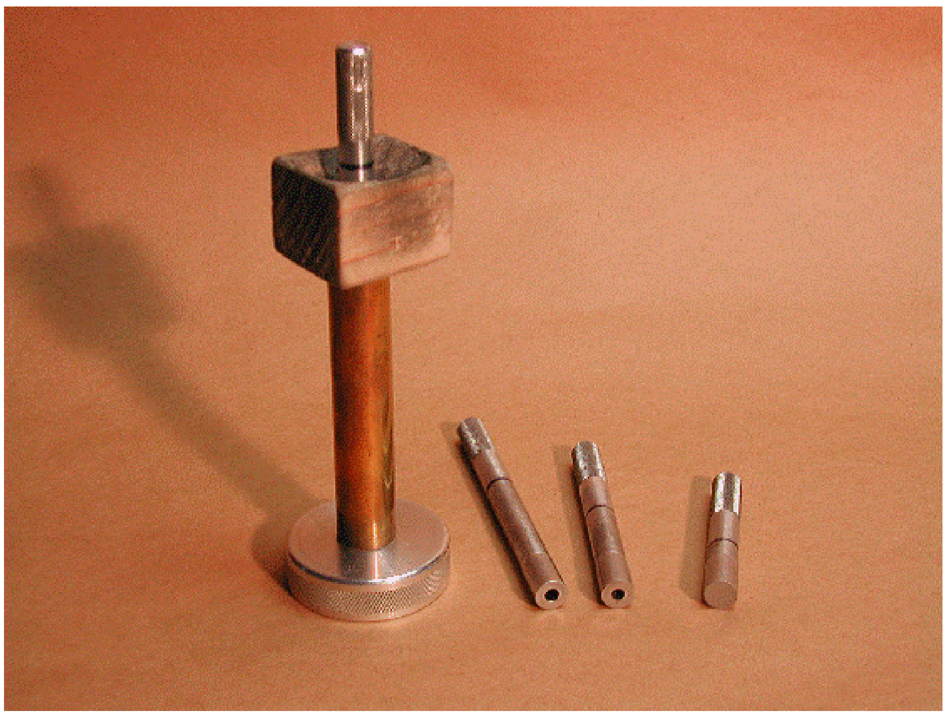
Always isolate the ramming surface from the black powder container to avoid vibration separating the composition (in effect un-mixing your black powder). Keep your container of black powder covered whenever you are not dipping into it. If you have an accidental black powder ignition while ramming, this will reduce the chances of your mixed black powder igniting as well.

Slip a rocket engine tube into the brass-ramming sleeve using the tag board wrapped around the rocket tube to take up the space and provide a nice sliding fit.

Place the rocket tube and sleeve over the ramming spindle. Look down into the rocket tube. You should clearly see the top of the metal spindle in the rocket tube. The spindle must be well centered in order for the different length rammers to slide down over it as they enter the rocket tube to ram the black powder. If it is not centered the most likely cause is that the end of the rocket tube has not been cut square. Replace the rocket tube if necessary.

Using a teaspoon-sized measuring scoop, measure out a slightly heaped amount of dry bentonite clay (4.0-4.2 grams). Use either a removable funnel or a ram-through funnel to dump the clay into the rocket tube.

Slowly slide the longest rammer down into the rocket tube. Since the clay is very fine it will tend to puff out the top if the rammer is inserted too quickly.



Ramming the Black Powder Rocket

Using only hand pressure, consolidate the clay as much as possible by slowly pushing down on the rammer, twisting it at the same time, and withdrawing it slightly several times. By withdrawing it, clay that has been forced up inside the rammer hole will be allowed to fall back down into the rocket tube.

After a while you will develop a feel for how far to withdraw it. Sometimes pulling it up only an inch or so is sufficient, and other times the rammer needs to be completely withdrawn and the excess clay knocked back into the rocket tube.

Give the rammer 10 fairly good blows with the mallet. Observe the limit mark on the rammer; it should stop about 1/2" above the top of the rocket tube. Once the rocket engines are working well, this point should be marked on the rammer to indicate the height of the rammed clay nozzle in the rocket tube.

Withdraw the rammer, and without taking the rocket tube off the spindle and base, turn the whole unit upside down and rap it on a hard surface over a piece of paper. Some loose clay will fall out of the rocket tube. Return the rocket tube and the spindle to an upright position on your ramming area.

Once again look to see if the tip of the spindle in centered in the rocket tube. If it is not and the rocket tube is cut square, the cause is due to forcing the rocket tube out of perpendicular while ramming the clay.

During ramming, always maintain the rocket tube in a vertical position with your hand. Once the clay is compacted in place, the rocket tube and spindle will maintain their relative positions, so it is important to get this right before proceeding further.

Next, scoop in slightly less than a teaspoon of black powder propellant (2.0 - 2.4 grams) and ram as before, using the same rammer.

Switching to the next rammer, ram two more increments of black powder. Again, watch your limit mark on the first increment. The limit marks on the rammers should ALWAYS be visible when ramming the rocket engine.

If the mark disappears inside the rocket tube then there is a good chance that the rammer will be driven into the spindle. The result could be a damaged rocket tool or, even worse, the accidental ignition of the black powder being rammed.

Switch to the third rammer and continue with two more increments. Since this rammer is used near the top of the spindle and the rammer is quite small, it is very easy to plug up the rammer hole. Make absolutely sure the hole is clear before ramming each increment (this is important advice on all the rammers being used).

An old drill bit can be used to clear out the hole if it should get plugged with black powder. Slowly twist the bit into the hole using just your fingers to turn the drill bit. Do NOT use a drill motor to power the bit.

At this point, depending on how much black powder was in each increment, you will be close to using the last (solid) rammer. Pay careful attention to the limit marks on this rammer so that the rammer is in no danger of striking the top of the spindle.

Ram approximately 5/8" of solid black powder above the tip of the spindle. This will leave an empty space of approximately 5/8" in the top of the rocket tube. Then ram in a teaspoon of clay to close off the rocket tube.

Removing the Rocket Engine from the Spindle

Slowly twist the ramming sleeve while holding the base with the other hand. If the sleeve (and tag board spacer) were not too tight to begin with, they should twist and slide off before the rocket engine tube will twist and release from the spindle. Remove the sleeve and set aside.

Slowly twist the rocket engine tube while holding the base. Carefully slide the rocket tube off the spindle once you feel it break free. The rocket engine tube can be stuck on the spindle quite tightly, but it should release without having to use any type of tools. (Larger rocket engines can be very difficult to remove).

Rap the released rocket engine, nozzle down, on a solid surface. There should be little or no loose powder falling out. It there is, the rocket engine may have been damaged while removing it or it may not have been rammed firmly enough. It may malfunction when lit.

Preparing the Rocket Engine for Static Testing

Attach a paper nosing to the nozzle end of the rocket engine by wrapping two turns of lightweight paper around the rocket tube. Use tape, a glue stick, or white glue to adhere the paper to the rocket tube. The paper should extend 1-3/4" past the end of the rocket tube.

Insert an 8" piece of good quality black match into the core of the rocket engine. Slide a 2-1/2" piece of paper match piping onto the match until it hits the nozzle.

Tie a clove hitch around the paper nosing to hold the black match and the piping in place.

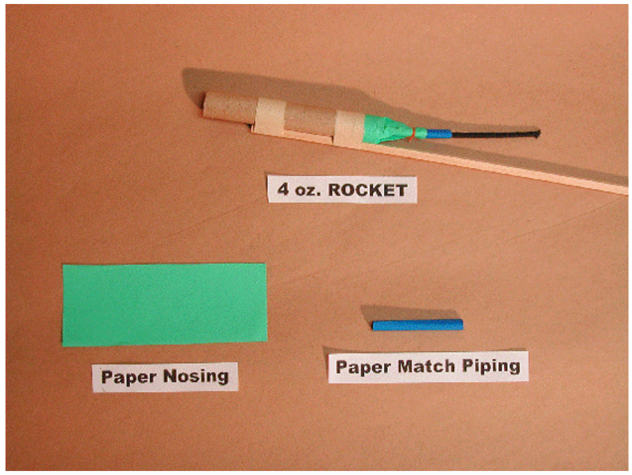
Bury the rocket engine 2/3 of its length in the ground or in sand with the nozzle/fuse end up for static testing.

Light the fuse and stand back to observe the results. The rocket engine should quickly fire up and burn smoothly and cleanly. If it does not, read the section on troubleshooting. If the rocket engine burns well, with a loud roar and does not explode, proceed to flight-testing.

Rocket Flight Testing

Load and fuse a rocket engine as described previously.

Cut a 1/4" dowel or stick to 30" and attach to the rocket engine. The dowel does not need to extend the full 5" of the rocket engine length; 3-1/2" is plenty. Two bands of masking tape are sufficient to hold the stick in place for preliminary testing. The complete rocket with stick and fusing should weight approximately 60 grams.



Black Powder Rocket Attached to Stick

Place a launch tube in the ground straight up. Slide the rocket stick down into the launch tube until the rocket engine section rests on the lip of the launch tube.

Light the fuse and stand back to observe the results. The rocket should quickly come up to full thrust and rapidly leave the launch tube. With no payload, the flight should be straight and very high. Watch for the falling rocket, as it is still aerodynamic as it comes back down and will be traveling very fast. If possible, recover the spent rocket and examine.

Troubleshooting

Problem: Rocket lights slowly, starts to take off slowly and then accelerates pretty well.

Solution: The entire surface of the internal core of black powder propellant needs to be lit instantaneously by the black match. The reason for adding a short piece of piping to the match is to get the flame to shoot into the core as fast as possible from the black match. If the core is only lit at the bottom near the nozzle by a piece of green visco fuse, for instance, the takeoff will be poor. See "Modifications and Enhancements" below for additional ways to fuse the rocket engine if good black match is not available.

Problem: Rocket nozzle blows out at or shortly after ignition.

Possible Reasons:

The clay was not rammed hard enough.

Clay was too coarse and did not consolidate well. Some people try to use kitty litter for nozzles; it is almost impossible to hand ram kitty litter into a solid enough rocket nozzle. Stick with bentonite clay.

Propellant is burning too fast. Add more charcoal to formula to reduce burn rate.

Problem: Rocket engine blows up at or shortly after ignition.

Possible Reasons:

Black powder propellant burns too fast. Add more charcoal to reduce burn rate.

Black powder propellant was not rammed hard enough.

Black powder propellant had internal cracks, from engine being dropped, or from shrinkage due to humidity change.

Charcoal was damp when it was weighed out but mix was dry when it was rammed. If the charcoal is damp when you weighed it out, you are weighing water AND charcoal. That means that the percentage of charcoal in the mix will be LESS than normal after the water evaporates. Having less charcoal in the mix will cause the mix to burn slightly faster which may be the reason the rocket engine blows up.

Problem: Rocket takes off and acceleration is sluggish.

Possible Reasons:

Black powder propellant burns too slowly. Add more potassium nitrate.

Make sure rocket engine is being lit correctly.

Problem: Rocket flight path is a corkscrew and/or is wobbly.

Possible Reasons:

Spindle is not centered on center axis of tube during ramming.

Stick is too heavy or long. Make it shorter or use lighter weight stick.

Rocket engine is mounted on stick at an angle.

Stick is too short.

Modifications and Enhancements

Both the clay and the black powder propellant can be granulated to cut down on dust when charging the rocket engine. The black powder is dampened with water until it forms a ball when squeezed. Do not over dampen.

A piece of 1/4" x 1/4" hardware screen in a frame is used as a kind of "cheese grater" to grate the ball of black powder in a thin layer over a large sheet of paper. Do not add any binder to the black powder when granulating it. The object is to make very soft, small grains of black powder that will crush down and ram easily into a solid mass.

Granulating often will cause the black powder to burn slightly faster, so don't be surprised if the rocket engine performance is a bit more energetic compared with the non-granulated black powder.

To enhance the tail of the rocket the percentage of the airfloat charcoal (AFC) can be reduced in relation to the coarser charcoal (80 mesh) to increase the hang time and length of the tail in the air. In larger rockets, 36-mesh charcoal can be tried.

The coarser charcoal will also make the mix less messy to mix and ram. Try different ratios of AFC to 80-mesh. The long tail is really the most beautiful feature of core burning rockets, and it is worth tinkering with the formula in order to enhance it.

Use the following tips to streamline the charging process so hundreds of rockets can be efficiently turned out. Remember that flights of rockets are much more impressive than singles.

Make a hold-down for the spindle and base, so the rammers can be pulled out without having to hold the base with your hand.

Machine limit-marks on the rammer shafts, as felt tip markers wear off quickly.

Make a Ram-Through Funnel

Extend the lengths and enlarge the striking end of the rammers. The rammer lengths are a bit too short in my opinion, and all should be at least an inch or two longer in order to get a better grip on them. The 1/2" diameter of this set really tears up the face of the mallet and enlarging the striking end of the rammers with a machined cap will extend and enlarge it at the same time.

This is one of my favorites: Tape your measuring scoop to the end opposite the striking face on the mallet head (see the rocket tools picture above). This really speeds up the ramming process. It avoids constantly setting the mallet down to pick up the scoop and vice versa.

Arrange the ramming area efficiently so that everything flows in a logical manner when charging the rocket engine. With all equipment set up properly a rocket engine can be turned out in five minutes or less.

Frequently Asked Questions

Q: Why don't I need to ball mill the black powder?

A: Ball milling is needed when the chemicals are obtained in a very coarse state and need to be reduced to a fine powder. Ball milling is also used when the burn rate needs to be increased above what is obtained by simply mixing the chemicals together. Chemicals bought from Skylighter should be already finely ground, and the burn rate for core burning black powder rockets is low on purpose.

Q: I don't have any good black match to light the rocket engine with; what else will work?

A: Although black match is the best, either a length of Skylighter's fast yellow visco fuse (#GN1100) or two lengths of Skylighter paper fuse (#GN1200) will work. I still like to use the paper piping and paper nosing as described for inserting the black match when using the fast visco or paper fuse. Make sure the match goes up into the hollow core as far as possible.

Q: Wooden dowels for rocket sticks are expensive; what else is good to use?

A: Cut your own sticks from straight grain pine. For this four-ounce rocket, the stick itself should weigh about 16 - 20 grams maximum.

How to Make Sugar Rocket Engines

By Matthew Carpenter

Learn how to make rockets with a very simple sugar rocket propellant. Using only sorbitol and potassium nitrate you'll be flying homemade solid fuel rocket sugar rockets in no time.

Materials Needed

- Aluminum rammer
- Bentonite clay (CH8078)
- Electric hotplate
- Metal rod, 1/8"
- Potassium nitrate (CH5300)
- Sorbitol (CH8293)
- Tubes, parallel
- Visco fuse (GN1000, GN1001, GN1004)
- Wooden stick, long

You don't need any special rocket tooling for this one. First ram a bentonite clay plug into a parallel rocket tube. Mix potassium nitrate (CH5300) and sorbitol (CH8293) powders in a ratio of 65:35 potassium nitrate to sorbitol.

Outdoors on an electric hotplate, carefully mix and melt the two together to make your rocket fuel. Do not melt these on an open flame, unless you want this to be your last project! When the rocket mix is milky, frosting-like goo, you can pour it into large diameter rocket tubes or spoon it into smaller diameter rocket tubes.

After you spoon it into the rocket tubes, wait a minute or two for the rocket fuel to cool a little. Then use an aluminum rammer to pack it into the rocket tube.

For a rocket tube with a 3/4-inch inside diameter make a core in the rocket by shoving a 1/8-inch diameter welding rod all the way down into the grain (fuel) of the rocket. Mount the rocket on a stick as usual, and then let it fly.

If you have never flown a rocket that uses a stick for a stabilizer, here's one way to do it. Firmly tape the rocket to the end of a square stick (round will work). Tape the rocket tube (nozzle down) to the rocket stick in at least two places. How long should the rocket stick be? Balance the stick with rocket attached on your index finger. The balance point should be right behind/under the rocket nozzle. Keep breaking off pieces of wood until it balances.

Insert a piece of visco fuse into the core of the rocket and attach it to the rocket stick with a little piece of tape. Shove a piece of pipe into the ground. Place the rocket and stick into the pipe. Make sure your rocket is aimed straight up, light the visco fuse, and retire quickly.

To Whistle or Not to Whistle?

Introduction

This is the first of three related projects that Ned is creating for you on how to make whistling fireworks. I want to preface them by saying one thing:

If you want to make whistles, this article can save your life!

Look, I think most of us build fireworks because we want to have fun. And whistles, when you see and hear them, are definitely awesome. But this is one area of fireworks making that, if it goes wrong, will definitely take the fun out of fireworks for you, and quite possibly for others in your life as well.

So, to anyone who has ever aspired to making a whistling rocket, or any other sort of fireworks whistle, read this fireworks-making project twice before starting.

Why You Might Not Want to Make Whistling Fireworks

Whistles are DANGEROUS. Whistle mix is highly explosive, and sensitive to just about everything you could inadvertently do: too much pressure, too much impact, or any friction, sparks or static electricity. Screw up and you'll have a catastrophic explosion that will possibly injure or even kill you.

Accidental Whistle Explosion
(photo Courtesy Jerry Durand)

Making whistles means equipment. You need a press and special tooling to start with. This can cost money and takes space. Only take this on when you're ready to make the necessary investment in the kinds of good equipment that Ned shows you how to use in this project. Believe me: you cannot cut corners when making whistles. Either you invest in the right equipment and learning, or you fail, possibly catastrophically.

Making whistle fireworks is not instant gratification. Whistle fuel takes time to make. You have to be extraordinarily careful, and you cannot rush it.

Why You Would Want to Learn to Make Whistles

Making a big whistling firework and using it in a fireworks display is a guaranteed crowd pleaser. It is something most of them will never have seen and heard before. This is a firework the big boys make and that audiences just love.

The satisfaction you can get from adding whistles to your aerial shells, or launching your first whistle and strobe rocket, is mind altering. It will pump you up like few other fireworks can.

Within this and the next two projects, you have what I consider to be the best tutorials ever written on making whistles and whistling fireworks (rockets, fountains, and so on). That means, that if you follow Ned's instructions closely, you can pretty much be guaranteed of successfully making just about any kind of whistling firework you can imagine. It's an opportunity to learn something that only pyrotechnic experts know how to do. And to do it well.

--Harry Gilliam

How to Make a Whistle

By Ned Gorski

What are Fireworks Whistles?

Often when making fireworks we focus on visual effects. But our ears can detect a lot of other effects that are going on. The special sound of a charcoal, core-burning rocket as it quickly "Whooshes" out of the launch tube is quite different than the slow "Shhhhhhhh" as an end-burner launches, and I enjoy the sound of them both.

For the Pyrotechnics Guild International's convention I have made girandolas containing multitudes of these core-burning motors, and I eagerly look forward to hearing them as they rise skyward. It's a bit like a jet engine taking off.

For a different sound, I have some girandolas, which have whistle motors on them, and I also have some of these whistlers on my competition Chromatrope wheel. Whistles add one more auditory dimension to fireworks effects, and while Saturn Missiles can wear thin on me after a while, I do enjoy a whistling effect occasionally.

Horizontal Wheel Driven by Two Whistles, Half Plain Whistle Composition, Half with Titanium Added

(Click Image to Play Video)

So what, then, is a whistle? For the purposes of this article it is a pyrotechnic device designed to produce a shrill audible effect. But there are whistles and there are whistles. There are two primary types, and you need to know the difference before you make them, so that you can pick the correct tooling.

There are whistles designed to generate powerful thrust in order to fly, and whistles, which have lower thrust. Whistles with high thrust are normally used as whistle rockets. Low-thrust (or simple) whistles are used to add a sound effect to a firework device and/or as drivers to turn wheels. Both types emit showers of sparks.

Note: To make any kind of whistle, you must use a press (either hydraulic or arbor) and tooling that is specially designed to make whistles. The important thing to remember is that you use different types of tools for different kinds of whistles. Simply put, there is whistle rocket tooling, and there is simple whistle tooling. Be sure you have the correct tooling before you start.

Warning: Attempting to make whistles without the proper tooling can be fatal. Whistle composition is highly impact and friction-sensitive, and is a very powerful explosive.

Whistle rockets have a sound all their own, and can be flown with only the whistle engine, or with other pyrotechnic effects, such as strobes, shells, or salutes.

A simple row of stand-alone whistles, mounted like fountains on the ground, will certainly grab an audience's attention during a fireworks display.

Whistles can also be loaded into an aerial shell, such as a color-whistle-and-report shell. When the whistles have a bit of titanium in them, they make wonderful silver-tailed whistling inserts. If they are used as shell inserts, only the amount of fuel that will burn for 4-5 seconds is pressed in them so that they don't burn all the way to the ground.

Whistles can also be mounted on the exterior of an aerial fireworks shell, ignited when the shell is launched out of the mortar, and serving as a whistling rising-effect as the shell rises skyward.

Making whistle fuel and pressing simple whistles are two of the first steps to making whistle rockets and strobe rockets, which I'll be exploring in follow-up articles. That means the skills I'm about to describe are building blocks for further, more advanced projects.

What Makes a Fireworks Whistle Whistle?

Honestly, the precise answer to that is a bit beyond the scope of my expertise. Rather than it being a result of gasses passing through a tube and across an opening, as in a musical instrument or a simple "coach's whistle," pyrotechnic whistles produce their sound through a rapid, oscillating burning, which produces the sound.

There, that's as much as I know about that. But I do know that if I follow the next procedures, I'll end up with a device that whistles.

How to Make Whistle Mix

Warning: Whistle fuel is powerfully explosive stuff, roughly equivalent in power to that of flash powder. Much care must be exercised when making and using it. You'll notice that in the method I'm about to describe, the fuel is never mixed in a dry state. Some parts of it are mixed together; then that mixture is dampened with a wet solution. Only then is the remaining dry ingredient added. This greatly reduces the risk of unwanted ignition due to static or friction.

Fireworks Tips #45 contains Dan McMurray's article, "Whistle Rocket Fuel in Under 8 Hours." I have always made my whistle fuel based on the recommendations in that essay, but have slightly modified it for my purposes. I'd recommend that readers familiarize themselves with that method before proceeding.

Especially, please study all the safety recommendations contained in Dan's article. I'm not going to repeat them all here. I strongly suggest that you familiarize yourself with them before proceeding with the following steps.

Making whistles is very similar to making gerbs, and I'd recommend a familiarization with that process, as well.

I'm about to make whistles using a common formula, which contains sodium salicylate as the fuel and red iron oxide as the catalyst. There are other fuels such as sodium benzoate and potassium benzoate, which can be used to make whistles. The list of alternative catalysts is almost endless.

My friend, Danny Creagan, has done extensive research using these alternative fuels and catalysts, and has tabulated his results, and you can see his whistle mix data here.

I highly recommend a look at this information for anyone interested in achieving different power or sound with their whistles by varying the fuel and/or catalyst in the mixture. I suggest you pay particular attention to the video of the whistle composition explosion there.

The first thing I do when making whistle fuel is get a large stainless steel pot of water boiling. This pot of hot water will be used to dry the whistle mix. I never get whistle mix anywhere near the burner that I use to heat the water.

Boiling Water for Drying Whistle Fuel

I use a slightly modified version of Dan's formula for whistle mix. This formula is slightly less energetic, and mineral oil is used instead of Vaseline.

Whistle Mix Fuel

Chemical	%	64 Ounce Batch	1800 Grams
Potassium perchlorate	0.66	42.25 ounces	1188 grams
Sodium salicylate	0.29	18.55 ounces	522 grams
Red iron oxide	0.01	0.65 ounces	18 grams
Mineral oil	0.04	2.55 ounces	72 grams
Total	1.00	64 ounces	1800 grams

Note: I use the mineral oil instead of Dan Murray's Vaseline, because it does not have to be melted before mixing it with the Coleman fuel. I use this slightly "toned-down" formula because I find it to be a little more forgiving, resulting in fewer "CATO's" (blown up devices).

The potassium perchlorate is a very fine powder, capable of falling easily through a 100-mesh screen. Screening it through a 40-mesh screen breaks up any clumps in it.

The sodium salicylate and iron oxide are mixed together by screening through a 20-mesh, kitchen colander screen. Be sure and use the 20-mesh screen; the sodium salicylate will not pass through a finer mesh screen. These two mixed chemicals are placed in a stainless steel pot, which is a bit smaller than the one that contains the hot water.

The mineral oil is placed in a one-quart jar, like a clean spaghetti sauce jar, and the jar is filled the rest of the way with Coleman camping fuel. VM&P naphtha, which is available in the paint department of Home Depot, may also be used, as described in Dan's article.

I get my Coleman fuel in the camping department of my local sporting goods store. The mineral oil can be found in the health-and-beauty section of a grocery store or pharmacy. The oil's label indicates it can be used as a "lubricant or laxative."

Coleman Fuel and Mineral Oil Used to Make Whistle Mix

I shake the fluid mixture a bit after putting the lid on the jar, and then the liquid is added to the sodium salicylate/iron oxide mixture. That composition is then stirred with gloved hands until it is a thoroughly dampened, homogenous mixture. I add just enough Coleman fuel so that the mixture is about the consistency of spaghetti sauce.

The screened potassium perchlorate is then added to the dampened mixture and more kneading is done until I have a thoroughly mixed, red composition. More Coleman fuel may be added as necessary in order to produce a putty-like consistency, similar to soft bread dough.

All of this has been done in the smaller stainless steel pot, and that pot is now placed in the larger pot of hot water, after the burner has been turned off and the pot of hot water has been relocated to an area away from the burner. I absolutely never want to get the whistle fuel anywhere in the vicinity of an open flame.

Every step of this procedure is carried on outdoors, of course.

Pot Containing Whistle Mix Drying in Hot-Water Bath

Every hour or so, as the fuel is drying, I stir the whistle composition with gloved hands to break it up and stir it around so that it dries throughout. Then after a few hours when it is almost completely dry, I screen the mixture through a 12-mesh kitchen colander, carefully pushing it through with my gloved hands.

I put it back in the pot to complete the drying, and then pour it out onto kraft-paper lined trays for additional drying overnight.

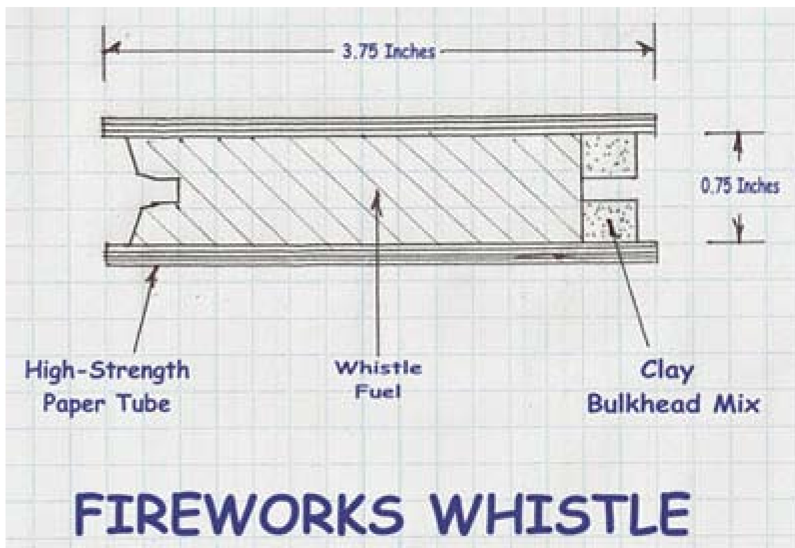
Screened Whistle Mix Drying on Kraft-Paper Lined Tray

Sodium salicylate, like most sodium compounds, is very hygroscopic--it will absorb moisture out of the air. Because of that, I store my dry fuel in a tightly sealed bucket with a bag of desiccant in with it to keep it dry.

The whistle mix shown above is a bit desensitized by the oil in it, but it is still a powerful explosive and those of us who work with it treat it with a large amount of respect.

Pressing a Fireworks Whistle

On my wheels and girandolas I like to use whistles pressed into 3/4-inch ID parallel tubes, 3.75-inches long. These little devices make quite a racket and will burn for up to 15 seconds, depending on how much composition is pressed into the tube.



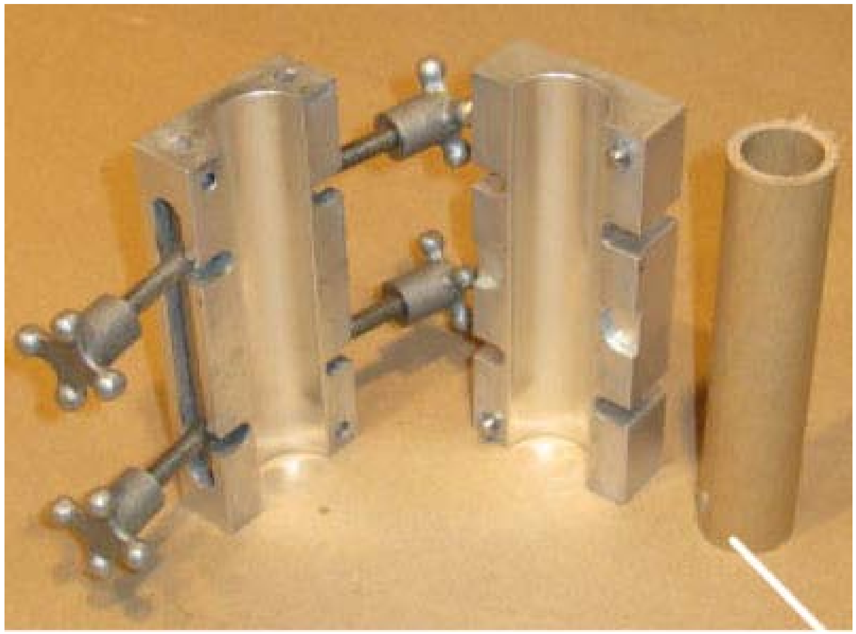
Cross-Section of a Fireworks Whistle

You'll notice I said, "pressed." Whistle mix is never rammed (pounded by hand with a mallet). It is shock sensitive and is liable to explode if rammed. Pressing whistles with a hydraulic press is much safer, but I still employ a safety shield on my homemade press.

Because of the high pressures necessary to consolidate whistle fuel, I use only Skylighter's TU1066 extra-strong-wall paper tubes. The inner layers of paper of a standard tube would crush outwards under the force necessary to press whistles. I cut these tubes to length, and use Skylighter's TL1270 Whistle Tooling.

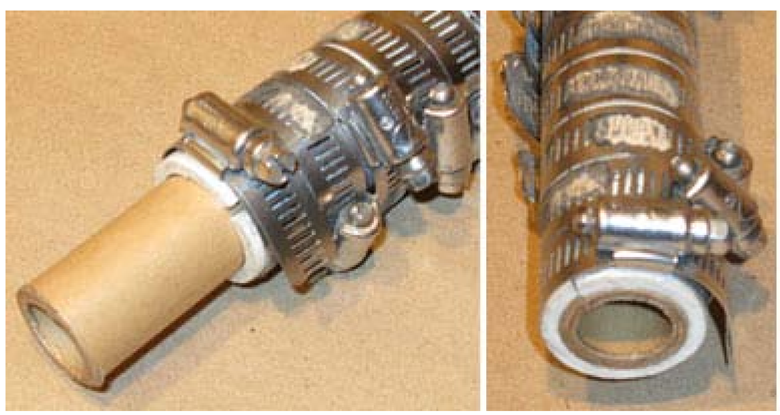
Some kind of tube support must be used to reinforce paper tubes during the pressing operation. Otherwise the tube would burst under the pressure while the fuel is being pressed. Several types are shown below.

For instance, I use an aluminum "clamshell" support like this one.



Clamshell Support for Pressing Whistle in Paper Tubes

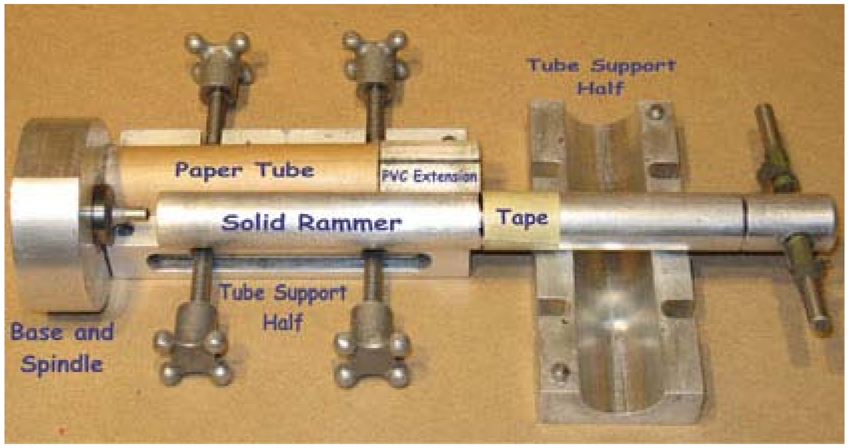
But a piece of 1-inch ID PVC pipe can also be used as a tube support. The pipe is split lengthwise with a hacksaw, and enough of a lengthwise slice of the pipe is removed to allow it to fit snugly on the paper tube. Metal band clamps are installed, side-by-side, on the support and tightened to create a very sturdy tube support.



Tube Support Made from PVC Pipe and Band-Clamps

A friend of mine, Dan T, uses double-walled PVC pipe tube supports. In this case a 1.25-inch ID piece of pipe would be split to fit snugly on the piece of 1-inch ID pipe, and then the clamps installed. This would create an extremely sturdy support.

Next, I carefully lay out my tooling and put a piece of masking tape on my drift so that it never comes into contact with the spindle, which could pinch whistle composition between the two and cause it to ignite.



Preparing Tooling to Make Whistles

The white PVC pipe tube-extension shown in the photo above is used to temporarily increase the length of the paper tube, which makes it easier to introduce and press the final fuel increments and the clay bulkhead, as described below.

I only use the solid rammer, which came with my whistle tooling. But, I am extremely careful to avoid any contact between it and the tip of the spindle, as I mentioned above. I can't overemphasize that point. Notice the 1/8-inch gap between the tip of the spindle and the end of the rammer in the photo above. The location of the tape ensures the rammer never gets any closer to the spindle than that 1/8-inch margin of safety.

Whistles and whistle rockets do not use a clay nozzle, as black powder rockets do. Whistle fuel burns so quickly that a clay nozzle would over-pressurize the tube and cause the device to explode.

The first thing I do prior to pressing any fuel is weigh out abut 2 ounces of the whistle mixture in a paper cup to work out of. I then tightly seal my larger container of whistle fuel and set it in a safe place, away from my immediate work area to minimize exposure of whistle composition during the pressing. This reduces the amount of explosive material near me in the event of an accidental ignition of any kind. This is the best way to avoid a serious accident.

I introduce a heaping tablespoonful (15 grams) of the whistle fuel into the tube through a funnel, and press it to 7500 psi (on the composition--2200 psi on my press's gauge. To understand the difference, see below). All the while I keep an eye on the masking tape marker to make sure the drift does not press into the tube so far that it would hit the spindle. If necessary I add a bit more fuel to this first increment before pressing it to the full pressure, to ensure that the drift never gets closer than 1/8-inch to the spindle.

Note when pressing this first increment of fuel: It's a larger quantity than the following ones, so that it can completely cover the spindle. But with this much fuel, the drift can get jammed in the motor, which is caused by too much fuel powder wedging itself between the drift and the tube wall. To prevent this, first press up to about 1000 psi on the gauge on the press. Then, remove the drift, and then reinsert it. Finish this first increment by pressing the rest of the way up to the 2200 press-gauge psi.

Note: Before pressing, you need to know something: the psi showing on the gauge is not the same as the actual psi being applied to the material in the tube. Without boring you with the reason for this seemingly nonsensical fact, here's what you have to do to convert the gauge reading to the actual 7500-psi (pounds per square inch) I want on my fuel.

The end of my drift is 0.75-inch in diameter, so it has a radius of half the diameter, 0.375-inch. The area of the end of the drift is determined with the formula: Pi (3.1416) x radius^2, or 3.1416 x 0.375 x 0.375 = 0.44 square inch.

There is a number of pounds of force, X, that I need to apply to that 0.44 square inch of area to achieve 7500 pounds per square inch. X divided by 0.44 square inches = 7500 psi. Multiplying both sides by 0.44 solves for X, and X = 3300 pounds of force. If I put 3300 pounds on 0.44 square inches, I achieve 7500 pounds-per-square-inch pressure.

As I stated in the article about building my press, the reading on its gauge must be multiplied by 1.5 to determine the actual number of pounds of force it is exerting. Dividing my desired 3300 pounds by 1.5 yields the reading I want on the press's gauge when pressing these whistles, or 2200 psi on the gauge.

So, I simply press each increment of whistle fuel to this 2200 psi reading on the press's gauge to achieve the actual 7500-psi pressure on the fuel grain.

Note: All of this ciphering is something that can sound a bit like "Greek to me" until one does it a few times and gets the gut feeling for what is being determined by the calculations. Don't be put off by it. You'll get it if you haven't already.

After the initial fuel increment is pressed, further increments of flat 1/2-tablespoonfuls (6 grams) are pressed until there is about 3/4-inch of empty space left in the tube. This takes a total of about 1.8 ounces (52 grams) of composition. I then press a bulkhead of 1/2 tablespoonful (8 grams) of bulkhead clay to finish the whistle. Except for the first one, each fuel increment and the clay bulkhead end up being about 3/8-inch thick (half a tube ID) after pressing.

Pressing a Whistle Using Hydraulic Press
(photo taken without safety shield installed, for clarity)

Sometimes I want titanium sparks in the spray from a whistle. If that's the case, I'll press the initial 15-gram increment without titanium in it to reduce the chance of sparks or damage to the tooling. I don't want that hard metal being pressed against my steel spindle.

Then I mix 4 grams of spherical titanium into 35 grams of the whistle fuel, simply swirling the metal and fuel together in a paper cup, and press the remaining increments of fuel.

If I am going to hand-twist-drill through the bulkhead to create a passfire, as when a whistle driver is to pass fire to another driver, I'll finish the pressing of the whistle mix with some whistle composition which has no titanium in it. I don't want to hit titanium with the hand-twisted drill bit when drilling the passfire hole.

Even hand-twist-drilling into whistle composition is not something to be taken lightly; it is something that should be done lightly and slowly with the utmost care.

Thrust End of Completed Pyrotechnic Whistle

Whistles take fire very easily, and do not require any priming. Nosing with kraft paper and fusing with visco fuse or quick match gets the whistle ready to perform its duties.

Horizontal Whistle Driver Mounted on a Girandola

Results

Here is a video of a whistle which had only plain fuel pressed in it. It burned for almost exactly 15 seconds.

Whistle with Plain Fuel
(Click Image to Play Video)

And, here's a video of a stationary whistle that had fine spherical titanium in all but the first 15 grams of the fuel.

Whistle with Titanium Fuel

(Click Image to Play Video)

Finally, here's a video of a 24-inch diameter girandola I flew at the 2007 PGI convention, which uses whistle drivers. Thanks to Steve Majdali for the video.

24 Inch Girandola at PGI 2007

(Click Image to Play Video)

Whistle Rocket Fuel in Under 8 Hours

By Dan MacMurray

Materials Needed

- Ball mill
- Container, 500 to 1500 milliliter
- Iron oxide (CH8166, CH8168)
- Mixing bowls (2 plastic, one stainless steel)
- Naphtha
- Pans, one large and small
- Potassium perchlorate (CH5400, CH5402)
- Scale
- Screen, 20-mesh (TL2002)
- Screen, 40-mesh (TL2004)
- Sodium salicylate (CH8284, CH8285)
- Vaseline

If you want to make whistle rockets or whistle and strobe rocket combinations, the most tedious part of the whole process is making the whistle mix. Dan McMurray has provided an excellent article on how you can cut the time it takes to make up a batch of whistle, and improve the quality of the whistle rocket fuel as well. Thank you, Dan.

The Process

To improve fuel quality and decrease preparation time, this recipe uses naphtha, (for example, VM&P naphtha, camping fuel, or mineral spirits) as the Vaseline solvent instead of acetone or toluene. The naphtha solvent minimizes moisture accumulation while drying and eliminates the need to crush and/or screen the dried whistle rocket fuel (see Solvent Comments below). Using VM&P (Varnish Makers and Painters) naphtha and drying over hot water, about 4 kilograms (around 10 pounds) of fuel can be prepared and ready for use in 3 to 4 hours.

Equipment List

Safety glasses

Chemical gloves, (for example, Playtex, vinyl, PVC, or other types) suitable for handling naphtha solvent. Thin latex gloves are not suitable - they will dissolve. Heavy-duty chemical gloves are too big and bulky to fit in the bowl. The best gloves I have found are the disposable vinyl gloves sold by Home Depot.

Breathing respirator suitable for working with organic paint solvents

Scale suitable for weighing chemicals

Two sieves (one 20-mesh and one 40-mesh).

Three mixing bowls, each of which is large enough to hold the completed mixture, with half the bowl space remaining. One of the mixing bowls should be made of stainless steel to withstand naphtha solvent and heat. The other mixing bowls must be made of plastic.

An 8-quart stainless steel mixing bowl ideal for this purpose is made by Metro (Item No. 0065) and available at Wal-Mart for about $5.00. This bowl is large enough to make a 4 kg (about 10 pound) batch of whistle rocket fuel. A 4-bowl set of covered plastic mixing bowls is made by Sterilite (No. 0747) and available at Wal-Mart for about $3.00. Only the 2 largest bowls are needed.

A 500 to 1500 milliliter glass, plastic, or metal container (e.g., a Pyrex beaker, 1-quart Mason jar) for melting the Vaseline and mixing the Vaseline with naphtha solvent.

Small pan suitable for heating about 2 quarts of water to melt the Vaseline

Optional: Ball mill with two containers and two sets of media: one for fuel/catalyst and one for oxidizer.

Optional: A large pan suitable for heating enough water to "float" the stainless mixing bowl, but small enough to keep the bowl from turning over.

A good combination of stainless mixing bowl and large pan can be purchased from Wal-Mart. The stainless mixing bowl is an 8-quart bowl made by Metro (Item No. 0065). The pan is a 16-quart covered Teflon coated aluminum saucepot made by Mirro (Mfg. No. 34018). The total cost of the bowl and pot is around $30.00. If you look a bit, less expensive 16-quart saucepots are available.

Ingredients for 76/23/1+3 Sodium Salicylate Whistle Rocket Fuel

Ingredient	Small Batch (1/4 lb.)	Large Batch (10 lbs.)
Potassium perchlorate powder (oxidizer)	76 grams	3040 grams
Sodium salicylate powder (fuel)	23 grams	920 grams
Iron oxide (catalyst)	1 grams	40 grams
Vaseline (stabilizer)	3 grams	120 grams
Naphtha (Vaseline solvent)	25 milliliters	1000 milliliters

Solvent comments: Unlike acetone or toluene, naphtha, (for example, VM&P naphtha, camping fuel, or mineral spirits) is an excellent Vaseline solvent and a poor sodium salicylate solvent. Naphtha evaporates without attracting moisture and hard whistle rocket fuel clumps do not form when the solvent evaporates.

Chemically, acetone and toluene are classified as "polar solvents." Both are very flammable, evaporate rapidly, and are hard on the respiratory system. Acetone mixes well with water. Toluene mixes with water, but not well.

Sodium salicylate is classified as a "polar reactant." Acetone and toluene are sodium salicylate solvents; thus, hard clumps of sodium salicylate form when the solvent evaporates.

Potassium perchlorate and iron oxide are not soluble in acetone, toluene, VM&P naphtha, camping fuel, or mineral spirits.

Vaseline, (for example, petroleum jelly) is classified as a "non-polar reactant." Acetone and toluene are poor Vaseline solvents.

VM&P naphtha, camping fuel, and mineral spirits are all classified as "non-polar solvents." All are excellent Vaseline solvents and poor sodium salicylate solvents. All are easy on the respiratory system. None of these solvents mix with water. All work well in this recipe.

Camping fuel is inexpensive, readily available and very flammable. Mineral spirits and VM&P naphtha are readily available and less flammable than camping fuel, acetone, or toluene. Mineral spirits, and VM&P naphtha are more expensive than camping fuel, but less expensive than acetone or toluene.

VM&P naphtha and mineral spirits can be found in the paint section at Home Depot and most hardware stores. Camping fuel for portable stoves and lanterns can be found in the sporting goods section of most discount stores like Wal-Mart or K-Mart.

VM&P naphtha evaporates faster than camping fuel. Mineral spirits evaporates slower than camping fuel. When stirred every 15 to 20 minutes over a pan of hot water, VM&P naphtha evaporates in 2 to 3 hours. Camping fuel takes a full 8 hours to evaporate and mineral spirits take even longer.

Recipe

Using the scale, weigh out the sodium salicylate and iron oxide into the stainless mixing bowl. Using the scale, weigh out the potassium perchlorate into a separate plastic mixing bowl.

Using the scale, weigh out the required amount of Vaseline into the melting container.

WARNING: While dry, potassium perchlorate must not be mixed with, screened with, or ball milled with sodium salicylate. The dry mixture of potassium perchlorate and sodium salicylate is very static, shock, and friction sensitive. THE DRY MIXTURE IS EXPLOSIVE!!

Optional: To increase burning speed, both the sodium salicylate & iron oxide mixture and the potassium perchlorate may be ball milled, but not together. In both cases, 8 hours of ball milling should be long enough. While being ball milled, the sodium salicylate & iron oxide mixture may have to be broken-up periodically because it has a tendency to stick to the sides of the ball mill.

WARNING: The sodium salicylate & iron oxide mixture (i.e., fuel & catalyst) must be ball milled in a different container with different media from the container and media used to ball mill the potassium perchlorate, (for example, oxidizer).

Fill the small pan with enough water to almost "float" the Vaseline melting container. Place the container of Vaseline into the water. Heat the pan, water, and Vaseline melting container until the Vaseline is completely melted.

If the optional large pan of hot water will be used to dry the final mixture, the large pan of water should be put on to heat at this time.

FOR THE REMAINING STEPS, WEAR SAFETY GLASSES, CHEMICAL GLOVES, AND A BREATHING RESPIRATOR SUITABLE FOR WORKING WITH ORGANIC PAINT SOLVENTS. REMOVE ALL HAND JEWELRY, WATCHES, AND BELT BUCKLES. OTHER THAN THE STAINLESS STEEL MIXING BOWL AND WATER POT, MAKE SURE THERE ARE NO METAL OBJECTS IN THE WORK AREA.

WARNING: GO OUT OF DOORS!!! DO NOT PERFORM THE FOLLOWING STEPS INSIDE!!! STAY AWAY FROM OPEN FLAMES, SPARKS, OR OTHER POSSIBLE IGNITION SOURCES!!! NAPHTHA IS FLAMMABLE.

WARNING: DO NOT PERFORM THE FOLLOWING STEPS IN DIRECT SUNLIGHT!!! THE STAINLESS STEEL MIXING BOWL CAN FOCUS THE SUNLIGHT AND IGNITE THE MIXTURE.

Using a clean plastic mixing bowl, screen the sodium salicylate & iron oxide mixture through the 20-mesh sieve. Place the screened result back into the stainless mixing bowl. Using a clean plastic mixing bowl, screen the potassium perchlorate through the 40-mesh sieve. Place the screened result into a plastic mixing bowl.

If the Vaseline melting container is made of glass, make sure the Vaseline melting container is cool enough to keep from breaking when cold naphtha is added.

Measure and pour about half of the required amount of naphtha into the container with the melted Vaseline. Shake and/or stir until the naphtha and Vaseline are thoroughly mixed.

Pour the naphtha & Vaseline mixture into the stainless mixing bowl with the sodium salicylate & iron oxide. Pour the rest of the required amount of naphtha into the Vaseline melting container, swirl it around to rinse off the Vaseline residue, and add the rinse to the mix.

Using one gloved hand only, distribute the naphtha & Vaseline mixture throughout the sodium salicylate & iron oxide. Scoop up the mixture, a hand full at a time, and squeeze it through your fingers until no dry powder is present in the bowl. Continue until the mixture looks like smooth tomato soup - no lumps.

Using your clean-gloved hand, pour all of the potassium perchlorate into the stainless mixing bowl.

NOTE: Adding naphtha & Vaseline to the sodium salicylate & iron oxide before adding the potassium perchlorate "wets" and stabilizes the mixture, making it much safer to handle.

Using both gloved hands, combine the ingredients. Scoop up hands full of the mixture and squeeze it through your fingers until the ingredients are completely mixed. This step typically takes 5 minutes - and I do mean a full 5 minutes. The resulting wet mixture should be smooth and a uniform dark red color.

Using both gloved hands, clean as much of the mixture as possible off of your gloves into the bowl. Your gloves may be removed at this time and placed to the side to dry. When dry, any fuel remaining on your gloves may be easily removed.

Using a soft plastic spatula, scrape the sides and bottom of the bowl, stir the mixture, and re-spread the mixture on the sides of the bowl. Repeat every 15 to 20 minutes until the mixture is dry and powdered.

Optional: To reduce drying time (especially during cold weather), fill the large pan with enough water to "float" the stainless mixing bowl, bring the water to a boil, remove the pan of boiling water from the heat, and take it outside. Float the bowl of wet mixture in the pan of hot water.

Using a soft plastic spatula, scrape the sides and bottom of the bowl, stir the mixture, and re-spread the mixture on the sides of the bowl. Repeat periodically for the next 2 to 3 hours. The more often the wet mixture is scraped, stirred, and re-spread on the heated sides of the bowl, the faster it dries.

During cold weather, insulate the outside of the pan to keep the water from cooling before the naphtha evaporates. As a rule, when the water is cold, the mixture is dry and powdered.

When completely dry, the properly combined mixture is soft, fluffy, and powdered. Any lumps are soft and crumble easily between the soft spatula and the side of the bowl. The dry, properly combined mixture should not need to be screened.

If required, carefully screen the mixture through the 20-mesh sieve using a soft plastic spatula.

Inspect the powder for white granules among the red. The presence of white granules indicates that the ingredients were not properly mixed. The correction is to thoroughly "wet" the mixture with naphtha and repeat the process.

When complete, properly store the resulting powder.

WARNING: At this point, the mixture is still static, shock, and friction sensitive (although the Vaseline has stabilized and desensitize the mix).

HANDLE AND STORE WHISTLE ROCKET FUEL, AS YOU WOULD FLASH!

This article is a vehicle for exchanging information in the pyrotechnics craft. Readers are urged to learn and obey all laws and regulations of all federal, state and local jurisdictions and their agencies and representatives. Some information herein may contain incomplete descriptions of fireworks techniques based on the experience of its author(s) in a controlled environment with circumstances and conditions different from a reader's.

Readers must form their own opinion as to the application of this information. This information is considered documentary in nature and no opinion is given as to its suitability or use. No warranties are made either expressed or implied, including but not limited to warranties of the accuracy of the information herein.

How to Make Fireworks Whistle Rockets

By Ned Gorski

What is a Whistle Rocket?

I think a really impressive fireworks device speaks for itself, so here's a video of one of these whistling firework rockets in action.

One-Pound Whistle Rocket
(Click Image to Play Video )

A whistle rocket does just that: whistles and screeches as it leaps skyward. The motor uses the same whistle fuel that was used in the "How to make a whistle" article. Whistling rockets are "hot." They leap off the launch pad and can really reach a seriously high altitude if they're made well.

I've made whistle rockets in sizes from 1/4-inch ID super-bottle-rockets up to 1.5-inch-ID "six-pounders."

I've lifted some big ball shells (called "headings" when they're carried by rockets) with the larger whistle rockets. But, often they fly so high that the effect of such a heading is lost. For that reason I prefer to simply put a large report heading on them with some coarse titanium in it for impressive silver sparks when the header explodes.

Other variations in construction can include various "delay" effects during the coasting portion of the flight following the initial powerful thrust portion--from simply allowing the rocket to continue whistling across the sky, to having the whistle change to a brilliant red flare or a color changing one, before the heading finishes the rocket's flight.

Be aware, though, that whistle rockets are not your "father's black-powder rockets." The rocket fuel used in these babies is powerful. If the rocket engines are not dialed in carefully and fused properly, very impressive CATO's ("bombs on a stick") can result.

Warning: Do not EVER hand-ram whistle rockets using a mallet. The fuel is sensitive and could be set off in that process. Whistle rockets must be pressed using a manual arbor press for small rockets or a hydraulic press for larger motors, which require more pressure. It is wise to use a safety shield on a press just in case something goes wrong and the motor ignites during construction.

Hydraulic Rocket-Press with Safety Shield

Whistle Rocket Fuel

I'll be using the same fuel that I specified in the article on making whistles. The alternative fuels I mentioned in that essay can be used to make whistle rocket motors. But there will be the requisite "dialing in" in order to maximize performance and consistency with those variations.

Whistle-Rocket Fuel on Paper Lined Tray

So, study that article and make some of that whistle fuel, observing all the pertinent safety precautions.

Whistle Rocket Tooling

I will be making one-pound, 3/4-inch ID, whistle rocket motors for this project. Skylighter carries TL1311 tooling used to make these engines.

Whistle Rocket Tooling

This tooling set comes with a base, a spindle, a hollow rammer for pressing the fuel increments around that spindle, and a solid rammer with which to press the increments of fuel above the spindle.

Note: You may notice the tooling I'm using in this project, which I've had for years, is different than the Skylighter tooling. But, my spindle is about the same size and the motor construction and performance are very similar.

Whistle Rocket Motor Tubes

Because of the high pressure at which the fuel is pressed in these motors, and the thrust they develop during flight, high-strength paper tubes must be used in their construction.

Skylighter TU1066 3/4-inch ID, 1/8-inch wall, extra-strong tubes are an excellent choice for these whistle rocket motors. I cut the 30-inch long tubes into 4.75-inch long tubes for these engines.

Cutting Tubes for Whistle Rocket Motors

The Tube Support

Because of the high pressure used to press these motors, the tubes would bend, split, and collapse if they were made using no tube support. A good support is absolutely essential when making these motors.

A 4.75-inch piece of 1-inch ID, PVC plumbing pipe serves well as a tube support. It is sliced lengthwise with a hacksaw to ensure that it will go around the paper tube and fit snugly when the slice is closed. The support is held tight with metal band-clamps, installed side-by side, and tightened with their screw-adjusters alternated around the circumference of the support.

PVC-Pipe Support for Whistle-Rocket Paper Motor-Tube

Polishing the Tooling

Unlike the fuels for charcoal tailed rockets, whistle rocket fuel tends to be "sticky." The high pressures used to press the fuel around the spindle cause the fuel to adhere to it. This makes the motor hard to remove from the spindle once the engine is pressed. And the sodium salicylate fuel I prefer is reportedly stickier than fuels made with potassium benzoate or sodium benzoate.

Here is a solution, though, regularly touted by master-rocketeer Steve LaDuke. Polish your tooling, especially the spindle, using very fine, 600-grit sandpaper and a good metal polish. I got an excellent polish, Mothers Billet Metal Polish, at my local auto-parts store.

Polish Whistle-Rocket Tooling with Fine Sandpaper and Metal Polish

First, if I have any scratches or small imperfections on the spindle, I remove them using a small piece of the sandpaper to smooth the tooling. Sanding in a lengthwise direction on the spindle ensures any remaining scratches run in that direction, rather than in a circumferential pattern, which would make the motor-removal more difficult.

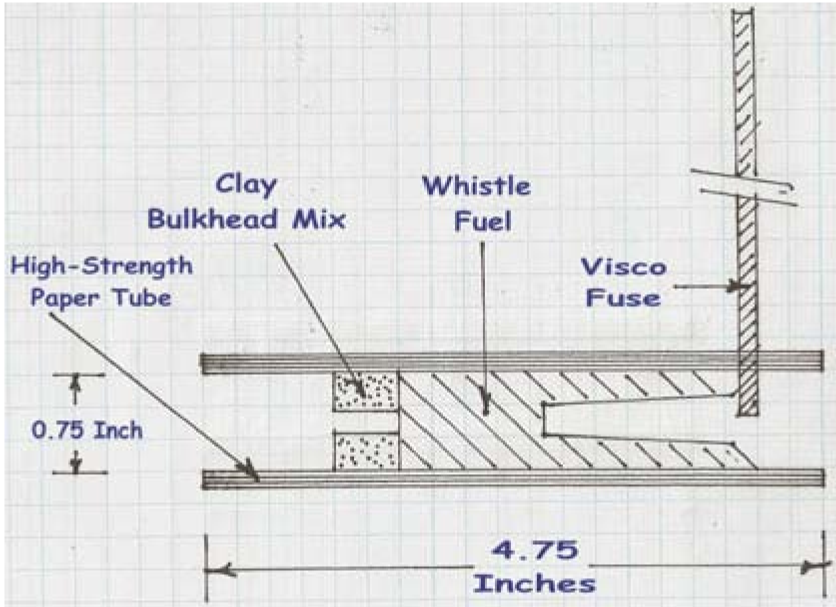
Then, using a small section of soft rag, the tooling, including the rammers, is polished until it all has a mirror-smooth finish. This really enhances the ease of use of the rammers, and the finished rocket motor's ability to be removed from the spindle.

I even do the best I can to polish up inside the hole inside the hollow drift ("drift" is another word for "rammer"). This will help release any fuel which gets between that hollow part and the spindle during pressing.

Polishing the tooling this way is time well spent. It will help avoid a lot of aggravation in the next steps of pressing the motor and removing it from the spindle when it's done.

Pressing a Whistle-Rocket Motor

Besides being pressed in a longer tube, and on a longer spindle, a whistle-rocket motor is not much different than a regular whistle. But I do fuse whistle rocket motors differently than I fuse standard whistles.



Fireworks Whistle-Rocket Motor Cross-Section

Drilling the Fuse Hole

You'll note that the fusing technique shown in the diagram is different than most rocket fusing. There is a method to my madness.

The first thing you might notice is there is no clay nozzle in whistle rocket motors. A whistle rocket needs to have the bottom of its motor tube wide open. So the fuel has to be ignited right at its bottom edge, or else there's a good chance the motor will blow up due to over-pressurization after ignition.

It can be a challenge to install a fuse from the bottom of the motor, only touching the edge of the fuel-grain, with no nosing to hold it in place.

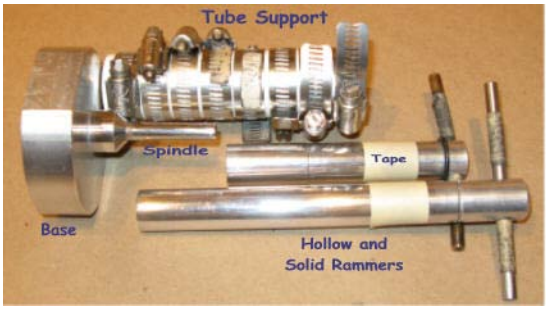
Some folks hot-glue the fuse to the inside surface of the paper tube. Others use masking tape to attach the fuse to the rocket stick. I've tried both of those methods. With some care they can work fine, but at other times I've had the fuse fall off as it was burning, before igniting the motor.

So, I came up with the solution of installing the fuse as shown above. Before pressing any fuel, I drill a 1/8-inch hole through the motor casing, right at the outside edge of where the fuel grain will begin. I use a piece of wooden dowel to back up the inside of the paper tube during the drilling operation.

Drilling 1/8-Inch Fuse Hole in Whistle-Rocket Motor Tube

Marking the Tooling Drifts for Safety

Next, I mark the tooling drifts with masking tape to ensure they never come into contact with the spindle when I'm pressing a motor. I allow about 1/8-inch margin of safety between the drift and the spindle when I'm applying the tape.



Marking Tool Drifts with Masking Tape for Safe Clearance

Pressing Rocket Fuel into the Tube

The hollow drift is used to press the increments of fuel, until the fuel is above the spindle. All the increments are pressed to 7500-psi (pounds per square inch) on the composition.

In the article on making whistles, I illustrated the method for determining how much hydraulic press force to use with a solid drift. Applying 2200-psi of pressure according to my press's gauge results in an actual 7500-psi on the composition with the solid drift.

But, since the hollow drift has the hole in it, less force will have to be applied to it to achieve this same pressure on the fuel.

End of Hollow Whistle-Rocket Drift

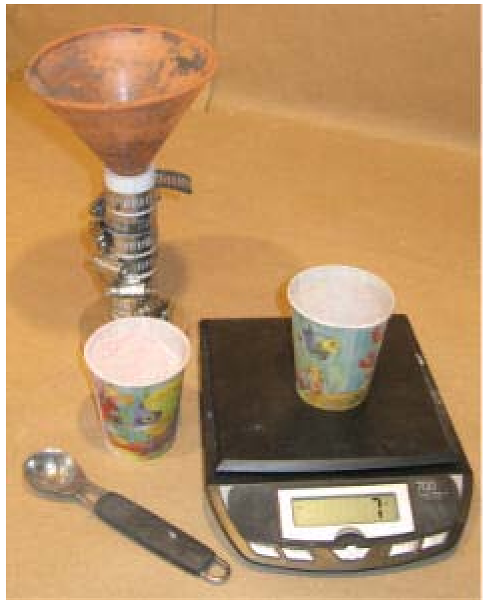
With some math, I've determined that the surface area of the end of this hollow drift is about 80% of the surface area of a solid-end drift. For this reason, when using the hollow drift I'll only apply about 80% of the force with my press that I'd apply when using the solid drift.

So, for the increments that are pressed around the spindle with the hollow drift, I'll press up to a gauge reading of 1750-psi on my hydraulic press.

The first thing I do when pressing a motor is remove a small paper cup of the fuel from the tub of fuel. Then I close the tub tightly and set it aside away from where I am working. That way, only the small cup of fuel is exposed in case something goes wrong.

Whistle Fuel Ready to Load into Rocket Motor Tube

With the support securely fastened around the paper tube, and with the fuse-hole-drilled end of the tube mounted on the spindle, I introduce 7 grams (1/4-ounce) of the whistle fuel, using a funnel.



Weighing Whistle Rocket Fuel

I then consolidate that fuel increment with the press in two steps, by first pressing up to only 1000-psi on the gauge.

I remove the drift and use the smooth, round end of my awl to clean any fuel that is wedged in there out of its hole. Then, I insert the drift back into the tube and press the rest of the way up to 1750-psi on the gauge.

Cleaning Whistle Fuel Out of Hollow Drift

If I press all the way up to the full pressure on the hollow drift in one step, fuel will work its way up between the drift and the tube, and between the spindle and the drift, in its hole. This can bind the drift in the motor, which makes it difficult to remove after the increment is pressed. Pressing the increment in two stages, and cleaning the drift between those two pressings usually eliminates stuck-drift syndrome.

When I'm pressing a really large motor, such as a 1.5-inch ID model, I'll actually press each increment in 3 or 4 stages to reach the full pressure in order to keep the drifts from getting stuck.

Pressing a Whistle-Rocket Engine in a Hydraulic Press

Four, 7-gram increments of the fuel, pressed in this manner with the hollow drift, bring the fuel to just above the spindle, using my fuel and tooling. This can vary a little from batch to batch of the fuel, or with different tooling.

After the fuel is above the spindle, I switch to the solid drift. Now I press the same 7-gram size increments in one pass up to the full 2200-psi reading on my gauge.

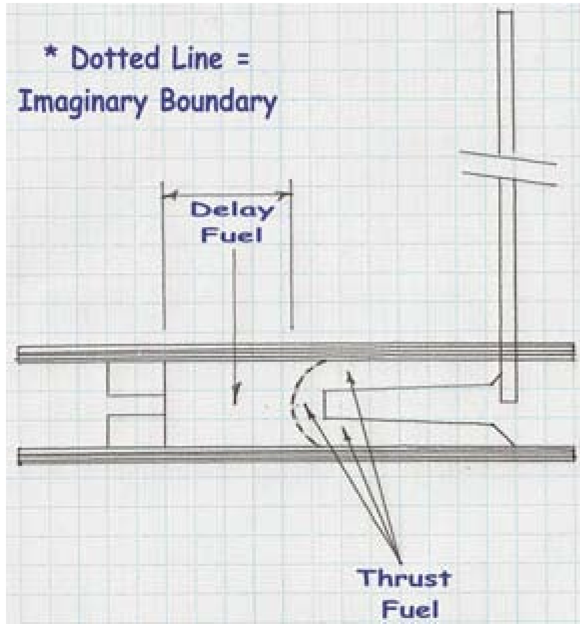
For the rocket shown in the initial video in this article, I press fuel to one inch above the spindle. That requires three 7-gram increments with the solid drift, for a total of 49 grams of fuel in this motor.

I cap the motor off with a 7-gram increment of bulkhead clay mix.

Adjusting the Total Flight Time of the Whistle Rocket

The portion of the rocket's flight after the initial high-thrust phase, and before the heading bursts, is called the delay section of the flight.

The fuel around the circumference of the spindle, and above it for that same distance, about 1/4-inch, burns very rapidly in the highly pressurized thrust period of the rocket motor's burn.



Whistle Rocket Motor's Thrust Fuel and Delay Fuel Sections

Then, the solid portion of the fuel above that thrust fuel burns more slowly in a less pressurized environment. That's why the whistle sound changes so drastically after the initial thrust burn.

So, in this rocket motor I had 1/4-inch of thrust fuel above the spindle, and then about 3/4-inch of delay fuel above that. If I shorten that delay fuel, the delay portion of the flight would be shorter. If I lengthen the delay fuel column in the motor, that delay portion of the flight would be longer.

Looking at the video at the beginning of this article, the one-inch of total fuel above the spindle produced that particular flight and delay before the heading exploded. I was pretty happy with that rocket's flight. I might have lengthened the delay fuel column another 1/4-inch to see if that produced a more pleasing flight in the next rocket.

Other interesting modifications can be made to the delay fuel grain. Once the fuel has been pressed to above the spindle, spherical titanium can be added to the fuel increments that get pressed with the solid drift. The delay fuel is weighed into a paper cup. I add 10% of that fuel's weight in titanium. Then the cup is swirled to mix the components.

The titanium fuel mix is pressed one increment at a time, the same as described above. The metal will produce a silver spark trail as the delay-fuel burns. If the hard metal is added to all the fuel (below the top of the spindle), it will tear the spindle up pretty quickly. Since it also might pose a sparking threat, I only add it to the delay fuel.

If I plan to have a passfire hole, I usually drill the hole down through the center of the clay bulkhead into the fuel. But, I don't want to drill into any fuel containing titanium, so I'll cap any titanium-fuel off with 1/8-inch of plain fuel (no titanium in it). Hand-twist-drilling into that is safer.

The effects you can create using the delay fuel are limited only by your imagination. For instance, in his article "How to Make Fireworks Rockets with Green and Red Tails," Dave Stoddard describes delay fuels used to change the rocket tail's color to a green or red flare as it flies upward.

Removing the Tube-Support from the Tube, and the Motor from the Spindle

After the fuel and clay have been pressed in the tube, it's time to remove the motor from the spindle. This is easier if the support is removed from the engine first, which loosens the motor on the spindle just a tad.

First, I loosen and remove the metal band-clamps from the support, and then slide the PVC support off of the motor.

Then the motor is twisted off the spindle. Putting the spindle base in a vise or holding it rigidly in the rocket press can facilitate this. Using both hands to twist it, the motor is carefully removed from the tooling. Do not use clamps or pliers on the motor itself, or you will risk cracking the fuel grain, which will cause the rocket to explode instead of fly.

Support Removed from Tube, Whistle Motor Removed from Spindle

Drilling Passfire Hole into Clay Bulkhead

If I am going to put a heading on the rocket, then I'll need a passfire hole in the clay bulkhead to transfer fire from the last of the rocket fuel to the heading.

I create this passfire hole by carefully hand-twisting a drill bit into the center of the bulkhead just through the clay into the pink fuel. (Remember that the last 1/8-inch of fuel that was pressed should contain no titanium, even if titanium was added to the rest of the delay fuel.)

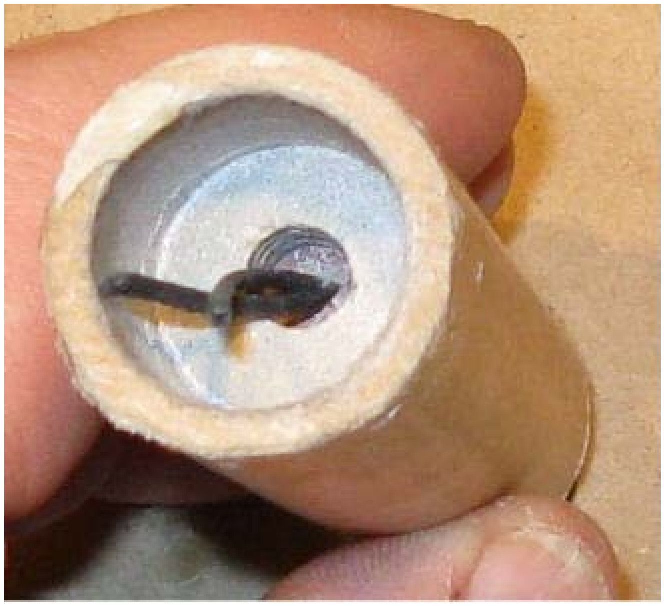
Warning: Never use a power drill to create the passfire hole. The friction and heat caused by such fast drilling could ignite the motor. Only use hand twisting on the drill bit to create the hole.

I've found that starting the hole with a sharp 1/8-inch drill bit, hand twisted through the clay until it just barely penetrates the fuel, works well. Then I'll expand the hole with a 1/4-inch diameter bit to widen and create the final passfire hole.

Hand-Twist Drilling a Passfire Hole through Clay Bulkhead

Simple Rocket Headers

Several types of simple headers can now be employed on this whistle rocket. There is a 1-inch long empty space in the motor tube above the drilled clay bulkhead. First of all I like to insert a couple of pieces of black match, from either quick match or fast-fuse, into the drilled bulkhead passfire hole. I cut these pieces of match about 1.5-inches long so they reach the bottom of the passfire hole, and extend just to the end of the motor-tube.



Inserting Black Match into Whistle Rocket Passfire Hole

These strands of black match ensure positive fire transfer from the last of the rocket-fuel to the header.

For a spray of stars at the end of the rocket's flight, a small amount of black powder can be put into the tube's recess, followed by some of the stars.

For a falling glitter comet, some of the black powder followed by a single 3/4-inch comet can be used to fill the end of the motor.

For a small report at the end of the rocket's flight, the end of the tube can be filled with either loose black powder or loose whistle fuel. A pinch of coarse titanium can be added to either of these powders to produce silver sparks when the header fires.

End of Whistle Rocket Motor Filled with Loose Whistle Fuel

With any of these types of headings, the motor is then capped with a 1-inch end disk, glued on.

If a report heading has been made, I like to reinforce the report tube-section and end cap with some strapping tape, finished off with some peel-and-stick aluminum-foil duct tape. This reinforcement really helps a report heading to "pop."

For a star or comet heading, simply gluing a paper disk on is sufficient to finish the end of the motor.

Finishing Rocket Report Heading with Strapping and Aluminum Tapes

Installing Rocket Stick

The last step to finishing this rocket is to install the stick. I'm using a square poplar stick that I ripped on my table saw. It measures 5/16-inch square by 36-inches long. I bevel the end of the stick, hot-glue it straight on the motor, and finish the attachment with two bands of strapping tape. I make sure the stick does not cover the fuse-hole.

Attaching Stabilizing Stick to Whistle Rocket Motor

A 6-inch piece of visco fuse can now be inserted into the fuse hole, and the rocket is ready to be placed in a launch tube and flown.

Visco-Fused Whistle Rocket Loaded in Launch Tube

Sealing the Rocket Motor for Storage

If I'm going to store the finished rocket for a while, I like to seal the bottom of the motor and the fuse-hole with some aluminum-foil duct tape. This prevents the hygroscopic rocket fuel from absorbing atmospheric moisture during storage, and protects the motor from flame or sparks until flight-time.

Sealing Bottom of Rocket Motor and Fuse-Hole with Aluminum-Foil Tape

Prior to flight, the tape is completely removed from the motor's bottom, and the visco fuse is installed through the fuse hole.

Motors without sticks can be stored in sealed plastic baggies along with a bag of desiccant to ensure they do not absorb moisture.

Conclusion

Well, there you have it - one of the most interesting and powerful rockets you can make. Next time I'll show you a nice variation on this basic motor, the strobe rocket, and some different ways to create a rocket heading.

Copper Salicylate Blue-tailed Whistle Rockets

By Ken Musgrave

First I'll give an overview, then my procedure. Keep in mind that I only had high school chemistry (though it was a great course!) and that was 29 years ago(!) so please bear with me as I mutilate Good Scientific Procedure. Hell, John Steinberg just had to tell me how to pronounce "stoichiometry" last week. I'd been using my own home-schooled hillbilly pronounseeashun for decades, and my chemist girlfriend was afraid to call me "stupid" again and correct me. Some support I get around here. >:-|

If my stoichiometry is correct, the mixing ratio of anhydrous copper chloride (CuCl) (#CH8091) to sodium salicylate (Na saly, in my notes) is 1:1.2. Here's the reaction:

$CuCl + NaC_7H_5O_3 = NaCl + CuC_7H_5O_3$

The $C_7H_5O_3$ group is salicylic acid; we're transferring it from the sodium to the copper. Cu saly is far less soluble than NaCl, so it will precipitate out. As will the NaCl, if the solution is hypertonic. Any chemists out there know if we should use more water than what I describe below? Solubility vs. temperature and such I know diddly about.

I start with 200 grams of CuCl and 240 grams of Na saly. This is very convenient, as the mixing ratio of Cu saly to Ammonium Perchlorate (AP) is--again, if my stoichiometry is correct (I'm terrible at lower math!)--1:3.96 or simply 1:4. So 200 grams Cu saly + 800 grams AP = 1 kilo of composition. Sweet! I've ball milled two batches of the comp for two hours. That's too long--it cakes on the bottom of the jar and turns green.

Why does it turn green, you ask?

Cu Saly appears to have at least 2, maybe 3, stable isomers at room temperature. The one I like best, because it's pretty, is sky-blue fine needle crystals. The other is a tarry, taffy-like forest green form. The possible third one is an ochre-colored fine powder.

The reaction of CuCl and Na saly must be done cold, or you'll get a big wad of the green tar. First time I did it this way--did the reaction hot, and got a nice green tar ball. I put the tar ball in the freezer then a coffee grinder. When I washed it with cold water, it turned to the sky-blue phase. If it gets warm again, as during ball milling, it turns green again. This shouldn't affect performance, but then all three batches I've made to date have turned green from getting warm as some point during processing, so I really don't know yet.

I tried drying some of the Cu saly in the oven at 225 deg. F, and it turned ochre, but still seemed to burn just fine. That may be a third isomer. So: We want to keep or Cu Saly cold or at least room temperature at all times, if we can.

The tarry phase is also evil for another reason: We need to wash out the NaCl (common table salt) that is the other product of our reaction. Sodium has a strong yellow emission line that will turn our blue flame white, if we don't eliminate it. We want a fine powder, not a tar ball, for this washing process. (Though, for all I know, the tarry phase may effectively exclude the sodium. I'm just too ignorant to know anything about that.)

Other comments: This process *should* be pretty non-toxic. (SOMEONE PLEASE CORRECT ME IF I'M WRONG.) The precursors aren't too evil, and the (main) products are common table salt and a form of blue aspirin. Desultory research on the Internet reveals that both Cu saly and Na saly have been used as analgesics, so I figure they can't be that toxic. Dunno about any other reaction products, though. Oh, and hot CuCl solution ate the plating right off the metal spoon I used to stir it the first time. And the liquid resulting from the reaction attacks stainless steel rather fiercely, so I recommend using all plastic implements in this process.

Our goal is to do this reaction cold, then wash the result to remove the NaCl, while maintaining our pretty blue crystals. With this in mind, this is how I proceeded on my fourth try last night:

1. Dissolve 200 grams CuCl in ~1 cup boiling water.

2. Dissolve 240 grams Na saly in ~2 cups boiling water.

3. Cool both to ~50 deg. F in an ice water bath (quickly, to avoid precipitation).

4. Pour the CuCl solution slowly into the Na saly solution, stirring constantly. See the pretty green tarry phase form instantly!

5. Stir constantly with a large plastic spoon for ~3 minutes.

6. For the first few minutes, the solution will stay a very dark forest green. Then a phase transition takes place, possibly even before you finish stirring in the CuCl solution. The blue crystals form rather rapidly. As this happens, the mixture goes from a liquid solution to a fairly dense sky-blue slurry. (Really cool to watch--have the family gather round!) If the slurry becomes too dense to stir, just add more water, which also helps to wash out the NaCl

[Then it was late, so I put it in the fridge overnight.]

7. Pour a bunch of the slurry into a coffee filter cone with standard coffee filter paper. Let it drip for an hour or so.

8. Remove the filter paper and semi-solid slurry and place it on a sequence of folded-up paper towels, replacing each paper towel when it is soaked.

9. When the paper towels stop absorbing water, dump the filtrate back into your reaction vessel and wash with ~1 liter or quart of cold water. Wash at least twice.

10. If you want to maximize your yield, you could skip the washing. If you want to intensify your blue, you might want to do several washings to get rid of that sodium.

11. Repeat the filtering process and allow the Cu saly to air-dry for as long as it takes.

12. Then you can mill up some comp!

The paper towels are my conjectured cheap-ass hillbilly chromatography; an effort to draw the NaCl out of the Cu saly in a process akin to how they make weapons-grade plutonium, only different. I may be completely full of it with this step, but what the heck; "seems like a good idea."

White Strobe Rocket Pyrotechnic Formula

By John Steinberg

Learn how to make white strobe rockets using a simple pyrotechnic formula and common firework chemicals

Materials Needed

- Ammonium perchlorate (CH5005)
- Ball mill
- Barium sulfate (CH8030)
- Dowel, 1.5"
- Magnalium, -200 mesh (CH2072, CH2073)
- Nitrocellulose (CH8198)
- Potassium dichromate (CH5525)
- Rocket press
- Screen, 20 mesh (TL2002)
- Screen, 40 mesh (TL2004)

White Strobe Rocket Formula

I would like to begin this article by thanking and crediting my instructors. Doc Barr introduced me to strobe rockets years ago. Steve LaDuke walked me through my first attempts at this pyrotechnic formula. Without them, this article could not have been written.

Ingredient	**Parts by Weight**
Ammonium perchlorate	60%
Metal (see the following)	25%
Barium sulfate	15%
Additional, by weight, potassium dichromate	5%
Nitrocellulose as a binder	

Some of the firework chemicals require prior preparation. The ammonium perchlorate is ball milled for 2 hours with a hard milling medium, until it is of powdered, chalk-like consistency.

The magnesium-aluminum (magnalium) metal I use is -200 mesh, and I ball mill 300 grams at a time for 3 hours with steel ball bearings as the milling medium. The potassium dichromate is ball milled for 18 hours to a very fine dust.

The firework chemicals used pose both inhalation and toxicity hazards and appropriate safety equipment is to be used.

The pyrotechnic formula I like best uses, as the metal component, a mix of 23.5% ball milled 50:50 -200-mesh magnalium metal and 1.5% 60-100-mesh magnesium flake. Steve LaDuke and I have used a pyrotechnic formula with 25% -200-mesh magnalium without ball milling it at all. It gives a slower strobe rate.

The first formula yields a rapid strobe with a loud popping sound. Fred Partin has also used many strobe rocket pyrotechnic formulas of this and other colors and may be consulted as well for variations on this theme. For a very slow strobe, of no use in strobe rockets where thrust is desired, you may use 25% 30-mesh magnalium.

The binder is standard 10% nitrocellulose (NC) lacquer diluted with acetone. I use 1 part NC lacquer to 3 parts acetone. The amount used in the mix is not critical. Doc Barr has even made strobe rockets with this formula using no NC binder.

Start by sifting the ammonium perchlorate, metal, and potassium dichromate twice through a 40-mesh screen. Then add the barium sulfate and sieve the entire mix through a 20-mesh screen twice. To avoid corrosion, use stainless steel sieves.

Take the composition and add enough diluted NC lacquer to just barely moisten it. You should be able to squeeze it and have it hold its shape. One kilo utilizes approximately 4 to 5 ounces of diluted NC lacquer.

Granulate the moistened composition through a screen of about 20 mesh or coarser using a 1.5-inch dowel section as a pestle. Dry the mixture thoroughly, at least 12 hours. It is now ready for use in making strobe rockets.

The mixture has a long shelf life. I have used batches that have been stored for over three years. As with any strobe rocket compositions, use caution at all times, and above all else, be safe.

Note: No clay nozzle is needed. For a two-pound strobe rocket, press whistle composition for the first 1 3/8 inches and finish with strobe rocket mix to 1/8th to 1/4 inch above the spindle top. Do not exceed 1/4 inch above the top of the spindle. Strobe burns very slowly; if you press too much strobe rocket composition above the spindle, your strobe rocket will burn all the way to the ground. Top off the strobe rocket with about one inch of pressed whistle composition. Confine the strobe rocket tube in a sleeve when pressing.

NEVER RAM/HAMMER WHISTLE MIX! ALWAYS USE A PRESS. Pressures? If you are using a 12-ton hydraulic press, your pressures should be between 2,000 and 2,500 PSI on the gauge.

How to Make Strobe Rockets

By Ned Gorski

What is a Strobe Rocket?

If I had to make the choice of being able to construct only one type of rocket, it would be a difficult decision. I truly love the low-level simplicity and effect of the Spectacular Glitter-Tailed Rocket with Willow-Diadem-Horsetail Finish.

But for pure, high-powered, awe-inspiring and crowd-pleasing rocketry display, the strobe rocket is sure hard to beat.

One-Pound Strobe Rocket
(Click Image to Play Video)

Note: The "one-pound" and "six-pound" rocket motor designations have nothing to do with what the rocket actually weighs. They are fireworking terms, which refer to the rocket engine tube's inside diameter (ID), and have their roots in antique rocket-making terminology.

Six-Pound Strobe Rocket (Video taken by Dan Thames)
(Click Image to Play Video)

That baby (video above) was really up there by the end of its flight. You can tell that from the delay between the video and audio of the report heading. These large strobe rocket engines really do sound like helicopters in flight, too. For such a relatively simple fireworks device, they sure are satisfying and attention grabbing when they work well.

Even when they don't "work well," and CATO (blow up) on the launch pad, these rockets are impressive! There is a lot of power packed into that engine tube, so it pays to put a long piece of visco fuse on them, and have everyone plenty far away from the launch area just in case.

Whistle Rocket Explosion on Launch Pad (Photo Courtesy Jerry Durand)

This is the third in a series of whistle-related articles. The first installment dealt with making whistle fuel and simple fireworks whistles. That same fuel will be used in these strobe rockets. The second article described the construction of basic whistle rockets. Many of those same techniques will be used now to make strobe rockets. So, it's a good idea for you to familiarize yourself with those basic methods before forging ahead with this project.

Note: I will not be repeating all the basic construction details from the whistle rocket tutorial. You really will need to be familiar with those techniques if you are going to tackle this strobe rocket project.

A strobe rocket utilizes whistle fuel for power, along with strobe fuel to create the popping sound and flashing light that is unique to them.

Pressing Rockets

Note: Once again, as in the whistle projects, hand ramming with a mallet is never employed with these fuels and devices. Only a press equipped with a safety shield should be used to press these items. Fireworks Tips #121 detailed the construction of such a hydraulic rocket press. For small rockets, some folks use a manual arbor press to consolidate (press) the fuels.

Hydraulic Rocket Press with Safety Shield

Strobe Rocket Fuel

In addition to the whistle fuel I referred to above, one other fuel is necessary for these strobing rockets - strobe fuel. This fuel is very similar to the composition that was used to make strobe pots. Please study the methods and precautions that were spelled out in that essay.

This strobe fuel is what gives these rockets their distinctive popping sound and flashing light as they fly. But, strobe fuel alone is not powerful enough to make a rocket fly.

Back in the '80's, Doc Barr started playing with a basic strobe rocket, using a black powder fuel to boost the strobe fuel's power. His results are chronicled on Page 58 of The Best of AFN II.

A funny and educational quote from Doc's article is, "All rockets have the potential of exploding on takeoff, but these do it with an annoying frequency. About 1 out of 10 act more like an open-ended salute than a rocket. So 'light fuse and retire quickly' is my Eleventh Commandment."

In the late 80's and early 90's, folks like Doc and Steve LaDuke started working with whistle fuels in rockets, resulting in the high-powered fireworks whistle rockets like I described in the whistle rocket article mentioned above.

Somewhere along the line, these rocketry pioneers had the bright idea to combine the powerful whistle booster fuel with the impressive strobing fuel, and the modern strobe rocket was born.

Traditionally, nitrocellulose (NC) lacquer is added to the standard white strobe composition specified in my strobe pot article. In his BAFN article, Doc Barr said he pressed his strobe fuel slightly dampened with NC lacquer. Many modern builders dampen their fuel with NC lacquer, granulate the dampened fuel through a 12-mesh screen, and dry the granules before pressing the fuel in the rocket motor.

Years ago I made a slight change in this method. Rather than using NC lacquer, I now dampen my strobe fuel with an additional 2% mineral oil dispersed in Coleman Fuel, as I described in the whistle-fuel procedure.

White Strobe Rocket Fuel

Chemical	%	16 Ounces	450 Grams
Ammonium perchlorate	0.57	9.15	257.1
Magnalium, 200 mesh	0.24	3.8	107.1
Barium sulfate	0.14	2.3	64.3
Potassium dichromate	0.05	0.75	21.5
Mineral oil	+0.02	0.3	9

Note: The ammonium perchlorate, barium sulfate, and potassium dichromate are each milled individually in a blade-type coffee mill until they are fine enough to pass through a 100-mesh screen.

Warning: Potassium dichromate is toxic and a known carcinogen. A good respirator and rubber gloves are required when working with this chemical, and when using it in pyrotechnic compositions. Don't breathe this stuff or get it on your skin. Wear your protective gear even when you are pressing the finished fuel in the rocket motor.

I'll be making 3/4-inch ID (one-pound) size, strobe rocket motors. Each motor will use about 39 grams of whistle fuel and 25 grams of the strobe fuel. So, the 450-

gram batch of strobe fuel shown in the formula above will be enough for approximately 18 motors.

All the dry chemicals are weighed out individually, and then mixed thoroughly by gently passing them through a 20-mesh screen or kitchen colander. I put this mixed powder into a small plastic bucket.

I weigh out the mineral oil into a clean quart jar, such as a spaghetti sauce jar, and then I add 1/2 cup of the Coleman fuel to the oil. After tightly screwing the jar's lid on, I shake the liquid to completely mix the two ingredients.

This mixed liquid is then added to the dry powder, and it is completely blended in with gloved hands. The damp composition is then dried over a pot of hot water, as described in the tutorial on making whistle fuel. Once again, the fuel is never brought anywhere in the vicinity of any open flame or source of sparks.

After a couple of hours of drying over the pot of warm water, the fuel will be dry, will stop smelling of Coleman fuel, and will resemble grayish-green sand. I use my gloved hands to break up fuel clumps as it is drying.

Strobe Rocket Fuel on Kraft Paper Lined Tray

The Rocket Tooling

To make the 3/4-inch ID strobe rockets for this project, I'll be using my tooling, which is very similar to the Skylighter TL1361 tool set. Strobe rocket tooling is almost the same as whistle rocket tooling. The main difference is the spindle is about twice as long. The number of rammers ("drifts") can vary from tooling to tooling.

Skylighter One-Pound Strobe Rocket Tooling

Just as I did in the whistle rocket project, I polish the drifts and spindle using very fine sandpaper and metal polish to facilitate removal of the drifts during the pressing.

Strobe Rocket Motor Tubes

Once again, because of the high pressures used to make these engines, and the high thrust they develop, I use the extra-strong TU1066 3/4-inch ID paper tubes. For these motors I cut the tubes 6 inches long.

Cutting TU1066 Tubes into 6-Inch Long Strobe Rocket Motor Tubes

The Tube Support

A 6-inch long, PVC plumbing pipe and band clamp tube support is used to reinforce the paper tube during construction.

PVC Pipe Support for Paper Strobe-Rocket Motor Tube

Drilling the Fuse Hole

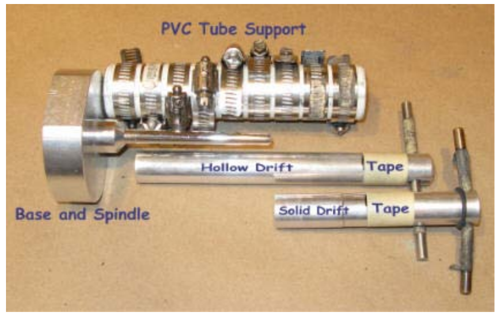
Just as I did with the whistle rocket motors, I drill a 1/8-inch hole through the side of the paper engine tube, right where the bottom of the fuel grain will be.

Drilling Fuse Hole in Strobe-Rocket Tube

Marking the Tooling Drifts for Safety

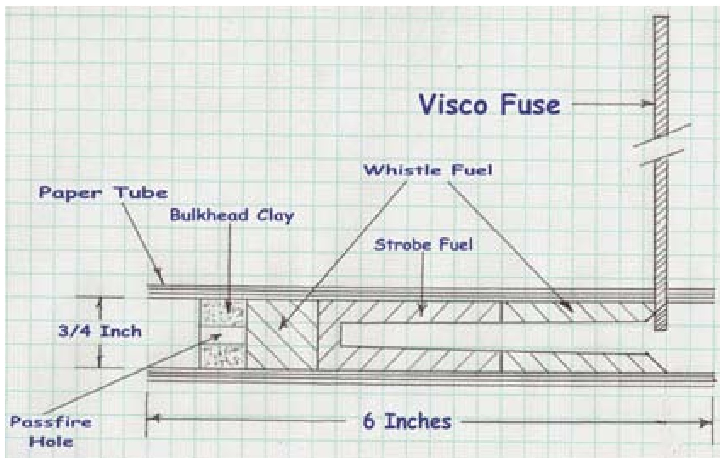
At least 1/8-inch clearance is allowed between the spindle and the point where the drifts would contact it. I mark my tool drifts with masking tape to be absolutely sure they never pinch fuel between the drift and the spindle while the fuel is being pressed. Pinched fuel can explode upon pressing. That 1/8-inch clearance is enough to prevent this.

My particular tooling set only has one hollow rammer and one solid rammer. Some tooling comes with two or three hollow drifts, and each one must be marked with tape accordingly for safety.



Strobe-Rocket Tooling Marked with Masking Tape for Safety

Pressing a Strobe-Rocket Motor



Cross Section of a Strobe-Rocket Motor

The first thing I do in this pressing process is scoop out a paper cup full of whistle fuel, and a paper cup full of strobe fuel, set them aside and put the large tubs of my fuels away in safe storage. As I've mentioned before, this is perhaps the most important safety precaution: limiting the amount of exposed flammable composition while working with it.

For my strobe rocket, I press the whistle fuel in the tube in the same way and with the same pressures I did when making the whistle rocket motors. Pressing three 7-gram increments and one 4-gram increment of the whistle fuel brings that fuel halfway up the spindle. These increments are pressed with the hollow rammer.

I use black rubber o-rings on my rammers to keep dust down to a minimum during the pressing. These o-rings, as seen at the top of the solid drift in the photo of the tooling above, also serve another purpose.

Each time the rammer is about to be reinserted into the tube, I slide/roll the o-ring down toward the end of the rammer. Then, as I insert and press the drift down into the tube, the o-ring seals against the top of the tube and prevents much dust from blowing out. When the drift is removed after that increment, the o-ring's position marks where the top of the tube was, and just how far into the tube the drift went while pressing that increment.

When the drift is removed from the motor after an increment is pressed, the o-ring stays put on the drift exactly where the top of the motor tube was before the drift was removed.

Critical: I keep a full-scale sketch of the motor on my workbench as I'm pressing the motor. I'll put the drift, with the o-ring marking where the top of the motor tube was, down on the sketch, and keep track of how high the pressed fuel is coming in the motor. In this way I can precisely determine when the whistle fuel is pressed up to the desired level, and switch to the strobe fuel increments.

Hydraulic Pressing a Strobe-Rocket Engine

I keep the hollow rammer cleaned out as I press the fuels, because I never want to be pressing fuel up inside the rammer, between it and the spindle.

Cleaning Fuel Out of a Hollow Drift

Then I press three 7-gram increments of the strobe fuel with the hollow rammer, and one 4-gram increment of that fuel with the solid rammer, being very careful to not press past the safety-tape line on that rammer.

This brings my strobe fuel up to about 3/16-inch to 1/4-inch above the end of the spindle, as checked once again by comparing the drift and o-ring with my sketch. The final strobe fuel increment is adjusted so that it reaches that level.

This strobe-fuel distance above the spindle is critical. Too little strobe fuel will cause the motor to start its whistling delay burn too soon. Too much strobe fuel above the spindle will cause the motor to burn too long, turn back toward earth, and perhaps even return all the way to the ground before the heading bursts.

Note: Ask me sometime how I know about the effect created when too much strobe fuel is pressed above the spindle. The story deals with a six-pound strobe rocket coming back to earth, going through the roof of a meeting tent as there was a "parting of the seas" in the crowd, bouncing off a swimming pool diving board, and the heading explosion nearly scaring Doc Barr to death, or at least into regaining the memory of most of his previous sex life. Oh, I can laugh about it now, but it was damn embarrassing at the time.

After the strobe fuel has been pressed to that critical distance above the spindle, another two 7-gram increments of the whistle fuel are pressed above the strobe fuel, as shown in the sketch above. This whistle fuel section creates the whistling "delay" portion of the rocket's flight before the ignition of the header.

As I mentioned in the whistle-rocket article, other "delay" effects can be produced. Colored fuels can be used instead of the whistle delay fuel, or titanium can be added to the whistle delay fuel. The amount of delay fuel has to be dialed in to produce the desired effect and length of flight.

The motor is then capped off with a 7-gram increment of bulkhead clay, with a passfire hole hand-twist-drilled into it. I never drill into whistle fuel with titanium in it, as I warned in the whistle-rocket article.

If I do use whistle fuel containing titanium in the delay section, I cap it off with 1/8-inch of fuel with no metal in it. Then I carefully hand-twist-drill the passfire hole.

Hand-Twist-Drilling Passfire Hole through Clay Bulkhead

Troubleshooting: The various amounts of fuel, and the distance up the spindle between the two fuels, have been dialed in for my own fuels and tooling. If your pressed rocket motor blows up on the launch pad, then less whistle fuel and more strobe fuel should be used. On the other hand, if your rocket doesn't have enough power at launch, more whistle fuel and less strobe fuel should be used.

So, there we have it, a finished strobe-rocket motor. One final thing I'll do is carefully re-enlarge the fuse hole with my awl since the hole can become a bit closed down and filled with fuel during the motor's pressing.

Enlarging Fuse Hole with Sharp Awl

Creating a Rocket Header

These rockets can fly so high that I really like to only use report headers on them. The effect of a star-shell header could get lost up at that altitude. As I showed with the whistle rockets, the hollow end of the motor tube can be filled with loose whistle fuel, perhaps containing some titanium, and then capped off to create a small report heading.

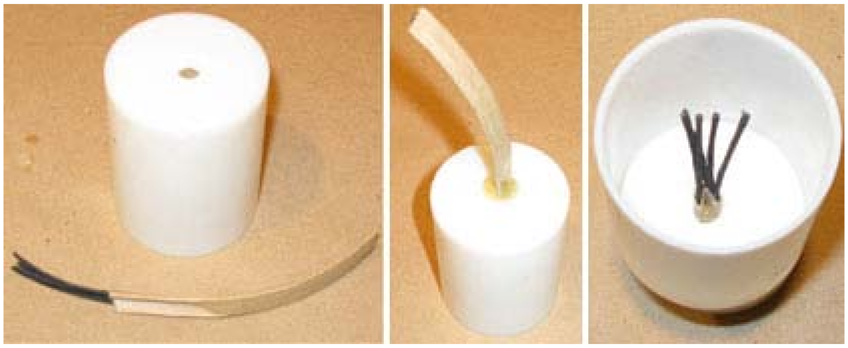
Loose strobe fuel, which is also a powerful explosive, can be used in this way, too. If more hollow space is desired, the motor tube can be extended with an extra piece of the same motor tube, glued and taped onto the motor tube to extend it.

For a larger, more impressive report heading, Skylighter's PL1020 or PL1022 plastic #5 can shell casings can be used. These plastic cans measure slightly less than 2 inches in diameter, and work well on these one-pound rockets.

I fill the recess in the can's cap with hot glue, drill a quarter-inch hole in the can's bottom, and hot-glue a piece of quick match or fast fuse into that hole. When gluing the fuse into the can, I make sure all the gaps around the fuse are filled with glue to prevent any composition from leaking out of the can after it is filled.

The fuse will transfer fire from the top of the rocket motor to the heading.

1/4-Inch Holes Drilled in Plastic Can Bottoms, Recessed Caps Filled with Hot Glue



Hot-Glue Quick Match into Plastic Can Bottom

Then I fill the can with my report composition of choice. The traditional filling would be flash powder, but making flash has become a bit problematic for some in the current legal climate.

If one has legal access to the necessary chemicals, I'll describe a safe way to make a flash report with one of these cans. But first, I'll detail three alternatives for making a report without flash powder.

A simple report can be made by filling the can with black-powder-coated rice hulls, with the addition of some coarse titanium if silver sparks are desired. One of the cans can hold 45 grams of the BP-coated hulls, and 14 grams of the titanium.

Plastic Shell Casing Filled with Black-Powder-Coated Rice Hulls

Two other alternatives would be to fill the can with loose whistle fuel or loose strobe fuel. A can will hold 57 grams of my whistle fuel, or 67 grams of my strobe fuel. For silver sparks, 14 grams of titanium can be added to either of these fuels by putting the fuel and the titanium into a small paper cup and gently swirling the two together to mix them before pouring them into the can.

Plastic Can Shell Casings Filled with Whistle Strobe Fuel

Note: I mention this flash report composition option out of a sense of responsibility. Folks will make flash reports. There is a long tradition of it in all kinds of fireworks. But, flash powder is the most powerful composition that fireworkers work with, and many really serious pyro accidents involve it.

Flash Report Composition

No matter which report composition I used, I then glued the caps onto the plastic casing cans with PVC plumbing cement from Home Depot. I did this outdoors because of the fumes, wiping the excess glue off with a paper towel.

I then strengthened the casings with some 1/2-inch wide fiberglass-reinforced strapping tape. Since my tape roll was 1-inch wide, I split the end of the tape in half. This allowed only one half of the width to tear off as I used it.

This flash-report method is called the "binary method" of mixing the composition. That is because the components are added to the report casing individually, and are not mixed until the casing is closed and sealed. This is the way theatrical flash powder is mixed when it is used professionally. This method isolates the flash powder from static electricity, friction, and stray sparks-frequent causes of accidental flash explosions.

Binary-mixing flash composition completely eliminates the need for the open mixing of flash, as well as handling and storing loose flash powder. This eliminates many of the dangers of using flash powder.

Since the flash powder is actually mixed in the report casing after it is glued shut, enough extra room must be left in the casing to allow this mixing to be done. For this reason, I only fill the casing about 2/3 full with the components of the report composition.

Through trial and error, by marking one-third and two-thirds marks on the inside of the plastic casing, and introducing increments of the composition ingredients a little at a time, I determined the recommended amounts below to add to these plastic cans.

First of all, I sifted some potassium perchlorate and some dark aluminum onto their own individual, clean paper plates. I used a fine mesh kitchen colander to do this, and cleaned the colander between chemicals to avoid cross contamination.

Potassium Perchlorate and Dark Aluminum Sifted onto Paper Plates

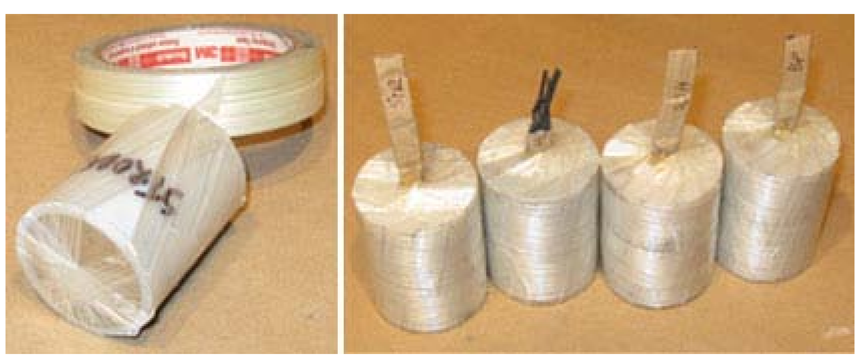
Then I assembled my perchlorate, aluminum, titanium, and some bran flakes on my workbench. Bran flakes aerate the flash ingredients once the casing is closed, and prevent the powder from settling and packing down too tightly.

Flash Report Composition Components Ready to Be Weighed

I filled the shell casing in two stages using dedicated scoops. I weighed the components individually, and placed them into a plastic casing in layers. First, I introduced 14 grams of the perchlorate into the casing, then 6 grams of the aluminum, then 1 gram of the bran flakes (slightly rounded teaspoonful), and finally 7 grams of the titanium. These components were never mixed together in the open. This filled the casing one third full.

In the second stage, I did the same thing again, which filled the casing to the two-thirds full line. That was as full as I wanted the casing, since I wanted to leave it one-third empty for easy mixing once the casing was closed.

Note: During this taping process, the normal handling of the binary-mixed flash report is enough to sufficiently mix the ingredients. No rough shaking is necessary. Once the can is closed, handling this report is no more dangerous than the normal handling of a commercial fireworks salute.



Plastic Casings Reinforced with Strapping Tape

I then finished the headings off with a layer of aluminum foil duct tape.

Rocket Headings Finished with Aluminum Foil Tape

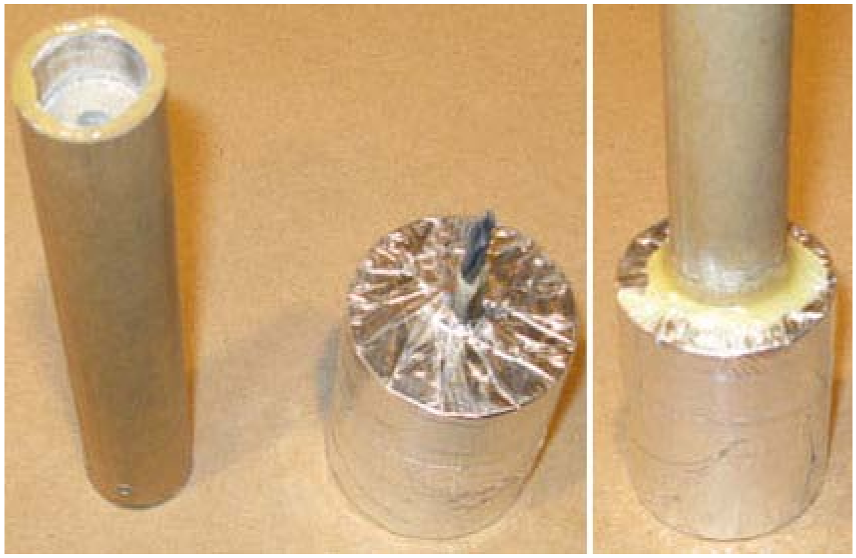
Attaching a Heading, Fuse, and Stick to a Strobe-Rocket

I first trim the header fuse so that it is long enough to go all the way through to the bottom of the passfire hole, and is pressed against the rocket's fuel grain. I bare the last 3/4 inch of the fuse.

Rocket-Heading Fuse Trimmed and Bared

Then I put a bead of hot glue around the top of the motor tube and quickly install the header, carefully making sure the fuse goes all the way down into the passfire hole as I do so. I reinforce the joint between the header and the motor tube with an additional fillet of hot glue.

I've found that the slick side of a piece of the paper backing from the aluminum foil duct tape comes in handy for smoothing fillets of hot glue without burning my fingers.

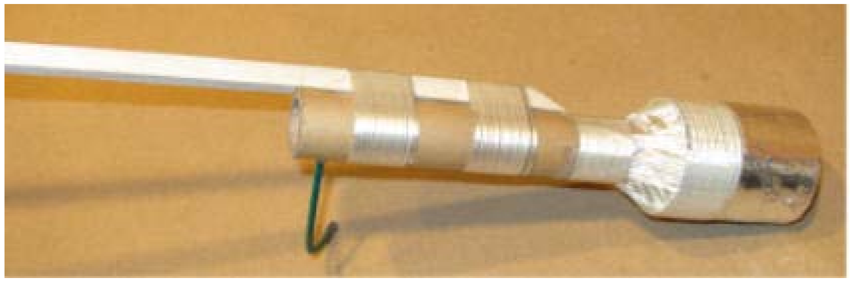


Rocket Heading Hot-Glued onto Motor Tube

The joint is then reinforced with some vertical, 3-inch strips of strapping tape, finished off with horizontal bands of the tape around the heading and the motor tube. This really strengthens the connection.

A 45-inch long, 5/16-inch-square, poplar rocket stick, with a beveled end, is then hot-glued and strapping-taped to the motor. If the rocket is to be flown immediately, then a 6-inch piece of visco fuse is inserted into the motor's fuse hole.

Final Heading Connection Reinforcement



Completed Rocket with Stick and Visco Fuse Installed

If I am going to store the motor for a while before launching it, I won't install the visco fuse now, but will instead seal the end of the motor and the fuse hole with aluminum foil tape to prevent the whistle fuel from absorbing moisture.

Conclusion

Well, it's been a bit of a journey, but in the last 3 projects we've made whistle fuel, whistles, whistle rockets, strobe fuel, strobe rockets, and impressive report headings. While these powerful fuels and devices are not exactly beginner's projects, if they are approached one step at a time, with good safe work habits, they can indeed be some of the most impressive and satisfying fireworking devices around, both for the builder and for the audience.

How to Make Blue Strobe Rockets

By John Steinberg

Materials Needed

- 40-mesh screen (TL2004)
- Ammonium perchlorate (CH5005)
- Balance
- Ball mill
- Copper oxide, black (CH8096)
- Fork
- GE II Silicone #5000 (bathroom caulk)
- Press (hydraulic or arbor)
- PVC powder (CH8216)
- Window screen
- Wooden dowel

Someone wrote me recently and asked how to make blue strobe rockets. Well, we have a video on the topic (#VD0011D), done by Doc Barr, who made the first ones I'd seen. Doc tells me that he first learned about them from John Burdick at a pyro convention in Ithaca, New York. One of the other rocket docs, John Steinberg, was kind enough to write up this description for the guy and gave us permission to reuse it here. Thank you, John. --HG

Blue Strobe Rocket Pyrotechnic Formula

This is a relatively simple composition to make, but bizarre in its behavior and a mess to formulate. The basic formula is:

Ingredient	**Percentage**
Ammonium perchlorate	63%
Copper oxide, black	10%
PVC powder	5%
GE II Silicone #5000 (bathroom caulk)	22%

First, take the three dry ingredients (ammonium perchlorate (ball milled to a fine dust), copper oxide, and PVC powder) and sieve them together three times through a 40-mesh screen. Then, place them in a container on a balance and tare it.

Slowly squeeze in the appropriate weight of silicone caulk. This requires some practice to be precise. Go slow and easy so as not to add too much.

Mixing requires some effort. I prefer to use an old plastic container. First I mix it with a fork as thoroughly as possible. Then, I use a wooden dowel, 1.5 inches in diameter by 6 inches long, as a pestle to try to force the strobe rocket mix through a window screen section stretched over a bowl. Not all will go through, but the kneading action will thoroughly mix even the congealed portion, which can later be grated through a wire mesh screen with 1/4-inch squares.

Some folks like to use a plastic bag of the Ziploc variety to manually knead the strobe rocket mix. I prefer not to be holding it! I always wear gloves and safety glasses when working with any pyrotechnic compositions.

And, I sure don't want to make a mess of anyone's shop who is gracious enough to allow me to work in their facilities. This strobe rocket composition is so messy that I recommend you set aside a set of tools to use with this and with nothing else.

The strobe rocket composition is highly flammable as soon as it is mixed, so be careful. Use an arbor or hydraulic press. It is best pressed (do NOT hammer or ram this composition!) into strobe rockets BEFORE it has a chance to set and cure.

When it cures, it's like working with small pieces of pencil eraser. Try making cut stars before the mix cures. Or, try pressing the soft composition into tubes for strobe pots and letting them cure overnight.

The strobe rocket composition actually burns quite slowly. Try burning some on the ground, outside a tube to see this effect.

There are many types of silicones. Different curing systems are employed. Some may not be compatible with the other chemicals used. I do not recommend any but the most cautious experimentation with any other silicones. Further, if you place a small amount of composition on a steel plate and hit it with a hammer, you will find it is also shock sensitive.

Spectacular Glitter-tailed Rocket with Willow Diadem Horsetail Finish

By Ned Gorski

With Thanks to Dr. John Steinberg, Kurt Medlin, John Werner, and Steve Majdali

What do I mean by a "spectacular" black powder rocket? By this term, I am thinking of a great looking rocket, with a unique tail as it ascends, followed by a long-lasting, eye-catching heading. Maybe I have in mind a rocket that I wouldn't know how to improve on. (Of course, I am playing with two-pound versions of this baby already, since bigger is almost always better, or at least different.)

Here is a link to a video of the rocket we are about to make, to get your juices flowing, and so that you don't have to read all the how-to information before you get to see what it is we're trying to accomplish.

Homemade Black Powder Rocket
with Ascending Glitter Comet and Horsetail Header
(Click Image to Play Video)

You'll notice that the rocket does not fly into the stratosphere. It stays relatively low, allowing the audience to watch the graceful, arching glitter trail, and then to be close enough to the sparking horsetail header finish to really appreciate it. This was all done by design, and I wanted this to be a really satisfying "fireworks rocket," not a high-powered machine.

In Fireworks Tips #65, John Werner discusses the construction of core-burning, black powder rockets, specifically 1/2-inch ID (4 ounce) models. John is a master pyro craftsman, and his articles are well-written, detailed, and complete. This one is no exception.

Toward the end of his article, after describing the rocket's construction in detail, John includes a "Troubleshooting" section, some options for "Modifications and Enhancements," and answers to some "Frequently Asked Questions."

I don't believe in constantly reinventing the wheel, so I'll simply use John's article as a foundation and base of reference for this one. I will be constructing 3/4-inch ID, one-pound, rockets in this project.

When I wrote my first article for Skylighter, in Fireworks Tips #89, I focused on making clay nozzle and bulkhead mix, and I will be using those mixes in this project. I discussed black powder techniques in Fireworks Tips #96, and that BP will be used in the shell headers for these rockets. I will be cutting and treating tubes, Skylighter #TU1065, as I described in Fireworks Tips #107.

I discussed making small plastic can shells in Fireworks Tips #112, and those small shells will be used as the headings on the rockets made for this article, with some minor modifications in technique.

I showed how to pump stars and make black match in Fireworks Tips #92, and how to prime the stars in Fireworks Tips #93, and I'll make stars and black match using those techniques, with a special star formula for these rocket headings. (Flying fish fuse could also be used in this project with a nice effect.)

Quick match pipe was illustrated in Fireworks Tips #94, and I'll be using some of that this time around, too.

And, last but not least, I'll be showing how to attach some glitter comets, as described in Fireworks Tips #111, to achieve an extraordinary rising tail with these rockets.

Special techniques for finishing the rockets will be described so that the finished product will be safe and look nice even before it is fired.

So, you can see that all the skills and techniques that have been described in the newsletter articles of the past years start to build on themselves and come together in this stunningly beautiful rocket I'm about to describe.

You have your homework. Fire up your printer, and get the above mentioned articles in front of you. Study them, and assemble your materials. Then we'll get to work.

Note: One thing you'll hear from experienced fireworkers is, "Always take good notes about your experiments and projects, and keep them in a good notebook for future reference. A year from now you won't be able to clearly remember which of those experiments was the one that worked so well if you don't take good notes."

One of the extremely beneficial things about writing these Skylighter articles is that they then serve as my notes, when I might have been too lazy to follow the above advice otherwise. I also have access to the notes of others like John Werner. If you print out the articles, and then annotate them with your own modifications, they can serve as your notes as well.

The Plan

In Fireworks Tips #'s 92, 93, and 94, I described the process of making "Nice Shells in 2 1/2 Days" at a fireworks event such as a local club gathering or the annual PGI convention.

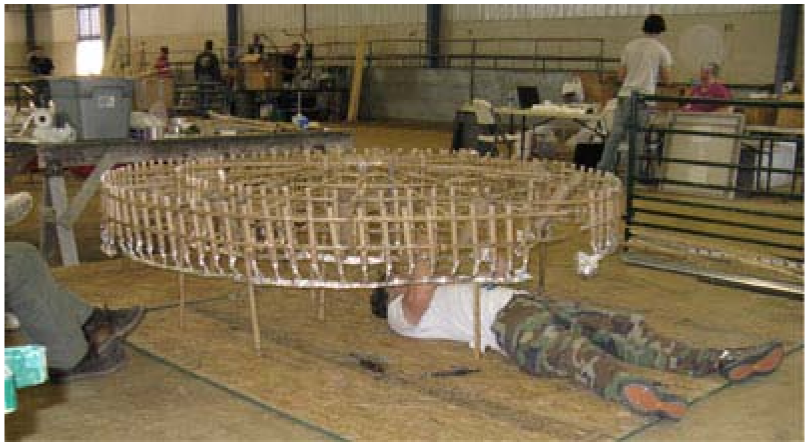
I think I'll approach this rocket project in the same way, wherein a fireworker travels to a pyro event with absolutely no complete pyrotechnic materials, and makes everything from scratch at the event, and only in the quantities needed for this project. This eliminates any worry about licenses, storage, or transportation.

In Fireworks Tips #111, Harry included a shot of him and me at the most recent PGI convention out in Gillette, Wyoming. One of the great things about the convention is the opportunity to work alongside others as fireworks devices of all sorts are constructed.

An Empty Room Transformed into a Pyrotechnic Playground

16-Inch Ball Shells Were Made and Shot the Next Day

Members like Dan Thames Constructed Fancy, Two-Stage Rockets and Some Real Monsters



Tony Stader Building His 14-Foot Girandola

Kids Like Sarah Widmann Could Even Get in on the Act

Speaking of kids at the PGI convention, the Junior Pyros there always plan and execute one of the best shows of the week. The next generation of fireworkers is nurtured and brought along slowly and safely. Where would I be now if I'd started in all of this at the age of 15 instead of 35?

So, let's imagine we are bringing some materials and supplies to the PGI convention, and we are going to build a few of these fine rockets. I'll actually scale this project so that 10 of these babies can be constructed in a two-day period.

I will arrive on site, and begin building on Friday morning, with the goal of flying some rockets Saturday night. I'll want to plan my activities according to a time-line.

Before I even leave for the event, I accomplish a few things on the project: Print out all how-to articles and formulae. Unwind 40 feet of 16-ply cotton string with which to make black match.

Untwisted 16-Ply Cotton String

Clean all my rocket tooling and lubricate with Sailkote (by Team McLube, available online or at sailboat distributors). This is a great lubrication product, which allows the tooling and spindle to release very easily from the rocket motor and tube. I also spray it on my star plates, comet pumps, and the aluminum rod I roll my match-pipe on.

SailKote Spray Lubricant

Treat and cut my rocket tubes to 7-1/2 inches.

Ten 3/4-Inch ID, 7-1/2-Inch Long, Rocket Tubes

Roll twelve, 18-inch lengths of paper quick match pipe

Paper Match Pipe for Quick Match

Rip rocket sticks on my table saw. I like to rip sticks out of clear poplar from Home Depot. A 5-foot piece of 1x3 will yield 18 sticks, 5/16-inch square. It is also possible to use round wood dowels, but I much prefer square sticks. 5/16-inch square sticks are nice because I can rip a 5/16-inch wide by 3/4-inch strip off my 1x3, and when I rip that strip in half, my 1/8-inch thick saw blade leaves two 5/16 x 5/16 square sticks.

Bundle of Freshly Cut Rocket Sticks

Tasks to accomplish on Friday:

- Making 40 feet of blackmatch
- Making 10.5 ounces of black powder for header-burst, and for star and comet priming
- Mixing, dampening, screening, and drying the rocket fuel
- Pumping and priming stars
- Pumping and priming glitter comets

That ought to be a good day's work, and after drying things overnight in the drying chamber, I ought to be able to assemble some rockets on Saturday.

Getting to Work on Friday Morning

I first set up my work station; I have a pop-up tent, work tables, and a chair. I'll need extension cords and a generator if no electricity is available where I'll be working. I might need a light if I get delayed too much on my timeline as I chat with pyro-pals. Some plastic sheeting can come in handy in the case of a sudden rain shower.

I have my drying chamber in which to dry various products as they are produced. It'll be especially handy to have an electric outlet somewhere, even if it's not right at my work station, so that the dryer can be plugged in there and left running all night long.

I have my tool box with my miscellaneous hand tools, my measuring cups and spoons, my little digital scales, some funnels, my miter box and saw for cutting tubes on site, and the various supplies which will be mentioned as I go along.

I've brought along some food and a cooler of drinks, so I don't have to pause for long in the midst of my pyro activities.

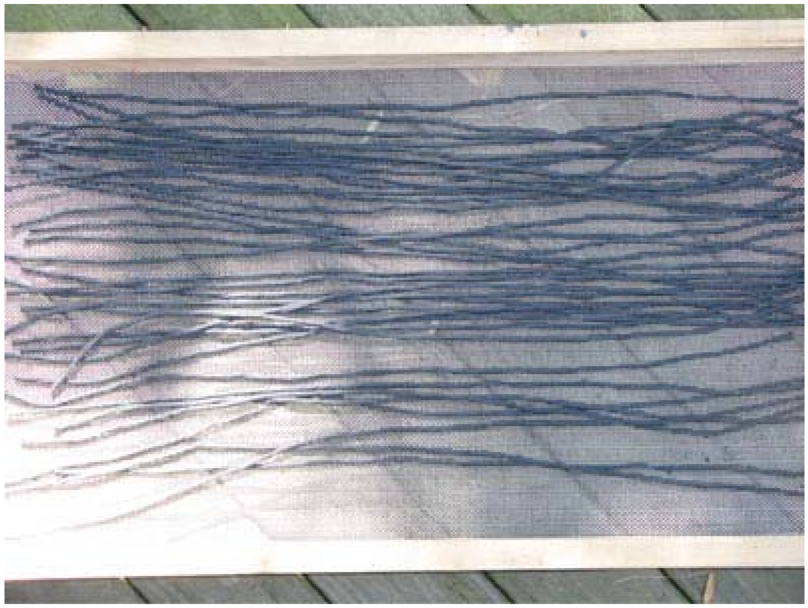
Note: As I go along describing this project, I'll be applying materials and methods that I have described in the articles above. I will not be re-citing those articles in the text below. I'll trust you have the references available and are familiar with them.

Making Black Match

I take the 40 feet of my untwisted string and make black match out of it. It's a nice, warm, sunny and breezy day, so I string it up between two trees, tied onto nails, to dry. Before it gets dark, I'll cut it into 18-inch lengths and put it on a screen in the drying chamber.

For this batch of match, I used a formula with a slight variation. 15 ounces of potassium nitrate, 3 ounces of commercial airfloat charcoal, 2 ounces of sulfur, 0.8 ounce of dextrin, and 0.2 ounce of CMC (Skylighter #CH8080). This batch took about 14 ounces of water, added carefully and stirred in with a paint stirring stick, avoiding getting the slurry too wet.

Replacing one-fifth of the dextrin in the original formula with the CMC produces a nice, smooth black powder slurry, which does not separate as I use it, and which produces a nice, smooth coating on the string.



Black Match Ready for the Drying Chamber

Making 10.5 Ounces of Black Powder

I run 7.5 ounces of potassium nitrate, 1.5 ounces of airfloat charcoal, 1 ounce of sulfur, and 0.5 ounce of dextrin through my 100 mesh screen and onto a piece of kraft paper. I know from experience whether or not the individual chemicals will pass the 100 mesh screen, and if one won't, I'll run it through my blade-coffee-grinder first to pulverize it. I never run mixtures through the grinder, only individual chemicals.

Then I run the mixture through the 40 mesh screen in order to intimately mix it.

I weigh 3 ounces of this mixture into a plastic tub, add enough water to it to make a putty out of it, and grate it through the 4 mesh screen. This will become black powder granules to be used to burst the shell headers. I have determined that it will take 0.3 ounce of this powder for each of the ten headers.

This granulated black powder, made with dextrin as the binder and not ball-milled, is called "polverone" rough powder (see Pyrotechnica IX, Traditional Cylinder Shell Construction, by A. Fulcanelli), rather than a hot black powder. I don't want a hot powder; I simply want to ignite the stars in the headers, and pop the headers open, allowing the lit stars to cascade down in a "horsetail" effect.

The remaining 7.5 ounces of the powder is set aside to be used for priming the stars and comets.

Granulated Polverone Black Powder

Making the Rocket Fuel

John Steinberg, Kurt Medlin, Steve Majdali, and Brent Anderson teach a "Black Powder Rockets for Beginners" seminar several times throughout the PGI convention week each year. It's a wonderful, hands-on seminar in which the basics of BP rockets are taught, and folks actually get to make a rocket of their own to take out to the rocket range and fly.

They use a rocket fuel formula which creates a pretty rocket tail during flight, has enough power to lift a nice heading, yet is foolproof enough that even beginners can ram a rocket and have it fly every time.

Each of the ten motors in this project will use 2 to 2.5 ounces of the fuel, so I'll make up a 24-ounce batch of it.

That formula is:

Basic Black Powder Rocket Fuel

Chemical	Percentage	24 ounce batch
Potassium nitrate	0.6	14.4 ounces
Airfloat charcoal	0.1	2.4 ounces
80-mesh charcoal	0.18	4.3 ounces
36-mesh charcoal	0.02	0.5 ounces
Sulfur	0.10	2.4 ounces

The potassium nitrate, airfloat charcoal, and sulfur are all screened through the 100 mesh screen. Then the coarse charcoals are added to the mix and it is all screened through the 40 mesh screen 3 times, and shaken in a closed tub to completely mix it.

Then enough water is sprayed onto the powder to dampen it to the consistency of brown sugar: just slightly damp, so it will barely stay together in a ball when squeezed in a fist. The water is worked in with gloved hands, and the fuel is pushed through the 16 mesh kitchen colander screen several times to fully integrate the moisture.

The fuel is then pushed through the 8 mesh kitchen colander screen and onto kraft-paper-lined screens to sit out in the sun and breeze during the day. I bring it in to dry in the drying chamber overnight.

The dry, mixed powder, can be used as-is before granulation, but wetting and granulating it significantly decreases dust during the motor ramming and probably increases the power of the fuel.

Rocket Fuel Drying on Kraft-Paper-Lined Tray

Making Stars for the Rocket Headings

I want a slow-burning star which will form a "horsetail" when ejected from the rocket headings. One of my favorite stars is Willow Diadem, which is a long-burning, charcoal, Willow star, with the inclusion of some ferro-titanium and titanium for metallic sparks in the stars' tails as they fall.

I'm going to use 2 ounces of the stars in each of the 10 rockets, for a total of 20 ounces of stars.

Willow Diadem Stars

Chemical	Percentage	20 ounce batch
Airfloat charcoal	0.66	7.8 ounces
Potassium nitrate	0.53	6.25 ounces
Sulfur	0.18	2.15 ounces
Dextrin	0.12	1.4 ounces
Ferro-titanium 30-60 mesh	0.08	0.9 ounces
Ferro-titanium 40-325 mesh	0.08	0.9 ounces
Titanium, medium spherical	0.05	0.6 ounces

Note: The original formula, as it has been passed around, specifies the metals as fine FeTi, medium FeTi, and medium Ti sponge.

This composition is made into 3/8-inch pumped stars and primed on one end. To prime them, I simply spritz them with a little water as they all stand on end in a tray, dust on a little of the BP prime that was set aside earlier, and spritz them lightly again. Then I tumble them a bit and place them on a drying screen.

Pressing the Rising tail comets

The plastic can shells that I'll be using for the rocket headers are 2 inches in diameter, so I want to press 1/2-inch thick comets that same diameter. Each of these will use 1.5 ounces of D1 glitter composition, so I want to mix up 15 ounces of it.

D1 Glitter

Chemical	Percentage	15 ounce batch
Potassium nitrate	0.53	7.95 ounces
Sulfur	0.18	2.7 ounces
Airfloat charcoal	0.11	1.65 ounces
Aluminum, 325 mesh atomized	0.07	1.05 ounces
Sodium bicarbonate	0.07	1.05 ounces
Dextrin	0.04	0.60 ounces

This composition is mixed, dampened, and pressed into the comets, and then primed.

Stars and Comets Drying on a Screen

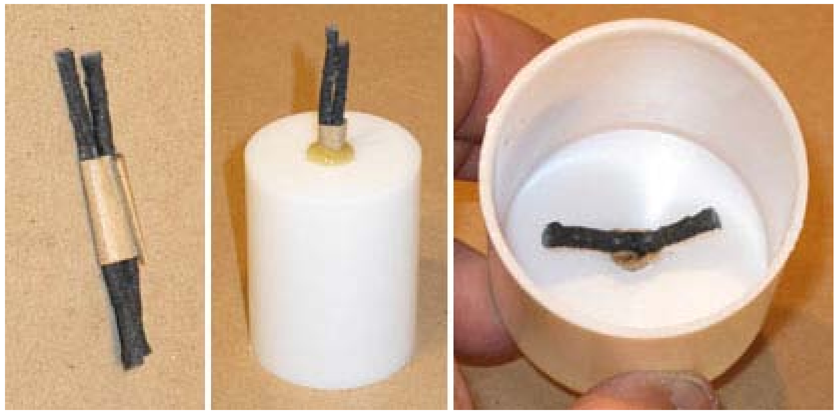
Everything that was in the drying chamber overnight is dry as a bone this morning. It's time to start making some rockets.

I'm going to assemble the headers first. These small shells will be identical to the 2-inch plastic can shells I described in Fireworks Tips #112, with a couple of exceptions.

Note: Similar headers can be assembled using kraft paper, paper discs, chipboard or manila folders, and glue if plastic shells are prohibited at a particular shoot site.

The fusing on the bottom of the shell will be quick match instead of time-fuse. I want the headers to pop at the same moment the rocket fuel burns out and passes fire out the top of the motor and to the header.

I cut a 1/2-inch long piece of the paper match pipe, insert two 2-inch pieces of the black match (cut with anvil cutters or a razor blade), pinch the pipe around the match and fold over the excess paper pipe. This fuse gets glued (hot-glue on the outside only), into the hole I previously drilled in the bottom of the plastic can (not the hole in the shell cap).



Quick Match Fuse Hot-Glued into Hole in Plastic Can Shell Casing

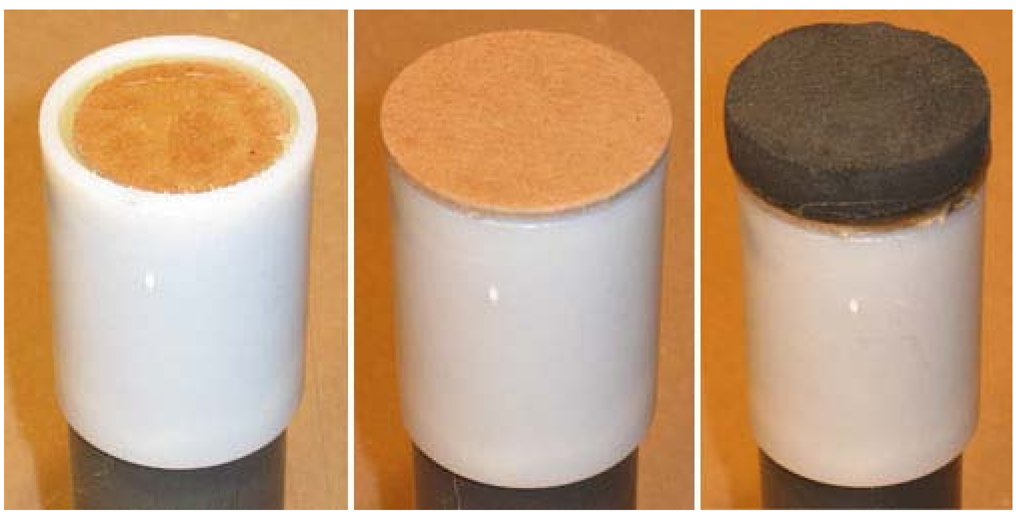
Then 0.3 ounces of black powder is poured into the shell, the tissue paper disc inserted, and then the stars are added.

Black Powder, Tissue Paper, and Stars Placed in Shell Casing

I use a coping saw to remove the fuse-hole protrusion from the plastic casing cap, and then I use PVC plumbing cement or thickened methylene chloride to glue the cap on the shell. The capped shell can be tapped with the handle of my awl, and as many more stars as possible can be introduced through the hole in the cap.

Cutting and Gluing on Plastic Shell Casing Cap

Next, a 1-1/2-inch paper disk is hot-glued into the recess of the shell's cap; then a 2-inch disk is glued on; and finally the comet is glued on.



Two Paper Discs and Comet Hot-Glued onto Plastic Can Shell

And that completes the assembly of a rocket header.

Completed Comet and Shell for Rocket Header

Ramming Rocket Motors

My work table has been cleaned up from the previous processes, and I've laid out my materials for ramming the rocket motors. Nozzle clay mixture, bulkhead clay mix, rocket tubes, rocket tooling, pounding post, rawhide mallet, 1/2-tablespoon measuring spoon, funnel, rocket fuel and paper cup.

Tooling and Materials Assembled and Ready-to-Ram Rocket Motor

The pounding post I actually use is 24-inches long. I like to work with a small amount of rocket fuel in a paper cup, keeping the tub of fuel closed rather than having it sitting open with all that fuel exposed.

All my tooling drifts have rubber o-rings on them to further minimize dust, which has already been reduced by granulating the fuel. The drifts also have 'do-not-pass' marks on them so they don't hit or get stuck on the spindle.

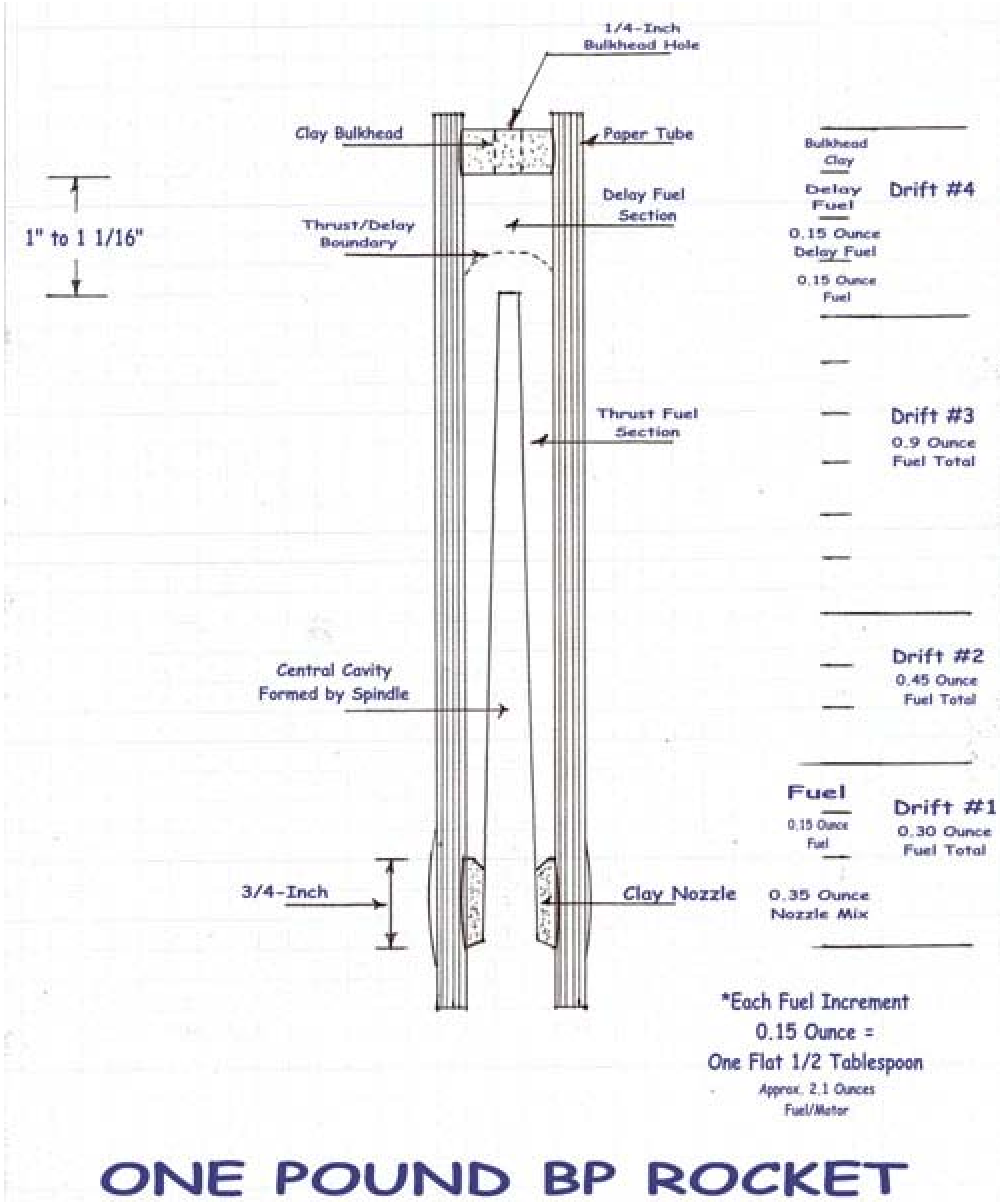
When hand-ramming these motors with the specified tubes, a tube support-sleeve is not necessary. Care must be used with the ramming/hammering so that you achieve good, consistent consolidation, without over-stressing or splitting the tube.

Note: I suppose the first real question that popped into my head back when I first assembled the materials to ram rockets was, "How will that dry clay and rocket fuel stick together with just pounding on it? Don't I need to moisten it or something?"

The answer is, "Nope." The dry powders will consolidate into a solid grain simply with the pressure of the ramming process. Pretty amazing!

Below is the kind of drawing I sketch up for each of my types of rockets once I dial them in. The sketches enable me to come very close to duplicating my results each time I make up another rocket of that type.

Of course, the details of the sketch will vary according to the exact tooling, tubes, and materials that are being used. But, if I keep those the same from batch-to-batch, the sketch becomes very useful.



Blueprint for One-Pound Black-Powder Rocket Motor

A tube is placed on the spindle, a flat 1/2-tablespoonful (0.35 ounce) of the nozzle mix is placed in the tube, along with the nozzle forming drift. Then, 8-10 solid whacks with the rawhide mallet will form the nozzle. I try to ram the tube hard enough to create a very small bulge in the area of the nozzle, without it being seriously deformed or split. This seats the nozzle more securely and reduces the chances of it being blown out.

I have determined that this amount of pounding is equal to 1000 pounds of force being applied to the hollow drift, which is equal to about 3000 psi of pressure being applied to the composition. These are the figures I would use if I was using a hydraulic press to press these motors. With 1000 pounds of force, and with the solid drift, about 2300 psi would be applied to the composition.

When I begin to ram the fuel grain in the motor, I weigh out the amount of fuel that will be rammed with each drift, according to the specifications I've noted on the sketch, and put it in the paper cup. Then I scoop the fuel out of the cup, one increment (1/2 tablespoonful) at a time, until that amount of fuel has been rammed. Then I know it's time to switch to the next drift, and I weigh out the total amount of fuel to be rammed with that drift.

This keeps me from having to constantly be counting the number of increments I have rammed, or guessing if it's time to switch to the next drift.

The delay fuel at the top of the motor, approximately 0.3 ounce of it, is weighed out, and I add a flat 1/8 teaspoonful of fine spherical titanium to that fuel and swirl it around in the paper cup to mix the metal in. Then I ram those increments of delay fuel into the motor, being careful to only bring the fuel grain up to between 1 and 1-1/16 inches above the spindle.

This amount of delay fuel gives me the proper delay between the powerful thrust fuel burn, and the heading burst. When I was dialing the motors in, it is this amount of delay fuel that I adjusted to get the heading to burst at just the desired point in the rocket's flight.

Once the delay fuel has been rammed up to the correct height, I plunge the open end of the motor into the bulkhead clay to pack the void full of that clay. Then I scrape off the excess clay, and ram the bulkhead.

Using a 1/4-inch drill bit, I carefully hand-twist-drill a hole in the bulkhead, just barely into the fuel grain. This creates the passfire hole which will transfer fire from the motor to the heading when all the motor's fuel has been spent.

Twisting the motor off the spindle reveals a nicely formed central cavity. The motor is now ready for the final rocket assembly.

Bulkhead and Nozzle Ends of Black-Powder Rocket Motors

Final Rocket Assembly

Whew! The hard part of this project is done. Now for the easy part. I trim the black match sticking out of one of the headers so that it is just long enough to go all the way to the bottom of a motor passfire hole when the header is pressed onto the motor. Then I hot-glue the header to the motor, and reinforce the assembly with some strapping tape.

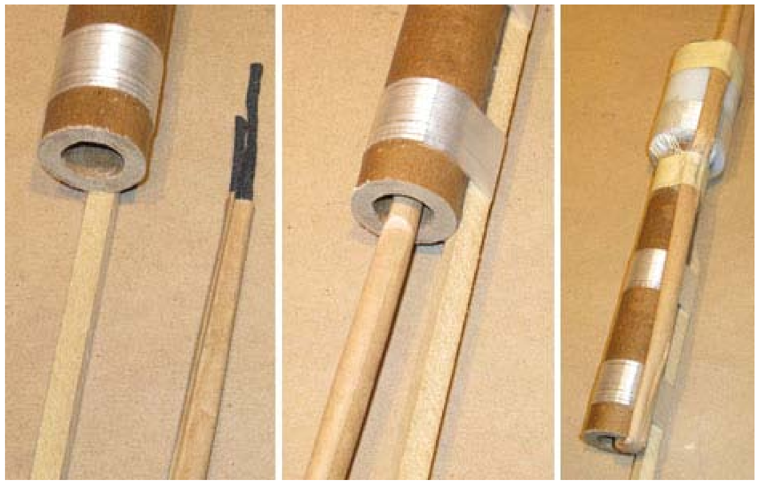
Rocket Motors with Headers Attached

Now I hot-glue and tape a 5-foot rocket stick to each motor. I glue the sticks on so that any bow in the stick curves it under the center of the motor. Instead of the stick curving out and away from the motor, or to the left or the right, I want it curving back in toward the centerline of the motor. I bevel the end of the stick with my anvil cutters to minimize drag (as if that big, clunky, flat-ended comet is aerodynamic).

Black Powder Rockets with Sticks Attached

It is now time to fuse these babies. I take two pieces of the black match I made, and slide them into one of the paper match pipes. One of the pieces of match protrudes from the pipe 2 inches, and the other one only 1 inch. The pipe is crimped around the match for about 4 inches, and that end of the quick match is inserted into the rocket motor as far as it will go.

Then I bend the quick match leader up alongside the motor, and secure it to the motor and header with masking tape.



Quick Match Inserted into Rocket Motor, Attached to Motor and Header

The quick match is folded over to the center of the comet, and bent upward. Using the awl, a hole is pierced in the match pipe, and an additional 4-inch length of black match is inserted into the pipe and bent onto the top of the comet. This end of the match will pass fire to the comet while the other end ignites the motor.

I want the comet to ignite just slightly before the rocket motor does, so that the comet is really emitting its fire as the rocket starts to ascend.

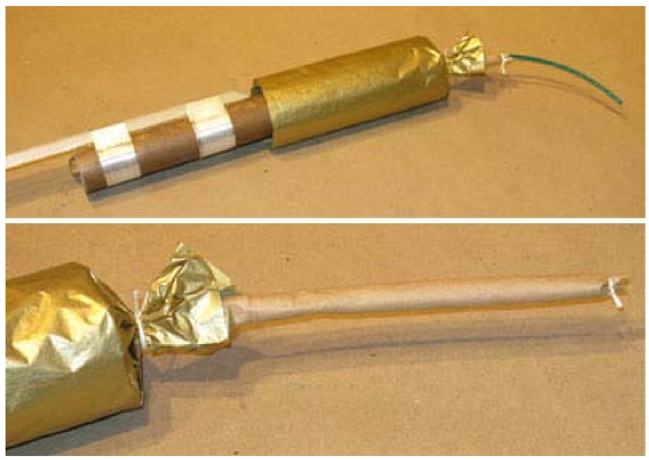
The quick match and black match are held in place with lengths of masking tape, and the quick match is cut with the anvil cutters to a length of 3 inches above the comet.

Quick Match Leader and Black Match Passfire Attached to Top of Comet

An 8-inch square of light tissue paper or wrapping paper is wrapped around the comet and header, and hot-glued to itself only. This creates a loose wrap which will protect the comet from unwanted fire, but will burn and fall away as the rocket ignites and ascends. This wrapper is tied around the quick match leader.

A piece of visco fuse is secured into the end of the leader, and a reusable safety cap, made of more match pipe, is installed to protect all the fusing from sparks (and to make the whole deal look a little more finished and pretty.)

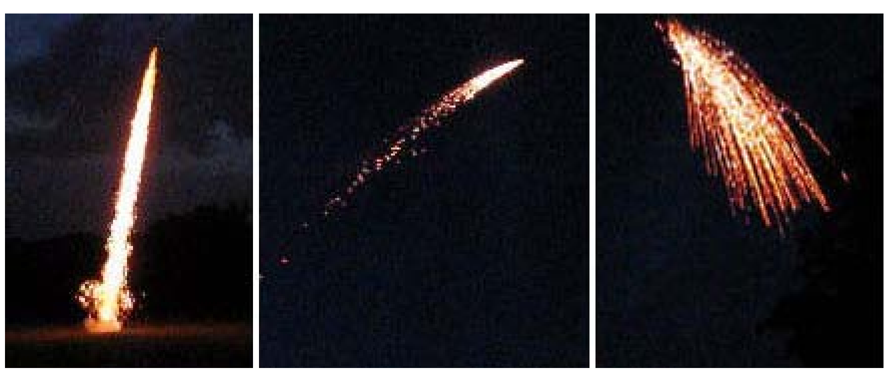
It's funny, but over the years I've seen other pyros who get to the point where they want to put as much effort into making the outside of their devices as attractive as they hope the performance of the inside will be.



Loose Protective Wrapping Installed Over Comet, Visco Fuse and Safety Cap Installed

The Finished Product

Two days. I started with nothing but a few chemicals, some materials, and a few basic tools. Now I have a finished product that I can watch the video of, and look at the photos of, and I can step back and say, "Yep, I'm proud of that." That's why I got into all of this in the first place.



Finished Black-Powder Rockets in the Air

I'm gonna go back and watch that rocket video a few more times. I hope you can follow these tips, create some of your own tricks, and come up with something you can be really proud of. Perhaps we'll see the results at the next PGI convention.

Line Rocket

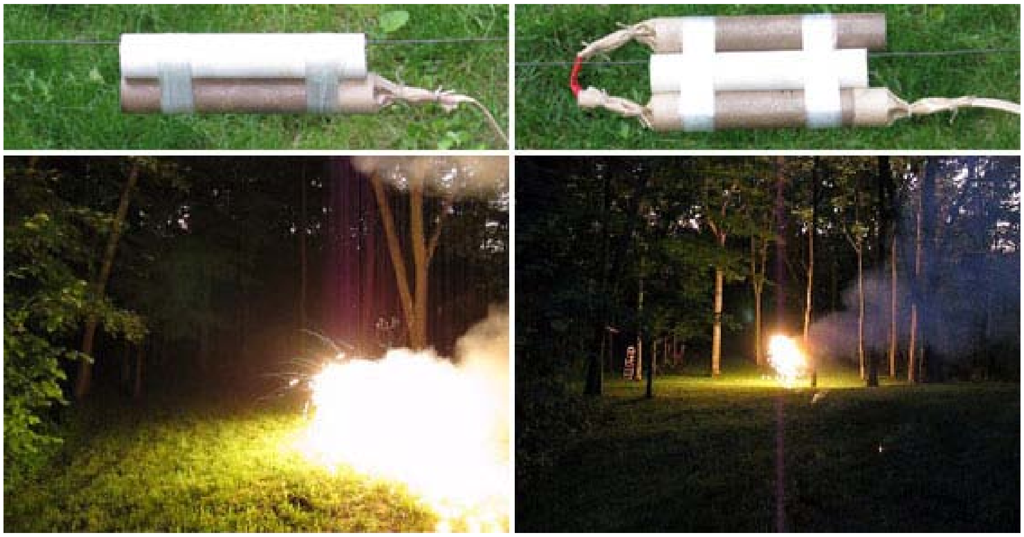
Introduction

This piece was excerpted from a larger article entitled Using Homemade Gerbs Creatively, as Waterfalls, Wheel Drivers, Set Pieces, and Line Rockets. For details on rocket construction, see that article.

By Ned Gorski

With one last little bit of creativity, I assembled a couple of line rockets from my homemade gerbs. The first one had one driver (this type of rocket makes a nice effect flying into a bonfire as the fire is lit). The second one had two drivers in opposite directions, one burned then passed fire to the other, produced a back-and-forth flight.

In both cases, the gerbs were taped to a piece of PVC plumbing pipe which has the same OD as the fountain tubes. The pipe is installed on a length of iron wire as the wire is strung tightly between two solid supports, like trees. In this case, in order to develop enough thrust with the Ti gerbs, I drilled the nozzles with a 3/16-inch drill.



Line Rockets

(Click Image to Play Video)

In his book, Introductory Practical Pyrotechnics, Tom Perigrin has some fun ideas for other creative variations on the line-rocket theme. Rat Packs, Jeweled Rats, Pigeons: So many experiments, so little time.

How to Make Fireworks Rockets with Green and Red Tails

By Dave Stoddard

Learn several formulas for making various colored rockets as well as the techniques for making them.

Materials Needed

- Barium nitrate (CH5101, CH5102)
- Bentonite clay (CH8078)
- Coffee grinder
- Magnalium, -325 mesh powder (CH2078, CH2079)
- Naphtha
- PVC powder (CH8216)
- Paraffin wax
- Parlon (CH8210)
- Rocket press
- Rocket tooling (TL1204)
- Strontium nitrate (CH5543)
- Vaseline

Thanks to Dave Stoddard for supplying this little article. These magnalium rockets are really quick to make using a rocket press. They're uncomplicated, yet very different than your average black powder rocket. Enjoy.

I have developed a couple of magnalium-based rocket pyrotechnic formulas over the past year that work well for rockets in the one pound to four-pound range. The benefit of magnalium-based rocket compositions is that they can be mixed, pressed, and flown in a matter of minutes. There is no potassium dichromate to mess with, and no drying time or extended prep time required for the rocket composition. This makes these rockets ideal for people to be able to build and fly on the same day.

First, some background -- Doc Steinberg and Doc Barr originally came up with a magnesium red rocket pyrotechnic formula that was published in the PGI bulletin in the late 1990's. The problem with the magnesium rockets was that it took too much time to prepare the rocket composition, and the use of potassium dichromate in the mix made it nasty to work with.

I developed a magnalium pyrotechnic formula based on the original magnesium pyrotechnic formula, and Doc Steinberg worked with me to tune the choke, pressing forces, and other elements to get the rockets to perform well. If you build these rockets correctly, a four pound rocket will fly at least 1500 feet high, or more.

Doc Steinberg and I published the first pyrotechnic formula, for red magnalium chuffer rockets, in the December 2004 PGI journal. I have since gone on to develop formulas for green and yellow rockets as well.

I flew four-pound versions of the red, green, and yellow rockets at the recent FPAG 4F event in November. Note that all of these rocket compositions are pressed on standard black powder rocket tooling using a choke (nozzle) that is as tall as the inside diameter of the tube is wide (on a tube that is 1-1/4 inch inside diameter, the choke would be 1-1/4" tall).

Red Magnalium Chuffer Rocket

The height of the choke is important as it makes the size of the exit smaller due to the taper of the spindle. The formula for red magnalium chuffer rockets is as follows:

Ingredient	Parts by Weight
Strontium nitrate	55%
Magnalium, -325 mesh powder	28%
PVC powder	10%
Parlon	7%
Vaseline (dissolved in naphtha)	+2%

I grind the strontium nitrate in a coffee grinder to get it as fine as possible. DO NOT grind mixed ingredients! I have since discovered that the VM&P Naphtha is responsible for the chuffing effect, and allowing the naphtha to evaporate completely from the mix results in no chuff whatsoever.

With good strong paper tubes, like the parallel tubes sold at Skylighter, you could probably omit the Vaseline altogether. Do not use Vaseline if you are making this rocket composition for one pound (3/4 inch ID) rockets or smaller.

If you look at the oxygen percentage in the strontium nitrate (by molecular weight), you find that $Sr(NO_3)_2$ is 45.36 percent oxygen. I suspected we could make a green version of this pyrotechnic formula by substituting barium nitrate for strontium nitrate.

Barium nitrate is 36.73 percent oxygen, so you need to increase the percentage of barium nitrate to get the same quantity of molecular oxygen as in the red pyrotechnic formula. We had the first successful flight of this pyrotechnic formula at a Crackerjacks shoot. Here is the pyrotechnic formula for the green magnalium rockets:

Green Magnalium Rocket Formula

Ingredient	Parts by Weight
Barium nitrate	60%
Magnalium, -325 mesh powder	25%
PVC powder	9%
Parlon	6%

The barium nitrate is ground fine in a Wal-Mart coffee grinder before use. Note that there is no Vaseline in this formula. We omitted it, as barium nitrate is not as vigorous an oxidizer as strontium nitrate.

These four pound rockets fly perfectly. You could probably add 5% VM&P Naphtha if you wanted to get them to chuff (a nice effect), although I have not tried this for the green rockets yet.

Finally, if you look at the color spectrum, you will find that yellow is between red and green, based on angstrom wavelength of the emitted light. I estimated that a mixture of 60% green pyrotechnic formula and 40% red pyrotechnic formula would create a nice yellow magnalium rocket.

I flew these at the FPAG 4F shoot in November 2005 with excellent success. In one particular flight, we estimated that one of the yellow rockets went over 2500 feet by counting the time between rocket heading break and the time we actually heard the report (about 2.5 seconds).

If you were to mix a yellow rocket composition without mixing the individual red and green rocket compositions, the pyrotechnic formula would look like this:

Yellow Magnalium Rocket

Ingredient	Parts by Weight
Strontium nitrate	22%
Barium nitrate	36%
Magnalium, -325 mesh powder	26.2%
PVC powder	9.4%
Parlon	6.4%

With my rocket press, I have been using 2600 pounds of force to press these rockets. If you have a copy of the PGI article John and I published in December 2004, I provide a calculation for converting pressure to force based on the size of the ram in your press. You can use more force, but the additional compaction slows the burn rate somewhat. All of the chemicals and paper tubes that were used to make these rockets were purchased from Skylighter.

For four-pound rockets, we used sticks that were 1/2" square and 7 feet long. The rocket tooling we used was standard black powder rocket tooling (from Skylighter, Wolter, or Harrison).

The choke (nozzle) is made from bentonite clay. I add 30% grog and 5% additional paraffin (Gulf Wax) dissolved in VM&P Naphtha. The percentages are very loose here. Some people use more fire clay; some do not use any.

Mix the bentonite and fire clay together. Then melt the paraffin wax in the naphtha and mix the melted wax into the clay. Spread the clay out on newspaper and let the naphtha evaporate from the mix. It only takes 30 minutes for the naphtha to evaporate in 70 degree, sunny weather.

A few safety notes: Don't hammer these rocket compositions. They are equivalent to a form of flash powder. Wear cotton clothing and appropriate safety gear when mixing and pressing these. Don't make these rockets if you do not have a legal place to make them. It isn't worth the risk.

Colored Rocket Fuel Formulas

By Rich Harrison

Materials Needed

- Ammonium perchlorate (CH5005)
- Barium carbonate (CH8025)
- Barium nitrate (CH5101, CH5102)
- Black powder, Meal D
- Charcoal, airfloat (CH8068)
- Chlorowax (CH8075)
- Copper oxychloride (CH8098)
- Dextrin (CH8107)
- Ferro-titanium, 30-60 mesh (CH8110)
- Hexamine (CH8142)
- Magnalium, 275 mesh (CH2080, CH2081)
- Parlon (CH8210)
- Potassium perchlorate (CH5400, CH5402)
- Red gum (CH8230, CH8231)
- Screen, 30 or 40 mesh (TL2003, TL2004)
- Shellac (CH8255)
- Strontium carbonate (CH8310)
- Strontium nitrate (CH5543)
- Sulfur (CH8315)
- Tooling, rocket, various sizes
- Tubes, parallel, various sizes

Colored Rocket Compositions

After playing for two years with the latest craze stinger missile rockets, and making all the sizes from 3/8 bore to the (and I believe I made the first) monster 6 lb., and garnishing them with all kinds of things from whistles to stars to aerial shells to cross-breaking quad stars and such, I'm starting to get bored.

I've wondered hard and searched high and low for articles and whatnot on colored rockets. I thought to myself, that new ruby red firework star pyrotechnic formula that's going around would make a fantastic rocket, if I could make the right size spindle.

Starting at the 4 oz. rocket size, I figured I could scale it up or down later. It took four tries carving up some 1/2" stainless in the lathe before I got one to fly...and then only so-so. The fifth try got it! I cut up some 1/2" bore cases to 2" long (these burn longer than black powder rockets).

The nozzle is 1/4" thick when rammed in and has a 0.1" bore made from the diameter of the spindle. The total spindle length is a tad over 1" (1.050"). So if you look at a cross section of the rocket, you see 1/4" thick clay nozzle, 3/4"+ of core in the comp, 1/2" comp solid over the spindle and finished with a clay plug.

I've shot about 20 of these so far with no problems (other than the need to shoot more--the color is unreal). I've been ramming these cautiously with leather gloves and facemask on in case the drift decides to take off. Pressing may work fine too.

Ruby Red Rocket Formula

Ingredient	Parts by Weight
Strontium nitrate	50
Potassium perchlorate	8
Parlon	18
Magnalium, 275 mesh	12
Charcoal airfloat	5
Sulfur	5
Red gum	2
Dextrin	+5

This particular spindle also worked with my blue and purple pyrotechnic formulas, although with a little less thrust. BUT! Here's the interesting part. Some of them CHIRP like birds in the early lift off!

My Blue Rocket Formula

(Variant from Baechle)

Ingredient	Parts by Weight
Potassium perchlorate	70
Copper oxychloride	10
Red gum	7.5
Chlorowax	7
Hexamine	2.5
Dextrin	3 (leave out of rocket composition)

My Purple Rocket Formula

(Variant from Baechle)

Ingredient	Parts by Weight
Potassium perchlorate	23
Ammonium perchlorate	40
Copper oxychloride	5
Strontium carbonate	12
Red gum	5
Shellac (helps remove some of the yellow from flame)	5
Hexamine	7
Charcoal airfloat	1.5
Chlorowax	1
Dextrin (leave out of rocket composition)	4.5

My ultimate favorite green pyrotechnic formula and expensive (from Weingart) - 9:1 barium chlorate to shellac composition - blew up! So I started carving up stainless again. It took three tries. This spindle is as long as the ruby-composition spindle but has a nozzle bore of 3/16" (0.187"). I kept the case length the same, 2", and the clay nozzle the same, 1/4" thick. I rammed it hard.

This mix I am real careful ramming (barium chlorate, remember?). I have had no incidents as yet. Thrust is good and the green fire is there from launch to burnout. This guy also chirps/sputters on take off.

Feeling confident at this stage, I decided to scale up to the 3/4" bore. Green composition first. No matter what or how I manipulated the spindle, the barium chlorate composition detonated every time. So, I abandoned the above green composition (I was getting too nervous ramming it anyway) in favor of some other potassium perchlorate pyrotechnic formulas. Although I could get these others to fly halfway decently, they would not give me the green thrust flame I wanted.

Hold everything! Why not substitute barium nitrate for the strontium in the Ruby Red pyrotechnic formula? Bingo! I went back to the 1/2" bore case and the 3/16" nozzle and it flew first try, but a little lazy and the green was a slight yellow.

This is starting to look like Bob Veline's green. Added some barium carbonate and the green came into play. Then to tweak the spindle, I cut it down to give me a 0.150" bore nozzle, and the rest is history.

Feeling twice as confident now, I scaled everything up to the 3/4" bore case about 3" long and before I did any calculations for the spindles, as the case reminded me of a stinger, I tried my existing stinger spindle as a regular rocket (no side hole for spin).

Polock Green Rocket Formula

Ingredient	Parts by Weight
Barium nitrate	50
Potassium perchlorate	8
Parlon	18
Magnalium, 275 mesh	12
Sulfur	4
Charcoal airfloat	4
Red gum	2
Barium carbonate	6

I've noticed that these colored rockets are a little hard to light, so I've been dribbling some 60-40 flash down the throat before taping in the fuse. Priming an end of some visco with Bleser's strobe igniter mix works excellently.

All pyrotechnic formulas above are in parts by weight, and mixed thoroughly by passing through a 30 or 40 mesh screen at least 4 times. I leave the dextrin binder (normally used when making stars from these compositions) out.

Finally, I managed to design an extremely thin, long spindle to get Dave Bleser's Blond Streamer composition to fly. Still using the 1/2" bore cases, 2" long, the spindle gives me a nozzle bore of, are you ready?.. 1/16" diameter and is a little longer than before, being 1.125" this time. You have to use Harry's skinny visco to light these. These take off real lazy; therefore you need a long, lightweight stick, 1/8 x1/8 x 25-30" long. The tail/streamer/fire is incredible! It blankets the launch pad and streams out 25-30 feet+ in flight.

Blonde Streamer Rocket Formula (Bleser)

Ingredient	Parts by Weight
Meal D	60
Charcoal airfloat	20
Ferro-titanium, 30-60 mesh	15
Dextrin (leave this out in rocket composition)	5

Results

Ruby Red flew magnificently.

Polock Green flew magnificently.

My Blue and My Purple flew, but lazy.

Re-cut a new spindle (skinny stinger) to give me a 0.20" nozzle and they flew much better.

Just imagine these FX rockets/drivers powering some wheels! I can!

DISCLAIMER: I WILL NOT BE RESPONSIBLE FOR ANYTHING Because of misinterpretations and or misuse of information presented.

Firefly Aluminum Powder Rocket Composition

By John Dudley

Learn a pyrotechnic formula for making rocket fuel using firefly aluminum powder.

Materials Needed

- Aluminum, firefly (CH1050, CH0155)
- Ball mill
- Boric acid (CH8042)
- Lampblack (CH8170)
- Potassium nitrate (CH5300)
- Sulfur (CH8315)

Firefly Aluminum Powder Rocket Composition

Ball mill the lampblack, sulfur and potassium nitrate together for two hours, just like making black powder. Next, mix in the firefly aluminum powder and boric acid. Make regular black powder rockets with this. Use a NON-SPARKING material to ram the rockets.

Makes a long streak of firefly sparks mixed with red/orange sparks from the slowly burning lampblack. This is a VERY fun rocket composition to mess around with. Like any other pyrotechnic device, experimentation is required when using this rocket mixture. Be careful!!!

Firefly Rocket Composition

Ingredient	Parts by Weight
Potassium nitrate	75
Lampblack	15
Sulfur	10
Firefly aluminum	6
Boric acid	3

How to Make Rocket Nozzle Mix

By Ned Gorski

Materials Needed

- Bentonite clay
- Funnel
- Grog
- Measuring spoons
- One-gallon paint can
- Oven
- Paraffin wax
- Rawhide mallet
- Rocket tooling, one-pound (TL1211)
- Rocket tube (TU1068)
- Scale

If you look in the end of most black powder rockets, or at the end of a gerb (fountain), you'll see a nozzle recessed into the end of the paper tube.

A Nozzle in Paper Tube

A nozzle is a mechanical device with an orifice (hole) in it, which controls and directs the flow of a liquid or gas as it passes through it. Think of the nozzle you put on the end of your garden hose. It controls the water flow, builds up higher pressure in the hose than would normally be there, and projects the water out in a nice stream. A rocket nozzle does essentially the same thing with the combustion gasses from the motor. This is what propels the rocket skyward.

Typically, the nozzle in a rocket, and the solid plug at the top of the rocket motor's fuel grain, is a rammed (hand pounded with a mallet) or pressed (with a hydraulic or mechanical rocket press) mixture of wax, clay, and grog. Some folks use only clay in their nozzles.

I did that for a while, but found that the clay was very susceptible to shrinkage/expansion, depending on the day's humidity. One time I pressed a bunch of wheel drivers with only bentonite clay nozzles, here in the Midwest hub of humidity. Then, when I got out to Gillette, Wyoming, which was so dry my lips started cracking, my nozzles got so loose in the tubes that I could turn them with my finger. (I quickly added a ring of Elmer's glue where the nozzle met the tube to secure them.)

Some folks expect their nozzle apertures to close a bit with the clay's expansion. So, right before flight, they open the hole up to the correct diameter with a hand-twisted drill bit. Wax makes the clay much less prone to this problem.

Also, the clay alone, when pressed, forms a smooth, glossy surface and nozzles and plugs have been known to get blown out of the tube by the pressure of the fuel burning. The grog in this mix really helps the nozzle 'bite' into the side of the tube and resist blowout.

The grog also helps the nozzle resist erosion of the hole during motor burn, whereas without the grog, the clay can wear away some and the nozzle aperture (hole) opens up some during the motor burn, which reduces pressure and thrust.

The technique I use to formulate these ingredients and mix them together is similar to the one David Sleeter recommends in his Amateur Rocket Motor Construction book.

I get the wax that I like to use from the canning supplies department of my grocery store. It reads "Household Paraffin Wax, for canning, candle-making, and many other uses." (I'm not sure why they don't list rocket nozzles on the box as one of those uses.)

Paraffin Wax for Making Nozzles

I either use bentonite clay from Skylighter or Hawthorne Bond Fireclay. They are both very fine, powdered, dry clay. (When I first started making rockets, I imagined that 'clay' that should be like putty, or that I had to turn the dry clay powder into a 'play-dough' by adding water. We live and learn. No water is ever added to the clay.)

Grog is a man-made, sand-like product. It is made from fired pottery, crushed and screened. One well known rocket maker uses crushed red-clay flower pots. Another uses busted up and screened ceramic floor tile.

I get my fine-medium grog from my local pottery supply house. Skylighter sells grog which has fine, medium and coarse (up to the size of peas) particles in it. To use that, I screen out the coarse grit to end up with something that looks like fine-medium sand. A fine-meshed kitchen screen colander works well for that.

For a batch of nozzle mix, I weigh out:

- One of the 4 ounce wax blocks from the box
- 30.5 ounces of the clay
- 15.5 ounces of the grog

Weigh Your Clay and Grog

Now, I add the clay and grog to a new, clean, one-gallon paint can that I get at Home Depot. After installing the lid, I shake the can to mix the two powders. Then, I open the can, make an indentation in the center of the dry mix, and lay the block of wax in the indentation.

Place Block of Wax in Can with Clay/Grog Mix

I then lay the lid on the top of the can loosely. (Caution, do not put the lid on tightly Pressure can build up during the heating and either burst the can or pop the lid off, sending wax and clay everywhere, and possibly causing injury.) The can, with the loose lid, is then put in my oven, set at 250 degrees, and cooked for about 1-2 hours or until the wax is completely melted into the dry mix.

Heat Can at 250 Degrees for 1-2 Hours

OK, OK. So my oven ain't so clean. I'll have to get on my wife, Molly, about that. Yeah, right. Oh, waitaminnit. That's the corn meal and cheese drippings from my pizza cooking on the bottom of it. Never Mind...

I don't use my kitchen oven lightly for this project. In fact this is the only time I do use it in my pyro pursuits—for cooking nozzle mix. I absolutely never use it to dry or heat any pyrotechnic compositions. Never. And I keep the heat in this process down at 250 degrees to prevent the wax from igniting. Puhleez, be mindful and careful.

Once the wax has completely melted into the dry mix, you'll see that it has only dampened about half of the clay/grog. The other half is still dry. This is remedied by removing the can from the oven with oven mitts-believe me the whole rig is hot-removing the loose lid, and stirring all the ingredients with a paint stirring stick until the wax is well incorporated into the clay. During this stirring, I only grabbed the can without an oven mitt once.

Mix Melted Wax with Clay/Grog Thoroughly

After stirring the mix with the stick, I install the lid, tightly this time, and, holding the can with oven mitts, shake the can violently to really incorporate the wax into the mix. Then, while the mix is still warm, I open the can and screen the mix through an old, wire mesh, kitchen colander onto kraft paper and let it cool down completely.

Screen Mix to Remove Lumps

This screening process really helps further integrate the wax into the mix, and also removes any waxy lumps which may form, which I just pitch out. The finished Nozzle Mix product will look like a tan, medium grained sand. I put it in an empty 5 lb. plastic chemical tub marked 'nozzle mix.'

I have another tub marked “bulkhead mix.” This mix is the same as the nozzle mix, but with the grog portion simply replaced with more clay. I use this bulkhead mix in many driver and rocket motors, where I'm not concerned about needing the grog in the bulkhead (top clay plug) to prevent blowout.

The advantage to this mix is that I can easily hand-twist a drill bit to create a passfire hole in the plug. If the mix had the grog in it, it would be very difficult to twist the bit through it, and the bit would get very dull quickly. So, let's pound a nozzle up, remove it from the paper tube, and see just what sort of component this new nozzle mix will produce. Whaddaya say?

Using a Skylighter, one-pound, 1/4" wall rocket tube (TU1068), some one-pound rocket tooling (TL1211), a rawhide mallet (I swear by this mallet), and a 6 x 6 x 4 ft. tall pounding post, I'll pound a nozzle into the tube, using a heaping 1/2 tablespoon measuring spoon and a funnel.

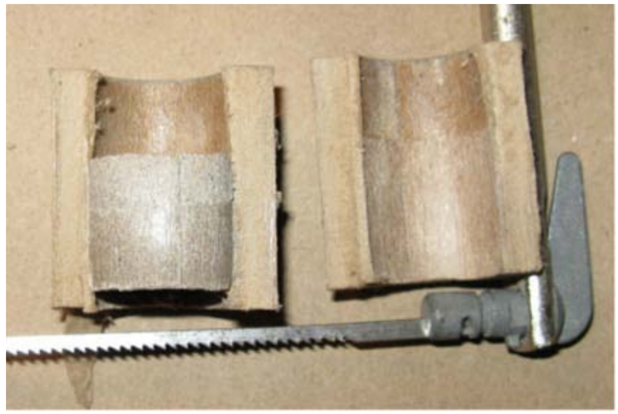
You might notice that black rubber O-Ring (from Home Depot) I like to use around my rocket tooling drifts. Between Skylighter, Home Depot, and the kitchenware department of my local department store, I get enough stuff to stay busy forever. The O-rings really help keep dust down. But my nozzle mix is not very dusty to begin with.

One nice tip, which I got from Tom D, is to soak the rocket tubes in Minwax Wood Hardener and let them dry. This will strengthen the tubes and make them more fire-resistant. I'll dip the tubes into a can of the hardener, let them set there for a minute, remove them, and stand them on end on some plywood scrap to dry.

Rocket Tooling - Note Black O-rings

Ram Mix into Tube with Nozzle Forming Tool and Mallet

8-12 nice whacks with the mallet and the nozzle mix is well consolidated. Now, to dissect this nozzle a bit, I use a coping saw to cut the paper tube off right above the nozzle, and slice the tube on both sides of the clay. You can see how the nozzle mix has consolidated into a solid mass, bulging the inside of the tube out just a bit in the process, which really locks the nozzle into the tube.



Cross Section of Cardboard Tube Showing Nozzle

Nozzle Removed from Tube

If you tap a metal spoon against the side of the clay nozzle, it “tinks” like a little piece of solid ceramic. Nice.

In the future, we'll have an article on how to build a one-pound, black powder, charcoal-tailed rocket based on the foundation that has been laid in this article. One really nice thing about these rockets is that they provide great pyro and immediate-gratification, even in the winter months. Make up some nozzle mix, blend together some fuel, pound a motor together, attach it to a stick, and take 'er outside to fly. Smell the Smoke.

2

Aerial Shells

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Film Canister Shells

By John Shupe

Learn how to make aerial shells using plastic film canisters.

Materials Needed

- 12" long, 1-1/2" ID plugged tube
- Black powder (FFFg & meal)
- Film canisters
- Firework stars
- Hot-melt glue gun & glue
- Mallet
- Masking tape
- Mothballs
- Nitrocellulose lacquer (CH8198)
- Plastic bags
- Pliers
- Soldering iron
- Utility knife
- Visco fuse (GN1000, GN1001, GN1004)

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This is a great project if you are new to firework shell making or are cursed with a small space in which to shoot your experiments. Thanks to John Shupe for providing this well written and clear article. This is a reprint of an article that originally appeared in the "The Fire Flies," the quarterly newsletter of the Michigan Pyrotechnics Arts Guild.

I was given a guest pass to the Pyrotechnics Guild International convention in Muskegon, Michigan in August of 1996. I hadn't realized that such a thing even existed. I joined the PGI the following week. I started surfing the Internet and gathering information on pyro subjects. I soon learned to winnow the pyrotechnic wheat from the "kewl bomz" and "Jolly Roger's" chaff.

One article that caught my attention early on described making aerial shells using plastic film canisters. I tried it and liked the result. This article chronicles my own experience building film canister shells. It will quickly become evident to even the most casual reader that this article is not the final word on building these elegant little devices. These are the techniques and materials that have worked for me. I make no claim that the reader will get safe or satisfactory results based on the information in this piece. I will leave that determination up to the reader.

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I would also like to acknowledge Dr. Stephen Haussmann of Athens, Georgia. Stephen has presented seminars on the construction and firing of film canister shells at each of the last three PGI conventions, written articles on the subject for the PGI Bulletin, pushed the envelope of film canister shell effects (including "stealth" lampares and mini crossettes), and has been an invaluable resource for me as I learn this craft.

Why Build Film Canister Shells?

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Film canister shells are appealing on many levels. For the beginning firework shell builder, film canister shells offer an excellent entrée into the world of shell construction. A careful builder can learn the basic concepts of simple shells and obtain satisfactory results fairly quickly.

Film canister shells require minimal investment in construction materials, tools, live compounds, and equipment. Chances are, most budding pyros already own the simple equipment needed to build a film canister shell. My basic toolkit consists of a hot-melt glue gun, a fine-tipped soldering iron, utility knife, and various homemade scoops. Mortars are built from commonly available materials.

Experienced pyros have found film canister shells to be a convenient and practical way to test new star compositions, since film canister shells can be fired immediately after construction. Often it is easier to judge the quality of a star composition when it is viewed as part of a group at 100 feet in the air, rather than a single star shot 30 feet in the air by a star gun. Film canister shells have also been employed as rocket headings and inserts for larger shells.

Because of the smaller scale of the devices and the relative simplicity of the manufacturing process, building film canister shells presents a somewhat lower risk factor as far as accidents are concerned. This is not meant to imply that the probability of accident is any lower.

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Indeed, proper pyro safety protocol must be followed at all times. But should an accident occur, you are typically dealing with quantities of live materials measured in tens of grams, rather than hundreds or thousands. This can be the difference between a severe burn and a traumatic amputation.

Construction

This article explains the basic techniques used in the construction of film canister shells. The article assumes that the reader has access to basic pyrotechnic materials such as black powder, visco fuse, and nitrocellulose lacquer (NC).

Finding Film Canisters

Unless you are a very ardent photographer, you will probably need to locate a source for a supply of empty 35mm film canisters. Try to find a camera shop that caters to professional and advanced amateur photographers. These camera shops usually do film developing on site and typically amass large numbers of film canisters that they are more than willing to part with for free. The first time I went into my local shop I walked away with two grocery bags full and could have had twice that many had I wanted.

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Film canisters come in two basic styles. The canisters used to package Kodak film typify one style. This type of canister is usually made of HDPE and has a lid that is larger than the OD of the canister itself. This style of canister seems to be the canister of choice among most shell builders, especially those working to perfect the symmetrical break.

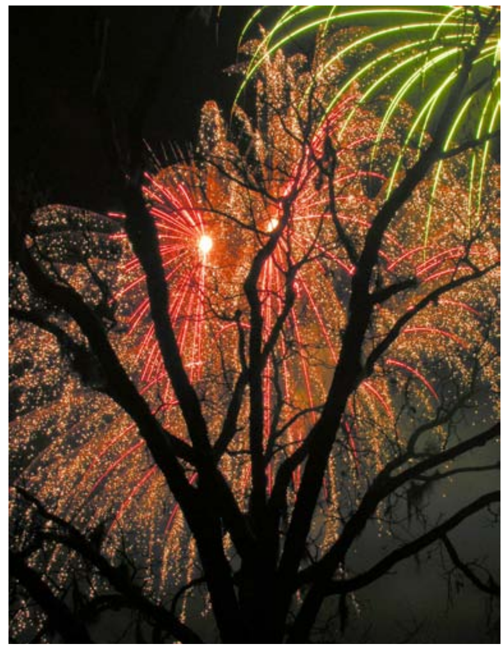
The second type of canister is typified by those used to package Fuji film. This canister is usually made of a translucent plastic that is somewhat brittle. The lids on these canisters are effectively smaller in diameter than the body of the canister and snap into the canister lip rather than over it. Canisters of this type have been used in the construction of multi-break salami shells and are preferred by the author for building solid-state "stealth" lampares.

You may run across a third type of container in your bag of goodies from the photo processor. The new Advanced Photo System (APS) film comes in an asymmetrical canister that is unsuitable for mortar-fired firework shells, though they do show some promise as inserts for larger, conventionally built firework shells.

Time Fuse

One of the most basic challenges facing any shell builder is devising a way to delay the ignition of a firework shell's contents until it has reached a sufficient height above the ground to be both aesthetically pleasing and safe. Time fuse and rammed spolettes are the two most common devices used to accomplish this task in standard shell construction.

Neither device, however, is optimal for film canister shells. Because of the small scale of the film canister shell, space is at a premium and the relatively large diameter of standard time fuse or spolettes leaves too little room for "payload." Instead, common green 3/32-inch visco fuse is modified to serve as a narrow diameter time fuse.



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Because of the "side spit" inherent to visco fuse, some means must be employed to insulate the shell contents from the visco fuse's fire until the appropriate moment. Several schemes have been devised to accomplish this and each has its proponents. Each general method is described below.

One method to create time fuse from visco fuse involves taking a short length of visco fuse and wrapping it tightly with two or three layers of aluminum foil. Care should be taken to make sure that the foil conforms closely to the surface of the visco. The foil-wrapped visco fuse is then wrapped with an additional two layers of masking tape. This method creates a reliable time fuse.

A variation on this method involves using electrical shrink tubing in place of the masking tape. The tubing is slipped over the foil-wrapped visco fuse and then shrunk using a heat gun set on low heat. This method creates a reliable and slick looking time fuse. I am not convinced, however, that this method offers a big enough performance advantage to offset the higher cost of materials and the additional risk of using a heat gun around energetic compounds.

Yet another method uses a thick layer of hot melt glue, applied to the visco fuse during the installation of the visco fuse into the canister lid or body, as a barrier. This is the method that I used when I first started building film canister shells and it works well. But it has several drawbacks.

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The method can be inconsistent and great care must be taken to apply a uniform and adequate coating of hot melt to the visco fuse, with particular caution paid to eliminating air bubbles from the coating. This method is really only suitable for fusing film canister shells through the lid, since free access to the visco fuse on both sides of the shell wall is required.

This method can be both messy and irritating since it requires fairly large gobs of molten glue and all the attendant mess and risk of burns until the glue cools. And of course there is the added risk of using a hot glue gun around bare visco fuse.

My preferred method involves simply wrapping a short length of visco fuse with four or five layers of 1" masking tape, eliminating the foil used in the first method described above. I have found that 1" tape affords a nearly ideal delay for the typical film canister shells. Some shell builders have expressed concern that a simple tape wrap around the visco fuse, leaving out the foil layer, can lead to a "quick match" instant-burn effect. In making and using several hundred film canister shells, I have not experienced this particular failure and consider it unlikely to happen if sufficient care is taken to wrap the tape tightly around the visco fuse.

I usually make the time fuse as a separate operation from firework shell construction and make enough time fuse during each session to meet my anticipated near term needs.

Technique

Using a utility knife with a sharp blade, cut green 3/32-inch diameter visco fuse into enough shorter 1-1/2-inch pieces to meet your needs. For each visco fuse piece, use a 2-inch length of 1-inch wide masking tape. Position the masking tape so about the same amount of bare visco fuse is exposed on either side of the tape.

Tightly roll the masking tape onto the visco fuse. A 2-inch piece of tape will wrap around the visco fuse about four times. The end result will look like a hot dog, with the green visco fuse "sausage" protruding past either end of the masking tape "bun." The protruding ends will be split and primed later in the building process.

Building a "Stealth Lampare" Film Canister Shell

One dilemma universal to all beginning firework shell builders is the question of what to put inside the shell. For most beginners, access to bulk firework stars or other professional inserts is limited. Traditionally, consumer (Class C, 1.4G) fireworks have provided a ready source of insert material, either through "repurposing" stars scavenged from marginal cakes or candles or by using class SC devices themselves as inserts (bees, jumping jacks, and firecrackers come immediately to mind). I have had good luck with class C inserts, using a gram or so of FFFg black powder as burst, though I would recommend priming each device with nitrocellulose lacquer and meal powder.

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Most builders will eventually want to move on to other effects. One of the great pleasures of building your own shells is the opportunity to create effects not usually seen in commercial product. One of my favorite effects is the aerial fireball, or lampare, effect. In large-scale fireworks, creating a lampare involves lifting a firework shell consisting of a gallon or so of volatile liquid in a plastic bottle along with a charge of several ounces of flash powder.

The shell is timed so that the flash powder charge ignites at the apogee of the shell's flight, simultaneously dispersing and igniting the liquid.

The result is an angry red fireball shot through with tendrils of malevolent black smoke, inevitably eliciting atavistic grunts of admiration from the pyros in the crowd. A similar effect can be easily and relatively safely recreated, on a smaller scale, using film canister shells.

The "stealth lampare" (so-called because it produces the fireball without the loud report of a traditional lampare) uses a solid-state mixture of powdered naphthalene and black powder. The naphthalene is obtained from common mothballs.

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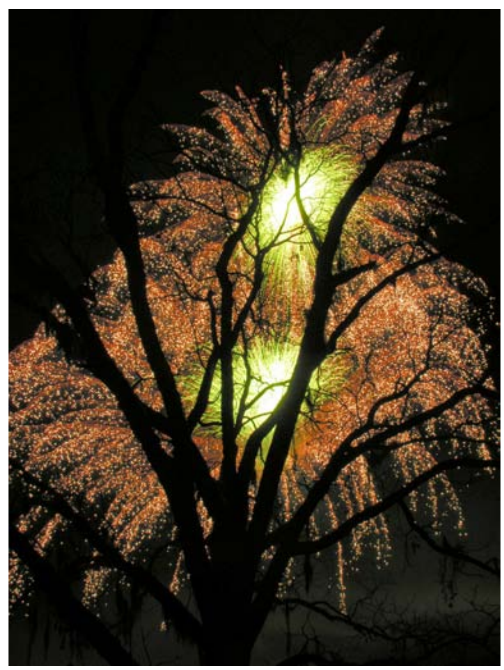
The mothballs are "baggie-milled" by being placed in several layers of plastic bags and then crushed using a mallet. The crushed naphthalene is then sifted through a window screen, with the fines that pass through the screen used in the mixture and the chunks that stay returned to the baggie for additional "milling."

The naphthalene powder is combined with meal powder in a weight ratio of 2:1. The resulting "salt and pepper" mix is then used as filler in the film canister shells.

I use the following process to build a film canister shell lampare:

Remove the cap from a Fuji-style film canister. Create a 1/8-inch hole in the bottom of the film canister body. Any of several methods can be used to create the hole. I use a pencil type soldering iron with a narrow tip to melt a hole. I have also used a 1/8-inch drill bit chucked in an electric screwdriver or a scratch awl to make the visco fuse hole. The most important thing is that the hole be just big enough to let the prepared time fuse fit snugly.



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Take a tape-wrapped visco fuse and, using a sharp utility knife, cut the exposed visco fuse on either side of the tape on an angle. The idea here is to expose as much of the powder core of the fuse as possible. Dip one end of the visco into NC lacquer and immediately dust with meal powder. This primes the fuse, ensuring the transfer of fire from the fuse to the shell contents.

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Using needle nose pliers or a hemostat, grasp the unprimed end of the time fuse. Thread the visco fuse through the hole in the bottom of the film canister from the inside of the canister, taking care not to damage the exposed fuse. The fuse should end up wedged snugly through the hole in the bottom of the canister, with the primed end of the fuse situated inside the canister body. Carefully position the fuse so it is approximately centered in the hole.

Apply a generous gob of hot melt glue to the junction where the masking tape-wrapped visco meets the outside bottom of the shell. Avoid touching the tip of the gun to the exposed fuse. I have never had the fuse ignite from the heat of the glue gun, even when deliberately touching the gun directly to the powder core, but prudence is always the wisest course when dealing with fireworks.

Once the glue is applied, I like to give the fuse a quick twist in the hole to make sure that there is a good seal between the visco and the shell wall. A good seal is essential to ensure that the fire from the lift charge cannot pass prematurely to the contents of the shell. Set the fused shell aside to cool.

After the glue is cool, fill the shell with the "salt and pepper" mix. Fill the canister about 3/4 full, clean the lip of the canister, and snap the plastic lid in place. Make a single wrap of masking tape around the top of the shell, overhanging the edge by about half the width of the tape. Pleat the overhanging tape down onto the lid.

Other than this–done more for a fire seal than anything else–no spiking is required for film canister lampares. Indeed, over-spiking the shell will cause it to function as a weak salute, rather than create a fireball. Dip the exposed visco into NC lacquer and dust with meal powder.

At this point you can add a lift cup and leader or use the firing scheme described below. To add a lift cup, I have found that the pleated, white paper catsup cups from fast food restaurants work quite nicely. Attach a quick match leader, long enough to reach up and out of the mortar being used, to the cup with a dab of hot melt glue, making sure that a sufficient length of black match is exposed in the bottom of the cup.

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Place about 9 grams of FFFg black powder in the cup. Apply a generous bead of hot melt glue around the perimeter of the bottom (the end where the time fuse is protruding) of the film canister (again, taking great care to avoid touching the primed visco fuse) and immediately apply the loaded lift cup to the shell. In most cases, the primed fuse is in direct contact with the lift charge.

I have yet to have an ignition failure with a primed visco fuse/lift cup combination. Finish the shell with a piece of visco attached to the end of the leader. Film canister shells prepared in this manner can be fired from any sufficiently stout 1-1/2 inch ID plugged tube. I use tubes constructed from Schedule 40 PVC pipe. Each tube is approximately 12 inch long, and each is plugged with a standard PVC cleanout fitting. *[Ed. note: we recommend you never use PVC as a mortar. Paper tubes are available, and are much safer.*]

On June 30, 2000, the film canister mortar firework shell stealth lampare made its first recorded appearance in a commercially shot public display. Summit Pyrotechnics featured a 12/20/40-shot barrage, built by the author, in a small-scale show shot in Muskegon, Michigan. The effect was well received, and integrated nicely into the rest of the show.

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Easy-to-Make 2-Inch Plastic Cylinder Shells

By Ned Gorski

Materials List

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- #5 Cylinder Shell (PL1020)
- Aluminum Foil Duct Tape
- Black Powder Coated Rice Hulls
- Disk, Chipboard, 1-1/2 inch
- Flying Fish Fuse
- Hot-glue
- Lift Powder, 2FA, Fg or FFg
- Masking Tape
- Methylene Chloride (CH8193)
- Paper Cup, small
- Plastic Bag
- Razor Blade
- Super-fast Paper Firecracker Fuse (GN1205), if not using quickmatch
- Time Fuse, 1/4-inch (GN2010)
- Tissue Paper

Introduction

After using flying fish fuse to make a reloadable star-gun cake, I thought it might be nice to go a little further and make some simple, small shells using that same fuse. I'll also make some star shells using the same methods.

These little, quick-and-easy shells are perfect for testing stars in a star shell, and also for simple shells for a backyard display. You can even attach gold glitter rising tails to the top of them.

With a little assembly line, a bunch of these small shells can be quickly made for launch the same day.

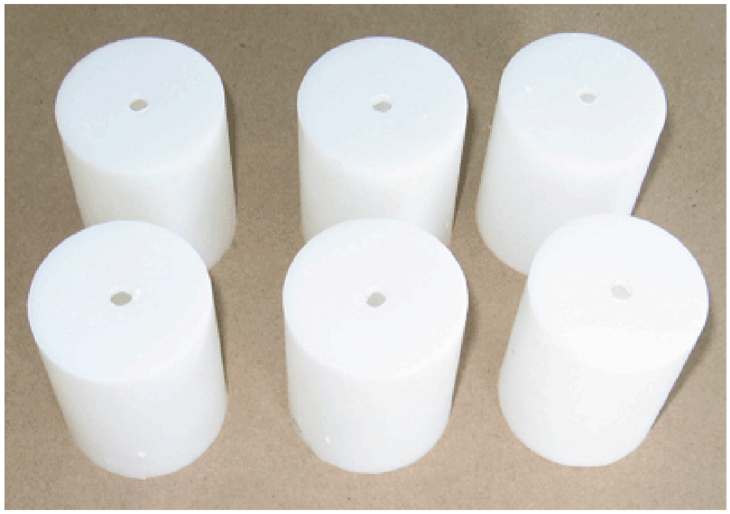
I'll be starting with Skylighter #PL1020 plastic aerial fireworks shell casings. These casings come with a 3/32-inch hole in the cap to accommodate visco time fuse. One could also use PL1022 casings, which come with a 7/32-inch hole in the cap. (I won't be using the fuse hole in the cap, so the size of the hole makes no difference.)

PL1022 Plastic Aerial Fireworks Shell Casings

I'll also be using 1/4-inch Chinese time fuse, GN2010, and super-fast paper firecracker fuse, GN1205. This same paper fuse can be used as a quick match leader by wrapping it with peel-and-stick aluminum foil duct-tape, or standard GN3001 quick match may be used.

Shell Construction

I will not be inserting time fuse in the caps of these shells, but through 1/4-inch holes drilled in the bottom of the plastic cans. This makes the assembly that I'm about to describe really easy.

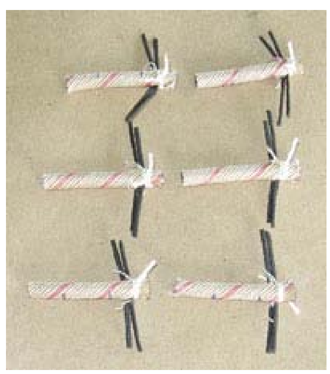


1/4-Inch Holes Drilled in the Bottoms of Plastic Shell Casings

In Fireworks Tips #99, One Way to Make a Really Nice 4-Inch Plastic Ball Shell, I describe 1/4-inch time fuse, how to determine its burn rate, and how to split and cross-match it.

The roll of time fuse that I'm currently using burns at a rate of 2.2 seconds per inch. For these little shells I want a 1.5-second time delay, which is about 5/8-inch of time fuse. I also add one inch to that length because I'll be splitting each end 1/2-inch for the cross-matching, so I cut 1-5/8-inch lengths of the time fuses for these six shells.

I split and cross-match one end of each fuse with short pieces of black match harvested out of the fast paper firecracker fuse or out of quick match.



Split and Cross-Matched Lengths of Time Fuse

After making sure the time fuses fit through the holes in the plastic cans, I put a ring of hot-glue around the mid-point of one fuse at a time, and insert the fuses into the plastic casings. I pull each fuse through until the cross-matching on the fuse is almost against the bottom of the can, keeping the cross-matching just out of the inside hot-glue.

Cross-Matched Time Fuse Hot-Glued into the Bottom of Shell Casing

Then I add another bead of hot-glue around the outside of the time fuse to really seal the lift gasses out of the shell when it is launched.

Time Fuses Sealed on the Outside of the Plastic Shell Cans

I fill the holes and recesses in the casing caps with hot-glue now.

Recesses in Shell Casing Caps Filled with Hot-Glue

In Fireworks Tips #96, I demonstrated Making and Testing High-Powered Black Powder. This article included several different ways of making and granulating black powder. In the following step, either granulated BP or BP coated on rice hulls may be used. Either commercial or homemade black powder would be suitable.

I fill the bottom of the shell can with BP coated rice hulls up to the level of the tip of the time fuse.

Shell Casing Loaded with Black Powder on Rice Hulls

Then I cut a circle out of cheap tissue paper and press it down on top of the black powder charge. A small paper cup, with the sides slit with scissors, is the perfect size for pushing the tissue paper down into the plastic can.

Pushing Circles of Tissue Paper into Plastic Shell Casings

Then it is a simple matter of filling the shell casings with stars or flying fish fuse, up to a level which will allow the caps to be glued on.

Shell Casings Filled with Flying Fish Fuse and Round Stars

Note: In some of these photos, I've temporarily taped the fused end of the shells that I'm working on onto the open end of empty casings so that the shell will stand upright during construction.

Next simply glue on the shell caps with PVC plumbing cement or thickened methylene chloride. I also further secure the cap on with a layer of masking tape.

Cap of Plastic Shell Casing Glued and Taped in Place

The outside end of the time fuse is now split with a razor blade, and cross-matching is inserted and tied in place.

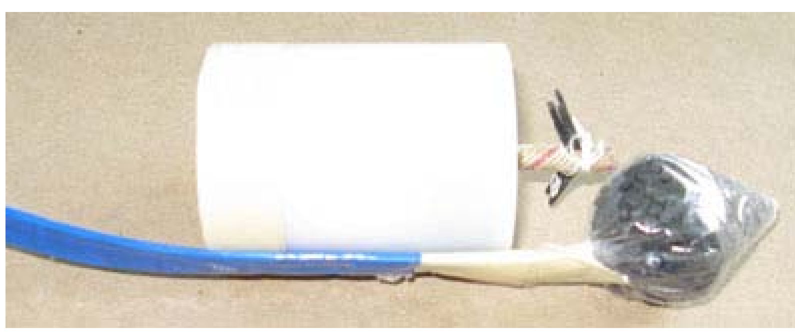
Time-Fuse, Split and Cross-Matched

Lifting and Leadering the Shells

I'll be shooting these babies out of a 2-1/2-inch HDPE mortar that I own. It's the smallest one that I have that these shells will fit into, and they will be a slightly loose fit.

I weigh out 1/2-ounce of 2FA lift powder for each shell. Fg or FFg commercial sporting black powder could also be used.

I place the lift powder in a plastic baggie, insert a piece of quick match leader with some of the black match bared, and tape the baggie closed around the quick match leader. The excess baggie plastic is trimmed off with scissors.

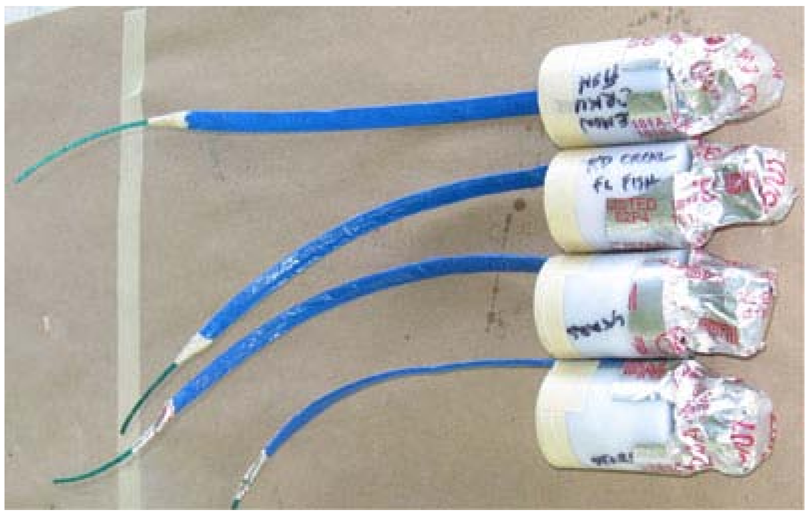


Black Powder Lift in Plastic Baggie, with Quick Match Leader

I hot-glue the leader to the side of the shell, and then I cover the lift powder and time-fuse with aluminum-foil duct tape.

Bottom of Shell Covered with Aluminum-Foil Duct Tape

Then I tape some lengths of visco safety fuse into the leaders, and the shells are ready to be loaded into mortars and fired.



Aerial Fireworks Shells Ready to Be Loaded and Fired

The Aftermath

My goal with this type of shell construction was the creation of a sort of "sky-mine" effect, where the shell contents are propelled out of the open end of the shell casing. I did not want the whole shell casing splitting open and bursting like a typical aerial shell. I thought the sky-mine effect would look better, especially with the flying fish fuse.

If I had wanted a more traditional shell starburst, I would have mixed the black-powder-rice-hull burst with the stars throughout the shell, and perhaps would have used some of the slow-flash booster.

The sky-mine type of burst was achieved with the shells made in this project, as evidenced by the plastic parts when they were retrieved from the field after firing.

Plastic Shell Parts after Shell Has Been Fired

Here's a link to a video of three of these little shells: one made with lemon crackling flying fish, one with red crackling flying fish, and one made with variegated (multi-colored) stars.

Three Shells Fired in Plastic Shell Casings

(Click Image to Play Video)

Note: I tried a shell with falling leaves fuse, and while some of the fuse pieces lit, many did not. I've heard that some of these "special effects" fuses, in order to ensure good ignition, need to be primed by dipping their ends in nitrocellulose lacquer and then in fine black powder. I did not try that, though, and will leave it up to the reader's experimentation.

A "Peanut" Shell Using Plastic Shell Casings

It is easy to construct a peanut shell with these small plastic shell casings. (A peanut shell is actually a shell that breaks twice, with a delay between breaks. It is called a peanut, because some shells made this way are constructed of two small, spherical shells. When taped together they resemble a peanut.)

First I construct two of the shells, in this case using multi-colored stars, using the same construction as outlined above, except that I want a one-second delay on the first shell, and a two-second delay on the second shell.

To accomplish this, I cut one piece of fuse 1-7/16-inches long, and the other piece 1-7/8-inches long. After splitting and cross-matching, this will produce the two delays I am looking for.

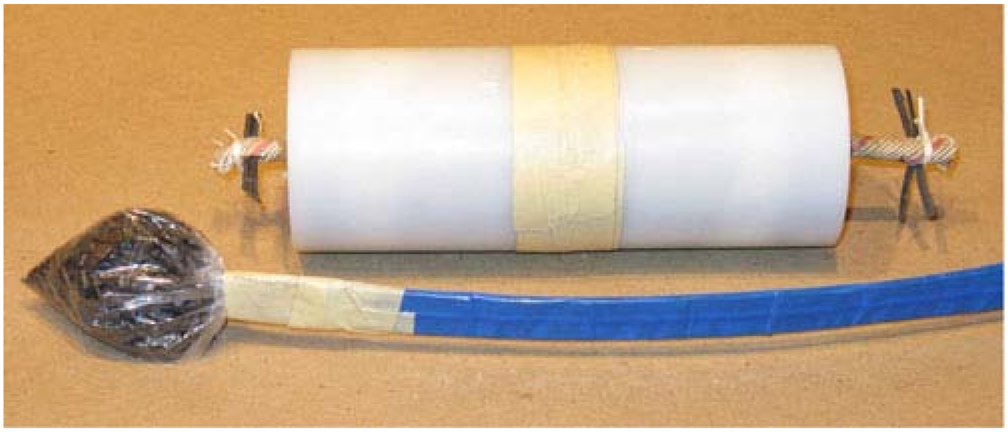
After I construct the two shells, I hot-glue 1-1/2-inch chipboard discs into the recesses in the ends of the shells to make those ends flat and flush.


Plastic Shell Casings and Time Fuse for Peanut Shell, and Filled Casings with Paper Discs Glued in Ends

Then, I hot-glue the two shells end-to-end, and cross-match the two time fuses. I also reinforce the joint between the shells with two turns of masking tape.

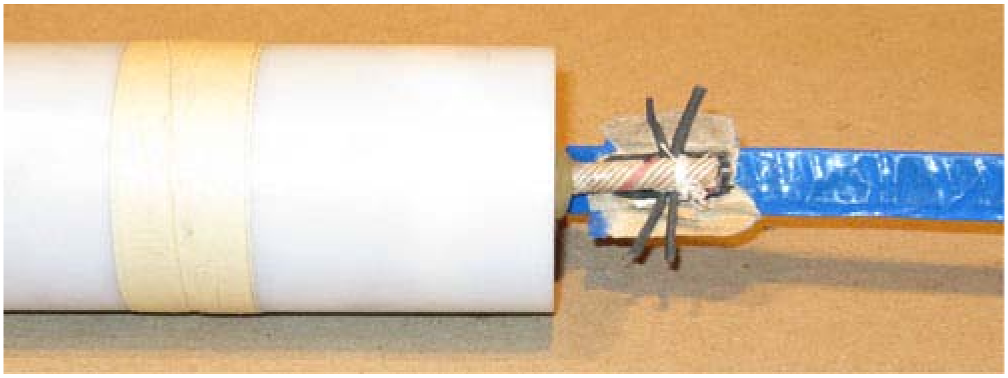
Assembled Peanut Shells with Cross-Matched Time Fuses

The shell is lifted and leadered as the shells above were, except I increased the amount of lift powder to 0.65 ounce.



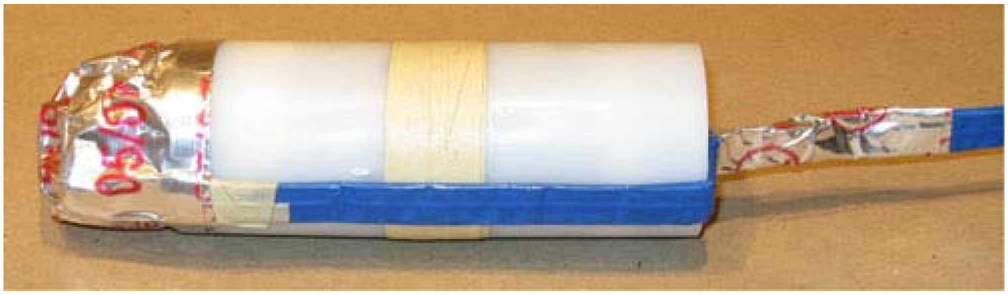
Lift Powder and Shell Leader

The quick match is hot glued to the side of the shell, and next to the top time fuse. I open up a small "window" in the side of the quick match so that fire transfers to the top time fuse when the leader lights.



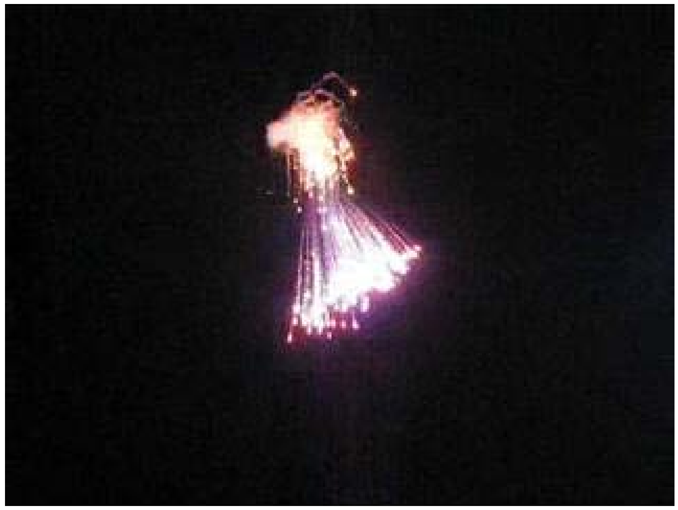
Passfire "Window" in Quick Match Leader at Upper Shell's Time Fuse

Then it's simply a matter of using aluminum foil tape to cover the bottom of the shell and the passfire "window" at the top.



Sealing the Shell's Top and Bottom with Aluminum Foil Duct Tape

Inserting some visco safety fuse finishes off the shell, and she's ready for the firing line. Here's a link to a video of this peanut shell.

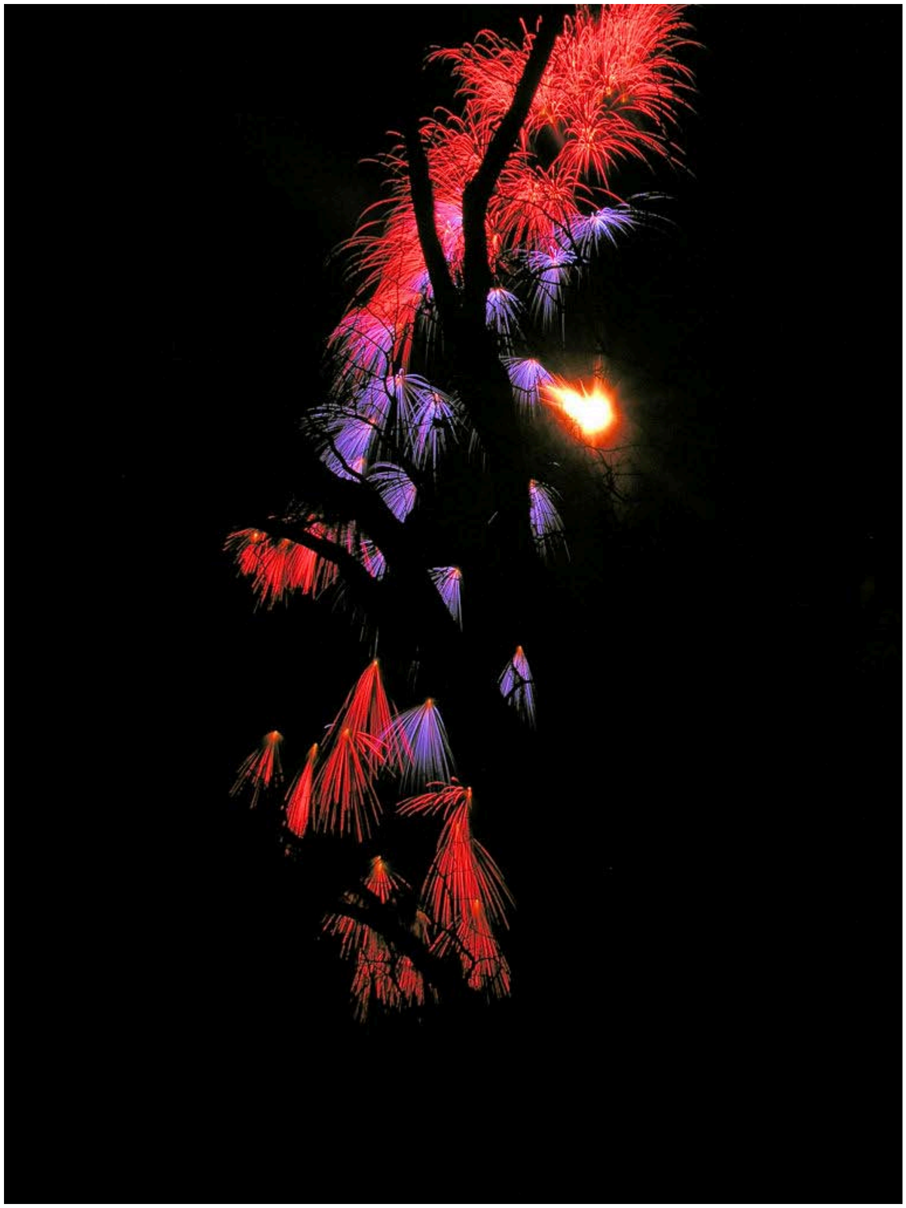


Peanut Shell or "Piled Shell"

(Click Image to Play Video )

Note: This type of shell, where the time fuses of both shells are ignited at the same time during the shell's lift out of the mortar, is called a peanut shell, or a "piled shell." A "multiple-break" shell is one in which each successive shell takes fire from the burst of the preceding one.

Have fun with these simple shells.



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How to Make Break Mix for Crossette Comets

By Harry Gilliam

Materials Needed

- Black powder
- Crossette comet
- Flash powder

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

I recently came by some fine-grained Goex black powder, around FFg or finer. A pyro friend and I were hashing over what the stuff could be used for, and he told me about a great crossette comet break mix which uses fine-grained black powder and flash powder. If you're unfamiliar with crossette comets, they are comets that, after rising or igniting, split into several pieces in the sky.

They can be constructed so that they split into either a precise number of pieces or into a random number of pieces. The comets are made with a cavity in their center. The cavity is then filled or partially filled with an explosive charge (the "break"). As the comets burn, the fire eventually reaches the break charge and splits the comets into pieces, creating the crossette effect.

My friend uses a break charge that is a mix of flash powder and fine black powder, 10 parts flash to 8 parts fine grained black powder (7FA or FFFFg or something in between). The reason for the black powder in the charge is to add some "fluff" to the flash powder. I have heard of people adding bran, sawdust, rice hulls, Cab-O-Sil, and other such agents to flash powder to aerate it, and thus speed up the burn/explosion, but this is the first time I had ever heard of black powder being used. Makes sense when you think about it. Black powder will burn quickly, the other agents won't.

My friend told me that this break mix works so well in his 1-1/4 inch crossette comets that he only uses about half of the volume of a .22-short caliber shell casing! The cavity in the comet is perhaps 3/8-inch diameter by 1/2 inch deep. (The best instructions I have seen for making crossettes can be found in the Fulcanelli article in Pyrotechnica IX, (BK0111)).

How to Make Black Powder Coated Rice Hulls Burst Charge

By Bob Svenson

Learn how to coat rice hulls with homemade black powder so they can be used as bursting charge inside an aerial shell. This is a much more economic burst composition than using straight black powder.

Materials Needed

- Black powder (homemade black powder or Meal-D)
- Charcoal (CH8062, CH8064, CH8066, CH8068)
- Dextrin (CH8107)
- Potassium nitrate (CH5300)
- Rice hulls (CH8236)
- Sulfur (CH8315)
- Water, warm

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Black powder coated rice hulls are commonly used as a burst charge in aerial shells. Many people have trouble finding commercial-quality fine black powder (called "meal" or Meal-D) to use for coating rice hulls for shell burst. Homemade black powder made by simply screening the ingredients together several times will burst shells just fine. The ingredients for black powder are:

- Sulfur
- Charcoal
- Potassium nitrate

Bob Svenson offers this tip for coating rice hulls with black powder:

"Here's a rice hull tip that was in American Fireworks News awhile back (from Tom Perigrin, I believe).

When making your (coated) rice hulls, divide the black powder up into 5 increments. Add 5% dextrin by weight to the first four black powder increments.

Now soak and drain your rice hulls as usual [for an hour in warm water]. Add the first increment of black powder and shake, rattle, and roll as usual. Add the next black powder increment, shake, rattle, roll. Repeat until there are four increments of black powder on the rice hulls.

Now for the secret to really nice rice hulls: do not add dextrin to the last increment of black powder! The dextrin makes the black powder sticky so it sticks to the rice hulls and to the next layer of black powder. On the last layer the rice hulls are already coated with sticky black powder so the dextrin-less black powder will stick just fine, BUT since the sticky rice hulls are coated with non-sticky black powder they won't stick together into lumps! Really shake the rice hulls good on the last black powder increment to break up the lumps and coat them with dextrin-less black powder.

This works great! It makes really nice and fluffy, individually-coated rice hull grains that make great aerial shell burst!

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Making 4-Inch Plastic Ball Shells

By Ned Gorski

Materials Needed

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

- Plastic ball shells, 4 inch (PL2060)
- Zinc stars kit (KT1010) or 1# of any stars
- Break/burst powder, 4 oz.
- Lift powder, 2 oz.
- Slow flash burst additive, optional
- 30" of quick match (or fast fuse and foil duct tape) (Skylighter #GN3001, or #GN1205) Fast fuse, if not using quick match
- Visco fuse (GN1000), 4"
- Time fuse (GN2000), 2"
- Cross match, (black match or visco cross-match, Skylighter #GN1010)
- Printer paper, 1 sheet
- Fiberglass reinforced strapping tape, or gummed kraft tape
- PVC cement
- Lift cup
- Hot glue gun and glue sticks
- Tissue paper (MS1110)
- Scale (TL5020, TL5030)
- String, thin
- Mortar tube, 4 Inch (PL3184)
- Shell support tubes

- Razor blade, single-edge
- Aluminum foil duct tape
- Rice hulls, optional (CH8236)

Introduction

In this article I am going to describe one way that I make 4" plastic ball shells. I want to emphasize the "one way" part, though.

In Volume 2 of Bill Ofca's Technique in Fire series, Design and Quick Assembly of 3, 4, and 5 Inch Plastic Ball Shells, some interesting and useful methods are described, and it was this booklet that I followed when I first started building plastic ball shells years ago.

Lloyd Sponenburgh has another way of building these shells, as described in his Passfire.com article, 4" Plastic Ball Shell. I've played with Lloyd's methods a bit as well. At regional club events, he has taught probably hundreds of folks how to build these shells his way.

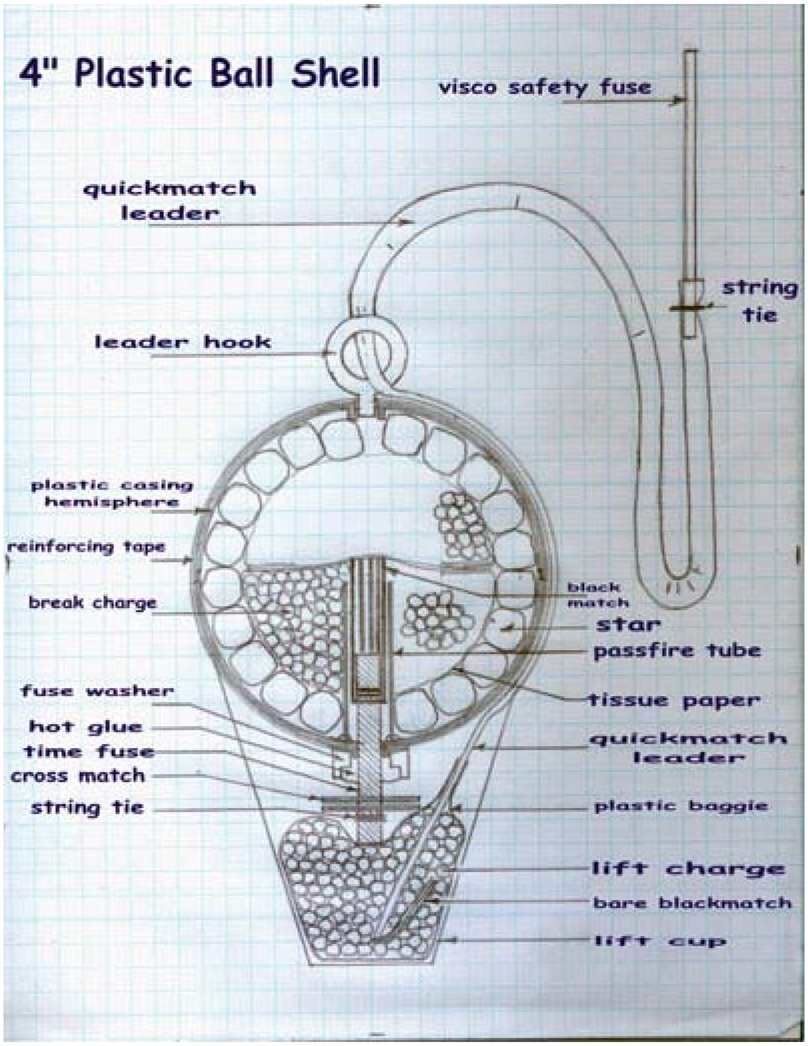
One thing that I've discovered over the years is that there are many ways to skin the cat in fireworking, and that there is much we can learn from each other. Usually each of us adopts a hybrid, personal way of doing things. And, each person's way can change and evolve over the years.

I do think my methods include some unique ways of approaching the subject, and I hope the information here can be useful to both the beginning fireworker and the seasoned pyro who is curious about how someone else does things. Suffice it to say, I am very pleased with how these shells perform using my method.

So, this article is simply a description of my current, personal, hybrid way of building these shells. But my way will probably evolve to be a little different in a year or two. Beyond just discussing how to build one of these shells, though, I'd like to ponder how to think about some of the various aspects of the shell's construction.

Parts of a 4" Plastic Ball Shell

First, look at the basic design of a 4" plastic ball shell in the diagram below.



4" Plastic Ball Shell Construction Diagram

Recommended Prerequisite Reading

Next, you may want to review the following articles. Parts of this project depend on the referenced articles below.

Making and Testing Homemade, High Powered Black Powder, Skylighter Fireworks Tips, newsletter #96

How to Make Cut Stars, Skylighter Fireworks Tips newsletter #97

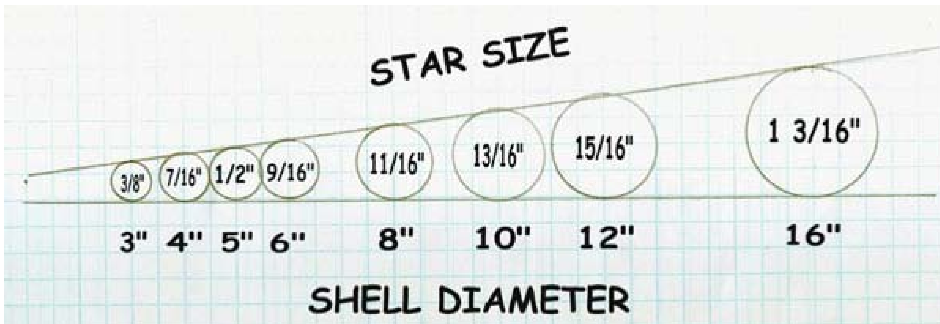
Wonderful Zinc Stars, Skylighter Fireworks Tips newsletter #98

The making black match and quick match sections of Skylighter Fireworks Tips newsletters #92 and #94, Nice Shells in 2 1/2 Days, Parts 2 & 4

The shell construction details in Nice Shells in 2 1/2 Days, Part 3, Skylighter Fireworks Tips newsletter #93

What Size Stars Should Be Used?

In Fireworks: The Art, Science and Technique (FAST), Dr. Shimizu includes a table on page 252 which lists shell sizes, and the corresponding recommendations for star size, number of stars, and amount of bursting charge. Based on that star sizing information, I've developed the following little graph:



Star Sizing Graph

This graph, of course, only shows a starting point when sizing stars for a shell. How fast does the star burn? Some burn much faster than others. Do I want a dense burst of smaller stars, or a “palm tree” burst of very large stars? The individual fireworker must experiment and develop his/her own personal preferences.

The chart shows that a good starting point would be 7/16" stars for this 4" ball shell. The FAST chart also indicates that approximately 170 round stars of this size would be used in the shell. But I'll be using cut stars in this particular shell, so that number will probably vary.

The weight of the stars in the shell will vary considerably with the type of star. It might take only 8-10 oz. of a lightweight star such as Willow, or up to almost a pound of a dense star like a zinc star.

What Kind of Break Charge, and How Much Is Used?

In the booklets cited above Ofca and Sponenburgh employ variations of a flash-powder bursting charge, with Lloyd combining his hot-flash charge with some black powder.

In Shimizu's Fireworks: the Art Science and Technique (FAST), pages 207-214, there is an extensive discussion of potassium chlorate bursting charge (H3), potassium perchlorate bursting charges (KP), and black powder bursting charge

(BP). Various considerations are discussed, and possible cores for coating the charges on are explored, as well as coating ratios.

For shells smaller than 4", Shimizu recommends the H3 burst charge, and for larger shells he specifies either the KP or BP burst powders.

I personally like to stick with black powder burst charges, sometimes augmented with a slow-flash-powder burst additive, which I'll describe later.

An interesting subject is the density of various burst charges. These can be useful to know when choosing a burst powder for a particular shell.

Burst Charge Densities (Amount of Black Powder per Cubic Inch)

Powder	**Density**
Commercial 2FA powder	(0.70 ounces/cubic inch)
Black powder granulated with red gum/alcohol	(0.35 ounces/cubic inch)
Black powder on rice hulls or puffed rice	(0.26 ounces/cubic inch)
Black powder on cotton seeds	(quite a bit less dense than even the BP on rice hulls)

Once again, in the FAST chart cited above, specific amounts of burst charge are specified for particular shell sizes. A little calculating will show that a burst charge density of 0.45 oz. per cubic inch is specified for 3" shells, 0.31 oz. per cubic inch for 4", and for shell sizes 5" through 12", a burst charge density of approximately 0.25 oz. per cubic inch is recommended.

So, for our 4" shell, our granulated BP with red gum/alcohol and having a density of 0.35 oz. per cubic inch is just about perfect.

How Much Time Fuse Should Be Used?

I have 1/4" time fuses that burn anywhere from 2.2 to 3.1 seconds per inch. I want a 2 second delay from my time fuse in this 4" shell. I'll typically use a time fuse delay (in seconds) of half the shell's diameter. So, I need an actual time fuse length, between cross-matches, of between 5/8" and 7/8." I could just split the difference and use 3/4," but I like to be more precise in my fireworking.

I have a new roll of time fuse and I don't know how fast it burns. So, I cut 10" of it, lay that piece on the ground in a safe location away from any flammables, light one end of it with my torch at the same time that I start my stopwatch, and I stop the stopwatch when flame spurts out the other end of the fuse.

Determining Time Fuse Burn Rate

This 10" piece of fuse burned for 21.65 seconds, which is close enough to 22 seconds for me. Dividing that 22 seconds by the 10 inches gives me a fuse burn rate of 2.2 seconds per inch. I put a masking tape flag label on one end of my roll of fuse indicating its burn rate for future reference.

I'm a bit on the particular side. My wife would say that I'm a bit compulsive and anal, but I know she's just kidding. I hope. Anyway, I actually cut 10" from each end of the roll of this fuse and time each of those pieces. Each one burned for about 22 seconds, so I know that figure is accurate for this roll of fuse. Heck, how do I know for sure that the machine and operator making this fuse stayed consistent the whole way through?

Using this fuse then, I'll make sure that I have my desired delay of 2 seconds, divided by the 2.2 seconds/inch, equaling 0.9 inches of time fuse between cross-matches. This is almost exactly 7/8."

Constructing the 4" Ball Shell

Well, I think we can start to actually build this baby now.

I heat the hot-glue gun up. I have had good luck with Arrow glue guns and glue sticks from Home Depot. A gun and a bag of sticks goes for under $25.

Glue Gun and Glue Sticks

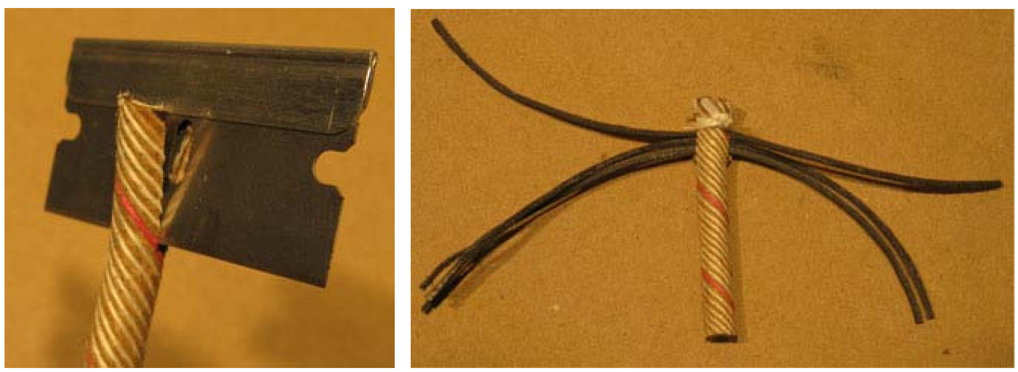
Note: For hot-glue-gun safety tips, see Skylighter Fireworks Tips newsletter #93.

I want 7/8" of actual time fuse delay, and I'm gonna split each end 1/2" with my razor blade for cross-matching. So I cut a 1-7/8" piece of the time fuse with the razor blade. I put marks with a Sharpie in 1/2" from each end of the fuse.

Warning: Fuse is never cut with scissors because it can be ignited by the friction of that kind of cutting. Fuse is always cut with a razor blade, or with an anvil cutter that uses a razor blade for the cutting.

Then I carefully split one end of the fuse down 1/2" (the actual blade on my razor is 1/2" wide), insert three 4" pieces of the cross-match, and tie the split ends of the fuse back together with string and a clove hitch knot and an overhand knot to secure the clove hitch. I split the fuse right down its center, disturbing the black powder core as little as possible.

Note: Skylighter's Super Fast Paper Fuse (#GN1205) has 3 strands of thin black match in it which are perfect for cross-matching.



Splitting, Cross-Matching, and Tying 1/4" Time Fuse

I hot-glue the fuse-washer onto the correct hemisphere.

Fuse-Washer Hot-Glued onto Correct Hemisphere

I then give the fuse a trial fit in the hemisphere fuse hole to make sure it inserts easily. If it does not, it is OK to slightly enlarge the hole with a correct diameter drill bit and drill.

When I know the fuse will fit in the hole easily, I apply a bead of hot-glue around the middle of the fuse. Then, with the cross-matched end inside the casing, the fuse is quickly inserted into the casing while the glue is still hot. (When the fuse is inserted into the hemi, the hot glue becomes a seal between the fuse and the hemi, being dragged with the fuse into the casing and forming the fillet on the inside.) I push the fuse through until the fuse's outside Sharpie mark is about 1/4" beyond the outside edge of the fuse-washer.

Then, I apply hot-glue around the fuse outside of the shell, filling the recess in the fuse washer, and building up another fillet of glue around the fuse.

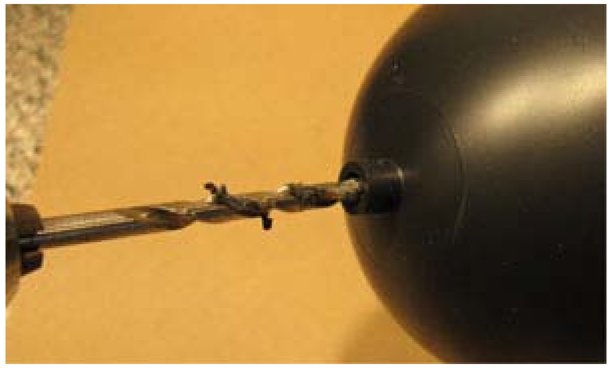
Note: These hot-glue fillets inside and outside the shell casing are very important. They keep the lift gasses out of the shell when it is launched skyward. For this reason the glue seals must be solid and secure without any gaps.

Time Fuse Hot-Glued into Shell Casing, and Sealed Inside and Out

A passfire tube is made of a 1-1/2" x 4-1/2" piece of paper, rolled up on a 3/8" dowel. This tube is inserted over the cross-matched fuse in the shell casing, and embedded in a ring of hot-glue to seal it to the casing. This tube conveys fire to the center of the shell after the time fuse burns through to the cross-match, which improves the symmetry of the shell's burst. It doesn't hurt to insert a few more pieces of black match into the passfire tube at this time to increase fire transfer to the shell's center.

Passfire Tube Hot-Glued into Shell Casing

A 1/8" hole is drilled all the way into the un-fused hemisphere, through the recess where the lift ring will eventually be installed. This vent hole will allow air to escape from the shell when the two halves are glued together. If this hole is not drilled, the air will have to escape from the equator, which may very well leave voids in the equatorial seal. This could, in turn, let lift gasses in and cause a "flowerpot." (A flowerpot is a shell bursting in the mortar and performing like a mine.)

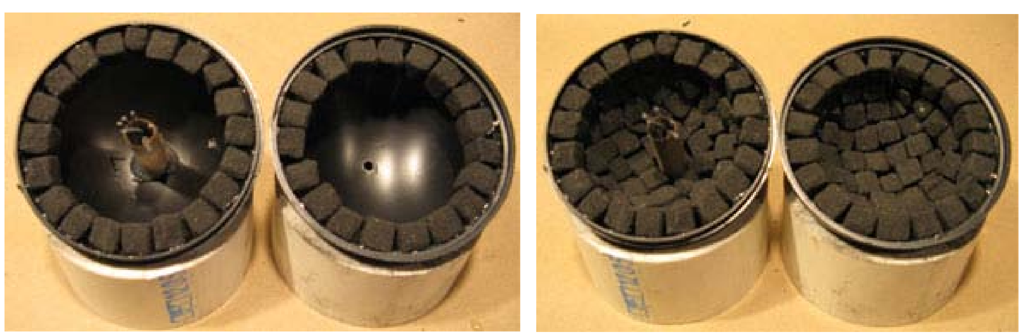


Vent Hole Drilled in Un-Fused Shell Hemisphere

Now, as described in Skylighter Fireworks Tips #93, I put the shell casing hemispheres on sections of PVC pipe which serve as work stands, and I lightly hot-glue rings of stars in the hemis flush with their equators.

Note: It is important in the un-fused hemi that you glue and position the stars below the equator's recessed edge, so that the halves will mate when the shell is closed.

Then the remaining stars are fitted into the casings without any gluing. The little wedge shaped stars that were created in the star-cutting process come in handy for filling odd-shaped voids.



Stars are Glued in at Equator, and Loosely-Fit into the Rest of the Casing

Now, I line the shell and cover the stars with tissue paper, fill the centers with homemade, granulated black powder burst charge, loosely dump in the optional slow-flash booster powder (see note below), and tap the casings to settle the powder. Then I cover it all with, and glue on, discs of tissue paper after trimming the excess tissue paper off.

Note: I'm very careful when it comes to clipping the excess tissue paper off with scissors. I never cut through any paper that has burst powder on it, and I keep the scissors clear of any area of the paper that does.

Tissue Paper Lining and Filling Shell Casings with Burst Powder

The optional slow-flash burst powder does not have to be used, and typically it would not be used for a softly-breaking shell like a "willow." It can be used in a shell where a hard, symmetrical break is desired.

This powder is a 2/1/1 mixture of potassium nitrate, sulfur, and American-dark or any 325 mesh bright flake aluminum. The chemicals are individually screened and are only mixed gently by rolling them together on a piece of paper. This is called the diaper-method of mixing flash powder.

For this 4" shell, I used 0.6 oz. of the slow-flash powder, which was made of 0.3 oz. of the potassium nitrate, 0.15 oz. of sulfur, and 0.15 oz. of the aluminum.

Diaper-Mixing Slow-Flash Booster Powder

Now it's time to close this shell up. I use heavy-duty PVC plumber's glue to glue the shell halves together. Using the glue can's applicator, I apply glue liberally to the mating surfaces of each hemisphere, and close the shell, twisting the hemis together until they won't move any more. I then wipe the excess glue off with a piece of kraft paper, and reinforce the seal/joint with masking tape, pulling the two hemis together as I do so.

Using the same glue, I fasten the leader-hook/lift-ring, which securely seals the vent hole we drilled.

Gluing Shell Casing Hemispheres Together, and Taping

I apply 4 rings of reinforcing strapping tape, one around the equator and the other three evenly spaced, striving for a finished shell circumference of 12”. Each ring of tape is 3 layers of tape thick.

4 Rings of Strapping Tape, 3 Layers Thick

I like to cover the shell at this point with aluminum foil duct tape to flame-proof the strapping tape, and to make the shell look a bit more presentable. I also split, cross-match, and tie the outside of the time fuse in the same way that I did the inside of the fuse.

Shell Covered with Aluminum Foil Duct Tape, Fuse Cross-Matched

I have found that Skylighter Super Fast Paper Fuse can be wrapped in foil tape, which has been cut down the middle to form 1" wide tape, in order to create very nice quick match if one cannot buy or does not want to make their own.

Foil-Tape-Wrapped Fast Fuse to Make Quick Match

I cut a piece of quick match 30" long and make sure bare black match is sticking out 1" from the end that will be in the shell's lift powder. I weigh out 1.5 oz. of commercial 2FA black powder, or about two ounces of homemade BP lift powder, put it in a thin plastic baggie, insert the bare match end of the quick match leader and tape the baggie closed. I cut the excess plastic off, and tape the baggie securely to the leader.

Then the baggie of lift powder is centered on the shell's time fuse. It is then covered with a lift cup which is hot-glued in place and the leader is routed as shown. For a lift cup, a cone-shaped drinking cup can be used as shown. A flat bottom paper cup or a homemade, funnel-shaped paper lift bag can also be used.

I like to hot-glue the leader to the side of the shell to further secure it, and then I tape some visco safety fuse into its end.

Shell Leader, Lift Powder in Baggie, Lift Cup, and Finished Shell

At this point a label can be affixed to the shell to identify it, if so desired.

This is how this 4" zinc star-shell broke. You can see that it is a nice, big, round, symmetrical break–just what I was looking for.

4" Zinc Star-Shell Burst

Tiger Willow Shells in 2-1/2 Days: Part 1 – Making Good Charcoal

By Ned Gorski

This is the first part of a series of four articles by PGI Grand Master Ned Gorski, detailing the production of 8" ball shells in a minimum timeframe, for instance at a 3-day fireworks club event. The original series ran in 2007 in the Pyrotechnic Guild International's Bulletins #152-155. This is a somewhat revised re-issue of that series.

Materials List

- Ball Mill (TL5010)
- Black Match Forming Die
- Black Match-Making Frame
- Bucket Separation Screen
- Bucket, 5 Gallon
- Charcoal, airfloat (CH8068)
- Comet Pump (TL3124)
- Cotton String
- Dextrin (CH8107)
- Drill
- Drying Chamber
- Drying Screens
- Extension Cord, 100'
- Hydraulic Press, optional
- Lampblack (CH8170)
- Plastic Tub
- Plywood sheet
- Portable Generator, if needed

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- Potassium Nitrate (CH5300)
- Rawhide Mallet (TL4100), if not using press
- Respirator
- Rice, puffed or hulls
- Rubber Gloves
- Screen, 10 mesh (TL2000)
- Screen, 20 mesh (TL2002)
- Screen, 40 mesh (TL2004)
- Star Plate, 3/4" or 9/16" (TL3007)
- Star Roller, optional
- Sulfur (CH8315)
- Timer
- Water
- Wax

Introduction

You can tell that ol' Harry is giving me a pretty free rein as I write these articles, allowing me to share how I make a product that Skylighter sells.

This essay on charcoal making is a slightly revised and updated version of one which appeared in the Pyrotechnics Guild International (PGI) Bulletin #152 in 2007. It was the first of four articles that explained how to make two, nice 8" aerial willow shells in 2 1/2 days, say at a weekend pyro club event.

We are going to reprint that four part series here in the Skylighter Fireworks Tips Newsletter over the next few editions, adding one more part to it which will explain Ball Milling 101.

Why Shells in 60 Hours?

In the summer of 2006, the BATFE (Bureau of Alcohol, Tobacco, Firearms and Explosives) was at the PGI convention gates asking if attendees were bringing shells onto the site and if so, where they had been made and how they had been stored.

The Consumer Product Safety Commission was pressuring the chemical suppliers to sell certain chemicals, in particular quantities, only to licensed manufacturers. Because of these pressures, many pyros are finding their shell manufacturing options limited.

Some folks have the ability to become licensed, quite a few local clubs are doing the same, or have licensed manufacturers in their ranks, and folks are being offered the opportunity to manufacture on-site at club get-togethers. For many of us, these guild events provide the only opportunities for shell manufacturing.

I'd like to present some ideas on ways to produce really excellent traditional paper ball shells, from scratch (stars, burst powder, shells, rising tail, and lift powder), in a minimal timeframe scaled to such an event. If one were to start this process on a Friday morning, these shells could be fired on Sunday evening, utilizing a 60 hour process, and with minimal chemical requirements.

A fireworker could provide a few basic tools of their own, such as a ball mill, and share other equipment, for example a hydraulic press and star/comet plates, with other people. They could travel to the event and enter the gates with no complete pyrotechnic compositions whatever.

Part 1 - Making Charcoal

The one custom chemical ingredient that I think really optimizes this project is homemade charcoal, which should be made prior to the event. If someone were to ask me what I think the most basic pyro skill is, I'd answer, "Making good charcoal."

To me, there's something most satisfying and almost magical about making this very basic pyrotechnic component from scratch. It's like a painter making their own paint from pigments found in the earth. Watching raw wood transformed into nice charcoal over a period of a couple of hours brings us back to the basics of this art.

Which Wood to Use

On the various pyro discussion lists, one of the most often-heard conversations is about charcoal. Many are searching for the Holy Grail of charcoals: That charcoal which will produce the fastest black powder, or the best sparks coming out of their stars and comets.

For fast BP, one will often hear folks tout the qualities of willow wood charcoal, or alder buckthorn, or aspen, or balsa. For good sparks, I've heard various woods recommended: apple, peach, (I'm feelin' hungry for some pie), pine root, pine, and others.

There is a really excellent article on making charcoal on the Passfire website, a resource I highly recommend for all of its informative articles. In that essay, the author discusses various woods that can be used in charcoal making, and settles on spruce/pine/fir (SPF) wood such as 2x4 scraps from house framing and the like. Sometimes this wood is referred to as whitewood. It is a softwood (conifer), as opposed to a hardwood (deciduous).

The advantage of these species is that the charcoal made from them can be used to make high quality black powder for lift and burst, and can also be used in charcoal stars where it produces nice, long-lasting spark trails. It's also a cheap, readily available wood. (In the Midwest US, where I live, all of our 'white wood' framing lumber is either spruce or pine, so I can't claim to have any experience with using fir, which may be available out west. Yellow pine, which is used around here for 2x8, 10, and12-inch framing lumber is not the same as the white wood spruce/pine. I don’t think its charcoal is useful for us.)

I refer to the type of charcoal available here at Skylighter as commercial charcoal. My understanding is that this charcoal is made from mixed hardwoods: oak, ash, maple, and the like. (For years there was a rumor goin' round that it was made from coconut shells, but that was just an urban myth.)

I guess the charcoal is made at some factory which is geared to making large quantities of generic charcoal for various purposes. I'd love to see that operation some time, and the resulting mess that must accompany such production. Believe me, if you saw my face and clothing after I've been making and grinding charcoal, you'd know what I mean.

Commercial charcoal can indeed be used to make perfectly serviceable black powder, stars, comets, and rockets. It may not make BP that is quite as powerful as that made with some of the homemade "designer" charcoals, but if a bit more of the BP is used it will work fine. It takes a bit of experimentation and testing to determine the final quantity to be used, and therein lies much of the pyro-fun for many of us.

After much of this R&D, when making homemade charcoal, I've determined that the SPF-whitewood suits my needs just fine for both black powder and sparks.

Making the Charcoal

Making charcoal is a simple, basic process which can be carried out at most homes and neighborhoods on a small scale. Large scale production is probably best done out in the country because there is a lot of smoke produced when cooking large quantities of wood. To cook charcoal, one simply needs some wood to cook, a fire, and a retort.

We've already decided what wood we want to turn into charcoal.

A fire, such as that in a backyard fire pit, fireplace, or chiminea (one of those little pot-bellied stoves that many folks have out on their decks) is necessary.

A Chiminea for Making Charcoal

I'd like to emphasize that, when I'm cooking charcoal in my fireplace as illustrated in some of these photos, I only cook loose, split whitewood, and I keep the wood a good half inch down from the lid. I don't want the wood to block the vent hole and cause pressure to build up in the retort. In general I prefer to cook charcoal over a fire outdoors because I think that is the safer practice. The last thing I want is a retort popping open and sending burning wood into my family room.

The vessel that the wood is heated in is called the retort, and it is the other major component of the process. In my fireplace, for a retort, I use a stainless steel stock pot with a stainless lid that I got from my grocery store. I have used this pot for numerous cookings with no noticeable degradation of its quality other than a bit of warping of its bottom.

In my chiminea, I use a new, empty, one gallon paint can that I bought at Home Depot. Or, if I want to cook a small 2-3 ounce experimental batch of charcoal, I'll use a new quart can. I call that one the "quart retort." A new paint will only cook 3-4 batches before the bottom begins to disintegrate. (Stop using it before this happens to prevent getting metal debris in your charcoal, which could cause sparks when ball milling the charcoal as a component of black powder compositions.)

To fill the large, stainless steel pot, I take 2x4 SPF wood scraps, cut them to the appropriate length, and split them into pieces about 3/4" square using a glove, an axe, and a log to split on. As I mentioned above, I like to cut the wood about a half inch shorter than the inside height of the retort.

I have found that the splitting works best for me when I place the axe on the end of the 2x4, lift both of them together, and then let them fall onto the splitting log. I've kept all my fingers with this method.

Splitting Wood for the Quart Retort to Make Charcoal

Then I fill my retort with the split wood, keeping the wood about a half inch short of where the bottom of the lid will be.

Stock Pot Filled with Wood

To fill the quart retort, I bought a piece of pine 1x4, which was almost free of knots, from the Depot. Knots are much harder than the rest of the wood and, in general, it is best to eliminate as many of them as possible when cooking the wood into charcoal.

Now I secure the lid of the stock pot with little C-clamps purchased at Home Depot. (I know, I know, Home Depot sees a lot of me.) There is a hole that I punched in the lid about 3/8" in diameter. If I am using the paint can, I simply install the lid securely after punching a quarter inch hole in the center of it with an awl. I don't use a drill on the lid, once again to avoid introducing metal shavings into the charcoal.

Lid Secured on Stock Pot

Since these photos were taken, the little aluminum rivets that held the side and top handles onto the stock pot melted during cooking, and the handles fell off. I had to enlarge the holes in the handles and the pot, and re-secure them with steel bolts. After doing the necessary drilling, I was very sure to wash off all the metal bits that resulted, so that they didn't contaminate my charcoal and cause a future problem during milling.

After filling the retort, or before I start filling it, I build a good fire in my fire location. Then I put the pot in the middle of it, building the fire up around the sides of the pot and keeping the fire burning well by adding firewood as necessary.

Pot on the Fire

In a few minutes smoke and steam will start to vent out of the hole in the lid, increasing until there is a quite noisy plume coming out of the hole. One of the advantages of doing this in a fireplace, as opposed to doing it on a hot plate or gas burner, is that the flames consume the smoke and steam coming out of the retort, which otherwise, can be quite smelly and a potential bother for neighbors.

After a half hour or so, the white emission starts to become transparent and will catch fire, forming a little blowtorch emanating from the lid until the wood in the retort is done cooking.

Stock Pot Emitting Burning Gasses

For the scientifically minded, this info is from Wikipedia:

> *Charcoal is the blackish residue consisting of impure carbon obtained by removing water and other volatile constituents from animal and vegetation substances. Charcoal is usually produced by heating wood, sugar, bone char, or others substances in the absence of oxygen (see char). The soft, brittle, lightweight, black, porous material resembles coal and is 85% to 98% carbon with the remainder consisting of volatile chemicals and ash.*

I guess the initial smoky steam column is mostly water being driven off, and when the column becomes transparent and catches fire, the 'volatile constituents' are being forced out, leaving only the mostly carbon remains.

The paint pot usually takes about 1 to 1 1/2 hours to cook, while the stock pot takes 2 - 2 1/2 hours. The charcoal is done when the flaming gasses stop coming out of the lid of the retort. At that time the retort is removed from the fire and allowed to cool, usually overnight.

Some folks plug the vent hole in the retort lid with a stick, or cover it with a coin while the contents cool, to keep them from igniting and burning down to ash, since oxygen is being allowed in during cooling. I have not found this to be necessary, but I always keep the possibility in the back of my mind.

Cooked Charcoal

After cooling, the lid and charcoal are removed from the retort. The charcoal can be broken up and smashed into small pieces by putting a small amount of it at a time into a 5 gallon plastic bucket and crushing it with a three foot length of 4x4 lumber.

This is a messy operation, to be done outdoors, with the wind blowing the dust away from you. And, I always wear a good respirator/dust-mask while doing it so that I don't breathe all that nasty dust.

The Big Smoosher

The crushed charcoal is poured from the large bucket into the small bucket, and the top of that bucket can be pinched into an oval for careful pouring of the contents into a ball mill jar for milling the charcoal into airfloat. (More on ball milling in the next article.)

Or, if one needed some other mesh size of charcoal, say 80 mesh, the mashed charcoal could be screened through various sized screens to separate out the desired particle size.

Another option for smashing the cooked charcoal is shown in the photo below. This works very well for small quantities of charcoal. The corner of the square pan comes in handy when it comes time to pour its contents into the mill jar. (I did not let my wife see me using this kitchenware for this purpose. Please don't tell her about it.)

Grinding Lump Charcoal with a Meat Grinder

When I used the grinder for the first time, I ran some charcoal through it to remove any metal shavings or debris from the grinder, and I threw that charcoal away. I can't emphasize enough how important it is to me to keep any debris, which might cause sparks in the milling operation, out of my charcoal. I've heard of folks putting their charcoal in doubled plastic baggies and running over it with their car in the driveway to smash it up. All I can imagine is little bits of sand, dirt and gravel getting into the charcoal, which would be a bad thing.

Square Pan Pouring Lumps into Ball Mill Jar

I then ball mill the pieces for a couple of hours until airfloat charcoal is produced. The stock pot yields about 3 pounds of charcoal and the paint can produces about a half pound, while the quart retort yields about 2 1/2 ounces. The end result of this process is quality charcoal that is very useful in producing powerful black powder or charcoal streamer stars.

Tiger Willow Shells in 2-1/2 Days: Part 2 - Day 1

This is the second part of a series of four articles by PGI Grandmaster Ned Gorski, detailing the production of 8" ball shells in a minimum timeframe, for instance at a 3-day fireworks club event. The original series ran in 2007 in the Pyrotechnic Guild International's Bulletins #152-155. This is a somewhat revised re-issue of that series.

Materials Needed

- Ball mill (TL5010)
- Black match forming die
- Black match-making frame
- Bucket separation screen
- Bucket, 5 gallon
- Charcoal, airfloat (CH8068)
- Comet pump (TL3124)
- Cotton string
- Dextrin (CH8107)
- Drill
- Drying chamber
- Drying screens
- Extension cord, 100'
- Hydraulic press, optional
- Lampblack (CH8170)
- Plastic tub
- Plywood sheet
- Portable generator, if needed

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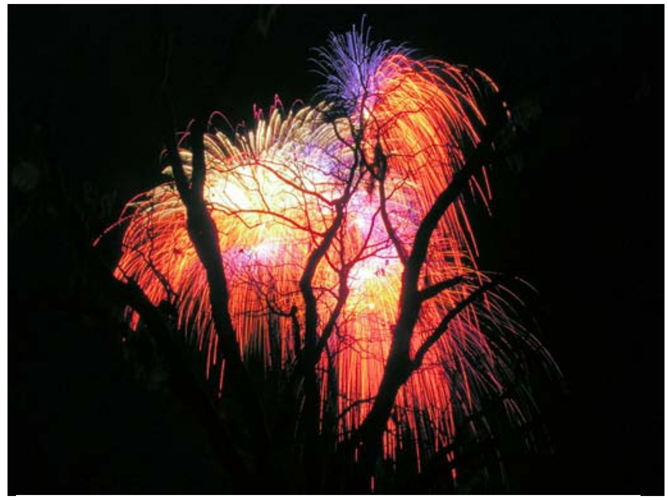
- Potassium nitrate (CH5300)
- Rawhide mallet (TL4100), if not using press
- Respirator
- Rice, puffed or hulls
- Rubber gloves
- Screen, 10 mesh (TL2000)
- Screen, 20 mesh (TL2002)
- Screen, 40 mesh (TL2004)
- Star plate, 3/4" or 9/16" (TL3007)
- Star roller, optional
- Sulfur (CH8315)
- Timer
- Water
- Wax



"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Introduction

In this series I'm exploring the possibility of arriving at the fireworks event with only a few chemicals, some other materials, some tools and equipment, but with no completed pyrotechnic compositions, and then producing good traditional paper ball shells from scratch.

One might ask, "Why paper ball shells? Couldn't you make plastic shells, or maybe pasted or rinfasciature cylinder shells?" (A. Fulcanelli, in the often-referred-to Pyrotechnica IX and XI series on cylinder shell construction, describes rinfasciature as "a traditional method by means of which shells may be made with dry paper wrap in lieu of pasted wrap.")

I could, but I like paper shells because they employ such simple, traditional, biodegradable materials. In the long run, I think there will be fewer and fewer places where we are welcome to shoot plastic shells.

I also like ball shells for the nice, round, symmetrical breaks that are possible with them. But, of course, these are just my 'druthers.

You may want to review the project "How to Make Charcoal" which detailed the charcoal options for this project. It included the production of homemade charcoal to be used in the various components of the shells. The charcoal-making step of the process would occur at home prior to travelling to the pyro get-together.

In "How to Use a Ball Mill Safely and Effectively," ball milling materials, skills and techniques were addressed. (Ball milling will be put into immediate action once we arrive at the site and begin actual production of these shells in this part of the series.)

Friday Morning, 8am - 9am, Arriving and Setting Up

Well, I've arrived on site at our pyro event with homemade charcoal and all the other supplies and equipment I'll need. At the end of this series of articles I'll include a complete checklist of all the materials and tools I've used in this project.

A pop-up tent is useful for shelter from the sun and possible rain. A couple of folding tables and a chair are also necessary. I like to bring an extra chair or two because the manufacturing area always becomes the place of choice for socializing and educational experiences.

If electric power is not available at the site, a small, portable generator will be required, along with a can of gas for it. In either case, a few 100' extension cords will be needed. It can be nice to barricade the sound from the generator with a sheet of plywood. (Honda makes some nice, very quiet generators, but they're not cheap.)

I organize the tools on my table, and I set up the ball mill and associated barricading in a safe, remote location.

9am - 10am, First Ball Mill Run

First of all, I am scaling this project to the production of two 8" tiger willow ball shells. The first manufacturing order of business will be to ball mill a batch of black powder (BP) with dextrin in it for use in the making of burst powder.

I run a 100' extension cord to the mill, plugged into a timer at an electric outlet or at the generator. I set the timer for a one-hour mill run time.

I use a small ball mill, with the jar half filled with ball milling media. This mill/media combination is very efficient, turning out very finely milled black powder in an hour. For this project I'll typically mill a 40-42 ounce batch at a time. (Please see the Ball Milling 101 article in Skylighter Fireworks Tips #91 and/or

Lloyd Sponenburgh's Ball Milling Theory and Practice for the Amateur Pyrotechnician, for more information on ball milling.)

Note: Normally, as I indicated in the article on ball milling, I only charge the mill jars with 20-21 ounces of materials to mill black powder. This is the optimal charge for these one-gallon jars to achieve the most efficient milling. But, for this project, I have doubled that material charge amount to speed up the process. This produces powder whose performance is adequate for this endeavor.

I mill a batch of BP with 30 oz. of potassium nitrate, 6 oz. of homemade airfloat charcoal, 4 oz. of sulfur, and 2 oz. of dextrin. While this batch is milling, I continue to unpack and organize my tools and materials. When the milling is done, I separate the powder from the media using a 5 gallon bucket separation screen, inserted in another 5 gallon bucket.

10:00 - 10:30 am

I now fill the mill jar with the next 42 oz. batch of BP chemicals to be milled, put the jar in the mill, and set the timer for the second one-hour mill run. From 10:15 - 11:15 am, I run the mill for second batch.

10:30 - 11:00am, Making the Burst Powder

For single petal ball shells, I like to use black powder, coated onto either puffed rice cereal or rice hulls, for the burst. I prefer BP on rice hulls, specifically for multiple petal shells where the burst powder needs to be packed tightly into narrow spaces. I'd refer the reader to the Passfire website for detailed investigations/instructions concerning burst powders and coating various cores with them.

I'm going to coat the 42 ounces of mill-dust/dextrin onto 6 oz. of puffed rice which has been screened with a 10 mesh screen, kitchen colander to remove the dust and chaff. (I use the cheap, puffed rice cereal which comes in 6 ounce bags in the breakfast foods aisle of my grocery store.)

Sift Dust Out of Puffed Rice with Colander Screen

I use a Hobby Fireworks star roller with the original plastic drum replaced by a stainless steel pot to coat the powder onto the puffed rice.

Hobby Fireworks Star Roller and Garden Sprayer

Hobby Fireworks is now out of business. One alternative star roller that many folks use is a cement mixer with the mixing blades removed, and any holes in the drum plugged. Below is a photo of a plastic-drum mixer that I bought at Lowe's for $300. The blades easily unbolted from the inside of the drum, and I simply covered the holes with duct tape.

Star Roller Made From a Cement Mixer

Warning: A cement mixer is a direct drive machine. It is next to impossible to stop the barrel by hand when it is turning. That is why I plugged the holes in it with duct tape. I did not want any rivets, bolts, and so on, sticking out of the barrel, ready to grab my clothing. I checked the barrel to make sure it was smooth and had no projections. I have short hair and no ponytail, I wear no "bling" chains around my neck or wrists, and I don't wear loose clothing when I'm using this roller. Please be careful if you convert a cement mixer to a star roller.

Wearing gloves and a respirator, I run the star roller on medium speed, and start spraying the puffed rice with water, sprayed out of a little hand-held, garden-sprayer bottle. Once the rice is dampened a bit and starts to stick together, I add a cup of the milled BP. I alternate spraying the rice with water and adding the BP, breaking up any clumps of cereal that form with my gloved hand.

Coating BP onto Puffed Rice in Star Roller

As I roll the BP on, I use my gloved hand and a plastic-mesh scouring pad to continually scrape off any BP which starts to stick onto the sides or bottom of the barrel.

Keeping Roller Barrel Clean with a Scouring Pad

I slowly spray on enough water so that all the loose, powdered BP is picked up by the puffed rice.

I don't want the rice to get so wet that the kernels look glossy-wet, but I do add enough water to form a nicely consolidated shell of BP on the rice. This simply takes a bit of practice. I keep this process up, spraying water and adding powder, until all 42 oz. of the BP has been rolled onto the puffed rice. Then, with the roller still running on slow speed, I tip it forward to dump the burst granules into a bucket.

Bucket of BP-Coated Puffed Rice

A bucket of water and a sponge comes in handy for washing tools, hands, and the star roller. If there is a water faucet available, a hose and nozzle are useful as well.

Drying Chamber and Drying Screens

I have made a little drying chamber and screens which stack inside of it. Read more about how to make two kinds of drying chambers.

Learn to Make a Drying Chamber and Drying Screens...

BP-Coated Puffed Rice in Drying Tray

I pour the coated puffed rice out in thin layers on two of the screens, insert the screens into the dryer, install the lid, and plug the heater in. The burst powder will be dry in about 12- 24 hours.

It is important to locate the dryer in a safe, protected location, as one would do with drying any pyrotechnic devices or compositions. There should be no possibility of anyone smoking in its vicinity. I also think it's a good idea to locate it in the same remote location that the ball mill is in, just in case some sort of ignition occurs.

So, now we've used the first mill run of BP to make the burst granules, and they are drying in the chamber.

11:15 - 12:30 pm, Making 36 Feet of Black Match

First, I empty the jar from the second BP ball mill run, and reload it with a 40-ounce batch which has 30 oz. of potassium nitrate, 6 oz. of airfloat charcoal, and 4 oz. of sulfur, but no dextrin in this run. This mill run takes from 11:30 to 12:30.

Half of the second batch of powder, 21 ounces with dextrin in it, is now used to make my own black match. I want to make this homemade match and quick match, starting this project with no pyrotechnic materials at all. The other 21-ounce half of the second batch gets set aside in a covered container marked "BP with dextrin."

Black Match and Paper Match Pipe Combine to Make Quick Match

Cotton String

This is the kind of cotton string that is often used for pyro purposes. It is typically found in 6/8/16/ or 24 strand string, rolled on cones as above.

I made a little match-making frame and stand that I use for small-scale black match making. The frame is sized to fit into my drying chamber once it has been removed from the stand. You'll note that the frame's cross members are half-inch aluminum tube, which I coat with a layer of wax.

The aluminum keeps those cross members from sucking the moisture/potassium nitrate out of the wet black match which will be wrapped around them. The wax keeps the black match from sticking to the rods, and prevents the chemicals from reacting with the aluminum.

Match Making Frame

Coating Cross Members with Wax

I tie one end of the string I'm using onto one of the frame cross-members near one end, and wind string onto the frame at about 3/4" intervals.

String Wound onto Frame

Removing the String Twist with a Drill

This measures off about 36 feet of 12-to-24 strand cotton string. I tie one end to something stationary, unwind the string from the frame as I walk backwards, and tie a knot in the other end. I then insert that free end into the chuck on my drill, and pull the string tight while running the drill in reverse to take the twist out of the string. My goal is to end up with all the individual strands in the string lying fairly flat next to each other.

It helps if I have my lovely assistant walk the string toward me from the far end, with her hands separating the strands into two halves, as I take the twist out of the string. (My wife, Molly, is much happier to help with these projects if I call her my "lovely assistant," so I don't hesitate to do so.)

Then I wind the untwisted strands of string back onto the frame.

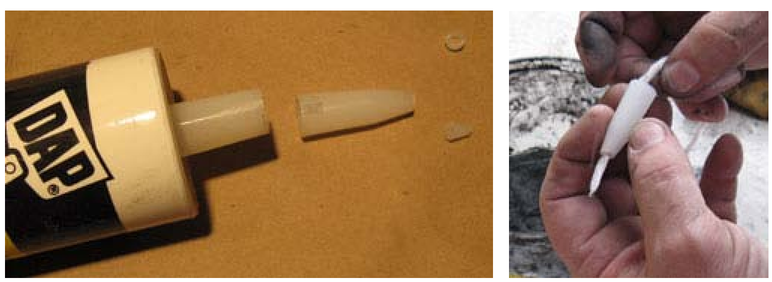
Untwisted String on Match Frame

Using a paint stick and a plastic tub (about the size Skylighter uses for 5 lbs. of chemicals), I stir about 9 ounces of water into the 21 oz. of BP-with-dextrin from the second mill batch. Stir the water in slowly, and stop adding it when the slurry gets to a thick, pancake-batter-consistency. Don't make it too thin.

I slowly work the string into the slurry, starting from one end of the string, and patting the string down into the slurry a few inches at a time, unwinding it from the frame as I go. The goal is to thoroughly impregnate the string with the BP mix. I'll pat and knead the string in the slurry for 5 minutes or so, being careful to press the mass, but avoid tangling the string.

Working String into Black Powder Slurry

I cut a section out of the nozzle of a tube of caulk to create a little forming die to pull the wet match through as it comes out of the tub. The die removes excess slurry and regulates the diameter of the match. (I've seen video of Maltese fireworkers using a rubber baby-bottle nipple for this purpose.) I want an exit hole in the small end of the die of about 1/8" - 3/16". It's best to start out on the small side with this hole, and enlarge it if necessary.



Plastic Forming Die with String Being Threaded Through It

I put the end of the wet match through this die, and then tie that end onto the drying frame. Pulling the match through the die, I then wind the match onto the drying frame, revolving the frame as I go, until I get to the other end of the match. I then tie that end onto the frame, also.

Pulling Wet Black Match through Die, and Winding It onto Frame

Frame Full of Wet Black Match

I now loosen the screws which hold the frame to the stand, and put the frame into the drying chamber on top of the two screens which contain the burst powder. This match will be dry in about 12-24 hours as well.

Only 8-12 ounces of the slurry will actually be taken up by the string in the above process. But I made up 30 ounces of it because I wanted the string and match to stay nice and wet during its impregnation and pulling through the die. If less slurry is used, too much is sucked up by the string. Then the slurry gets dry, and the match becomes hard to pull through the die.

The leftover slurry can be highly diluted with water and disposed of in a safe location.

12:30 pm - 1:00 pm

Dump the third ball milled batch of BP, screen out the mill media, add another 40 oz. batch of BP chemicals into the mill (same proportions as the third batch, no dextrin), and run the mill for another hour, 12:45 - 1:45.

1:00 - 2:00 pm, Press Lift Powder

Note: There are various ways to make very satisfactory black powder for lifting shells. I have experimented with using BP-coated rice hulls, and they work just fine in the same amount that I would use of commercial 2FA.

I have also granulated BP dust, straight out of the ball mill, by adding denatured alcohol in which red gum has been dissolved (red gum = 1% of BP weight, 1 3/4 cups of alcohol for 40 ounces of mill dust). I granulate this 'putty' through a 1/4" mesh screen onto kraft-paper lined trays and allow it to dry. When using BP made this way, I only have to use 3/4 of the amount that I would of commercial 2FA.

For me, so much of the fun of fireworking is this sort of curiosity, pondering, experimenting, recording and comparing results, drawing conclusions which I can use in the future, and so forth. This is science combined with the art, which I find so satisfying.

For this project, I am making the BP in a more traditional manner, making pucks and granulating them after they are dry.

I add 2 oz. of water to 20 oz. of the ball milled BP dust (half of the third mill batch, no dextrin) and knead the water into the powder thoroughly in a small bucket with my gloved hands. Then I force the dampened comp through a fine, 20-mesh screen (a kitchen colander) to further distribute the water in the BP.

Screening Black Powder to Incorporate Water

Below is a photo which shows a 3 1/2" comet pump from Rich Wolter with a block of aluminum to use under the pump while pressing. Also shown is a brass 2" comet pump from Skylighter.

2" and 3 1/2" Comet Pumps

I use one of these pumps, along with my 12 ton hydraulic press, to press the dampened BP dust into 1/8"-thick pucks, using about 7 tons of force on the large pump, or 5 tons on the small pump. I can press 1 1/4 ounces of BP at a time with the large pump, and 1/2 ounce with the smaller one. I apply enough pressure with the press that water starts to seep out between the comet pump and the aluminum plate.

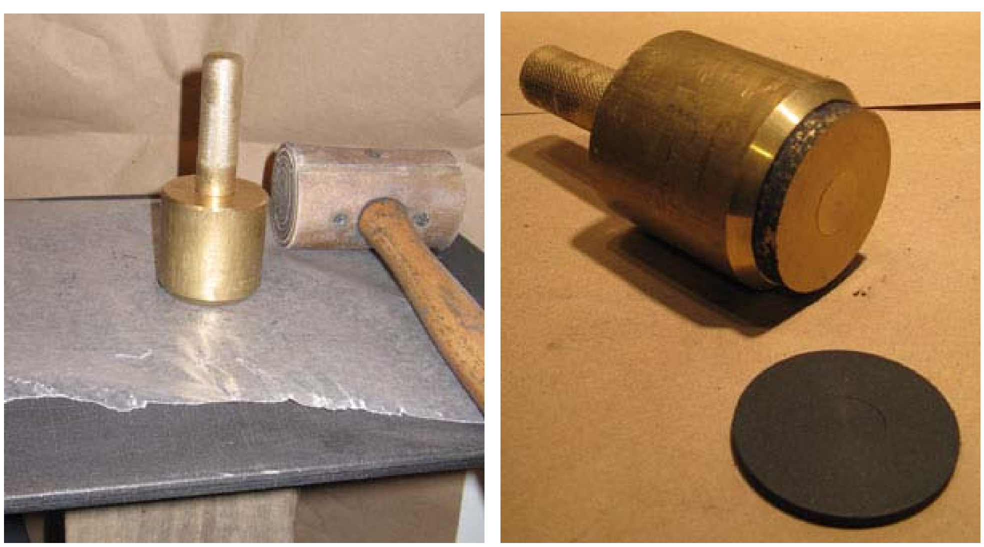
When I add the powder to the large comet pump with the sleeve sitting on the aluminum block, I use a small dowel to distribute the powder evenly at the bottom of the pump sleeve so that a nice puck of even density is produced.

I add the BP to the small comet pump while holding it upside-down, and lightly press the powder into the pump so that it stays in place when I turn the pump right-side-up.

Distributing Black Powder in Comet Pumps

Pressing Pucks with a Hydraulic Press

Note: It is possible to hand-ram the powder in the brass pump to consolidate it, using a pounding-post, a cutting board, wax paper, and a rawhide mallet. The pucks that are made this way will not be quite as dense as the ones made with the hydraulic press, but they ought to be quite usable, nevertheless.



Hand-Ramming Black Powder Pucks

Black Powder Pucks on Drying Screen

I place my finished pucks on a drying screen, and place it in my drying chamber.

I want to end up with 6 oz. of 2FA BP for each 8" shell, for a total of 12 ounces. I have determined that after the pucks are dry and I crush them I will end up with about a 60% yield of 2FA sized particles, with the rest being a finer powder. Based on this I should end up with about 12 oz. of the 2FA from the 20 oz. batch which was just pressed into pucks.

A note on presses: I use two presses that I bought from Hobby Fireworks, a 4 ton and a 12 ton. But since Hobby Fireworks is no longer in business, you might want to look online at the various shop presses available at places like Harbor Freight, Northern Tool, or Greg Smith Equipment. There is a very nice 12 ton hydraulic shop press, with a pressure gauge and lots of adjustability, available at Greg Smith for only $159. That is the type of unit I'd be looking at for a starter press.

Greg Smith 12 Ton Press

A ball mill, a star roller, and a hydraulic press, are the 3 basic machines that are very useful in this hobby.

2:00 – 4:00pm, Pressing Stars

I've formulated a star comp, which is halfway between tiger tail and willow, which I refer to as "tiger willow." I've further modified this comp by replacing 5 of the airfloat charcoal percent in the formula with lampblack, which increases the sparks' hang time. The lampblack can be replaced with the original, equal amount of charcoal if desired.

My adjusted comp is as follows, using the 60 ounces of BP mill dust (half the third, and all of the fourth batches, which had no dextrin in them).

Tiger Willow Star

Component	**Weight**
BP mill dust	60 oz.
Homemade airfloat charcoal	36 oz.
Dextrin	8 oz.
Sulfur	4.2 oz.
Lampblack	5.7 oz.
Total dry weight	113.9 oz.

I screen all the ingredients through a 40 mesh screen, and mix them thoroughly in a 5 gallon bucket with a tight lid. Then I screen them all together one more time and shake them in the bucket again. 14 ounces by weight of 3/1 water/denatured alcohol is blended into the comp, first with gloved hands, and then by screening the comp through the 20 mesh screen. This produces a slightly dampened, fine flowing composition.

I press the stars using a star plate from Rich Wolter, which produces 49 three-quarter inch stars at a time, with all 12 tons of force from my press. It takes a bit of practice to evenly fill the plate, tamp the comp down with the pin plate, fill it again, tamp it down again, and fill it to the top one last time, before the final compaction in the press.

Loading Composition into Star Plate

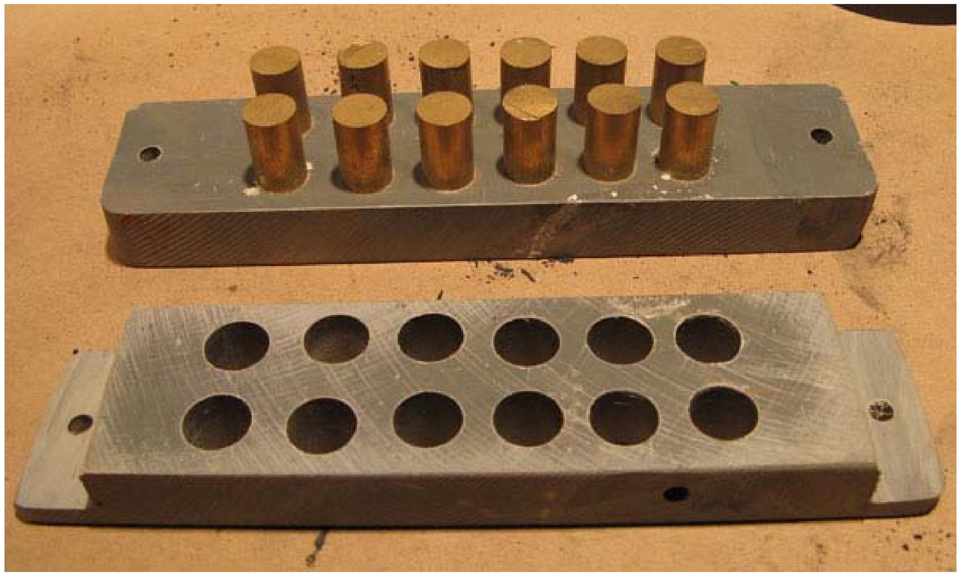
Pressing Star Plate in 12-ton Press

The goal is to produce 3/4" long, 3/4" diameter stars of equal density. The stars are then stacked on drying screens and placed in the dryer.

Stars Ready for Drying

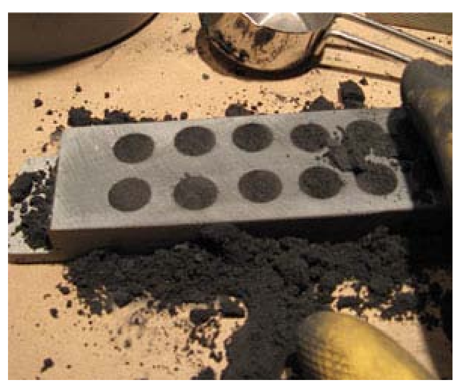
Note: As an alternative to pressing the stars with the relatively expensive star plate and hydraulic press, a smaller, less expensive Skylighter star plate can be used. This plate produces a dozen 9/16" diameter stars at a time. While this diameter is a bit smaller than the 3/4" stars produced by the above method, the stars can still be rammed 3/4" long. The amount of composition that was mixed up would still all be used, but more stars would be made in this smaller size.

This plate can be used with the mallet, cutting board, wax paper, and a pounding post.



Skylighter Star Plate

Loading Star Plate with Comp



Ramming and Ejecting Stars

Once you get going with this method, stars can be knocked out fairly quickly.

The Day's Results

So, I've worked from 8am to 4pm, and have produced burst granules, black match, black powder pucks, and stars. All of these are busy drying in the drying chamber. The ball mill, star roller, and hydraulic press have all been put to good use. Now I'm free to clean up a bit, using a sponge and 5 gallon bucket of water, and sit around and tell exaggerated pyro stories with my pals. All in all a very good day.

Tomorrow I'll be granulating the BP pucks, priming the stars and drying them a bit more, making spolette fuses for the shells, and assembling the shells. Finally, the shells will be pasted in for an overnight drying.

Tiger Willow Shells in 2-1/2 Days: Part 3 - Day 2

This is the third of a series of four articles by PGI Grandmaster Ned Gorski, detailing the production of 8" ball shells in a minimum timeframe, for instance at a 3-day fireworks club event. The original series ran in 2007 in the Pyrotechnic Guild International's Bulletins #152-155. This is a somewhat revised re-issue of that series.

Materials Needed

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- Awl (TL4002)
- Black match
- Black powder burst
- Black powder meal
- Black powder pucks
- Blender
- Cutting board
- Dextrin (CH8107)
- Dowel, 1/2"
- Drying chamber
- Drying screens
- Gummed paper tape and dispenser, optional
- Hot glue gun and glue sticks
- Knife
- Kraft paper, #40
- Masking tape
- Meat tenderizer, metal
- Paint brush
- Paper ball shell hemispheres, 8"

- Paper plates
- Propane torch
- Pounding post
- PVC pipe, 4"
- Rammer, 3/8" (TL1002)
- Rawhide mallet (TL4100)
- Screen, 4 mesh
- Screen, 8 mesh
- Screen, 12 mesh
- Spolette tubes (TU1013)
- Screen, 20 mesh (TL2002)
- Tiger willow stars
- Tissue paper (MS1110)
- Visco fuse (GN1000)
- Wheat paste
- Zip-lock bags

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Introduction

This is a continuation of a series of articles that details the production of good, traditional, paper ball shells in a minimum timeframe, possibly at a three-day fireworks club event. I'm exploring the possibility of arriving at the meet with only a few chemicals, some other materials, some tools and equipment, but with no completed pyrotechnic compositions, and then producing these shells from scratch.

The original series of articles ran in 2007 in the Pyrotechnics Guild International's Bulletins #152-155, and this is a somewhat revised and expanded re-issue of that series.

You may want to review the project "How to Make Charcoal" which detailed the charcoal options for this project. It included the production of homemade charcoal to be used in the various components of the shells. The charcoal-making step of the process would occur at home prior to travelling to the pyro get-together.

In "How to Use a Ball Mill Safely and Effectively", ball milling materials, skills and techniques were addressed.

In Part 1, "Tiger Willow Shells in 2-1/2 Days, Day 1", production of the black powder (BP) shell burst granules, black match, shell lift powder, and charcoal tailed stars were begun. Options for star rollers, drying chambers, hydraulic presses, star plates, and homemade shell casings were also discussed.

Goals for Today - Saturday

Today I want to check on how dry the items in the drying chamber are. I also want to granulate the BP pucks, prime the stars and finish drying them, make the spolette time fuses, assemble the shells and paste them in so that they can dry overnight.

8:00 - 8:15 am, Like Christmas Morning

I woke up this morning wondering how everything in the dryer was doing. I opened it up, took two stars out of the top screen, and tapped them together. I've learned that when they are pretty dry they produce a crisp, clacking sound like two stones being knocked together. The stars are doing just that.

I then took a couple of the stars out to a safe place and lit them one at a time with the propane torch, tossing them into the air when lit. They both ignited well and burned with nice spark trails, burning out just after hitting the ground. This is just how I want this star to burn.

Back in the drying chamber, under the star screens, I unearthed the screen with the BP pucks on it. I stacked the pucks up and weighed them. Yesterday, I started with 20 oz. of mill dust and added 2 oz. of water, so when the pucks are totally dry they ought to weigh 20 oz. again.

They now weigh 20.2 oz, so they have just a bit to go. When the pucks are completely dry, they "clink" when they are tapped together, sounding like pieces of pottery or china. This morning they have a slightly duller sound.

I cut a 6" piece of the black match off of the match frame and took it out into the field to light it. It was nice and stiff and it burned well and consistently.

And, from one of the bottom frames, I removed a very small handful of the burst granules. Putting them on a rock out in the field, I inserted a 6" piece of the black match and lit it. Great. A quick poof and the puffed rice cores disappeared in the flame. Good and dry.

Ah, life is good. Warning: I have a buddy who wanted to demonstrate how his BP rough powder burned. He made a pile of it and lit it with the torch. The whole backside of his arm got badly burned. Always test burn compositions and devices by installing a piece of fuse so that you can retreat before it all ignites.

8:15 - 9:00 am, Crush BP Pucks

Now I want to crush the black powder pucks and screen the granules into usable sizes. First, I put a puck in a little plastic baggie. Then I put the baggie on top of my 6x6 pounding post and whack it with a metal-headed meat-tenderizing hammer until the puck is busted into about 2FA (about 1/4 inch) size granules.

"Corning" (Breaking Up) Black Powder Pucks

I do this with all the pucks, one at a time, and dump the BP into a 4 mesh sorting screen.

Corned BP in a 4-Mesh (1/4") Screen

I sift all the granules out that will pass through that screen, and re-crush the granules that won't pass through, until all the BP has passed through that screen and onto a sheet of kraft paper.

4-Mesh Black Powder Screenings

Then I pass that pile through an 8-mesh screen. The granules that won't pass the 8-mesh, but have passed through the 4-mesh are dumped onto a paper plate, and are the 2FA lift powder, which will propel the finished shells into the air. (See black powder size charts.)

I then pass the remainder of the powder through a 12-mesh screen, and the powder that has passed through the 8-mesh but won't pass the 12-mesh forms a pile of 3FA when dumped on a plate.

Doing the same thing with a 20-mesh screen kitchen colander separates the remaining powder into 4FA (same size as Fg) and meal powder. What passes through the 20 mesh colander is Meal powder. What doesn't pass through that colander is 4FA.

Four Grades of Black Powder

I wanted to end up with 12 oz. of 2FA for lifting the two 8" shells, and I actually ended up with 14.3 oz. of it. So I weighed out and set aside 12 oz, and further crushed up the extra 2.3 oz. of the 2FA, along with the 2.5 oz. of 3FA, until it was all sorted into the 12 ounces of 2FA, 4.8 oz. of meal powder and 2.75 oz. of 4FA.

I measured 1 oz. of the meal powder onto a paper plate, and put it back into the dryer to use later in the making of the spolette time fuses. I also spread the 12 oz. of 2FA lift powder out on a screen and put it back in the dryer to insure that it is completely dry when I use it.

Lift Powder Note. I've compared black powder made this way with commercial BPs. In tests performed with baseballs shot out of a 3" mortar, to produce a 300' high flight (6.5 second flight time up and down, 4.33 seconds of fall from apogee to ground), the following powder amounts were needed:

- 0.35 oz. 3FA made from pine charcoal
- 0.45 oz. Commercial charcoal 3FA
- 0.55 oz. Wano brand BP 3FA
- 0.75 oz. Pine charcoal 2FA
- 0.75 oz. Commercial charcoal 2FA
- 0.75 oz. Wano brand BP 2FA

Testing with 6" dummy shells, 2 lb.-6 oz. shell weight, using 3 oz. of lift, produced the following results:

Lift Type	**Flight Time**
Willow charcoal 2FA	11.06 seconds
Pine charcoal 2FA	11.65 seconds
Commercial BP 2FA	12.46 seconds
Commercial BP 3FA	13.28 seconds

So, I'm confident that making BP with the SPF (spruce/pine/fir) homemade charcoal, or with commercial charcoal, produces results that are comparable with willow charcoal and commercial powders.

Note: In a future article, I'll be detailing various black powder production methods, and procedures for testing the various powders and comparing them with each other. Stay tuned.

9:00 - 10:00 am, Priming the Stars

Now I want to prime one end of each star. With the black powder break charge that I'm using in these shells, these stars will probably all light without priming. But I like to be on the safe side. The primed end also adds a bit to the break, and speeds up flame propagation on the star.

I mix 0.2 oz. of dextrin with the 3.8 oz. of BP meal and wet it with some water to make a prime-slurry in a plastic tub. Using a little paint brush, or at other times dipping the end of the star into the slurry, I wet one end of each star with the prime-slurry. Then I press the wet end into the 4FA to form a rough, granular-primed end on each star. It took me an hour to prime all the stars and put them back in the dryer.

Priming the Stars with Black Powder

Star Primed with Meal & 4FA BP

Note: The method of priming stars outlined above is not my favorite or standard method. I employed it in this project to speed the process up, since the stars can be primed, dried, and assembled in the shells the same day.

My regular method of priming these 113.9 ounces of stars would be as follows:

Make a "scratch-mix," BP prime by screening together:

Component	Weight
Potassium nitrate	24.9 oz.
Airfloat charcoal	4.9 oz.
Dextrin	1.7 oz.
Sulfur	3.5 oz.
Total weight	35 oz.

(This is a 15/3/2/1 ratio of the ingredients)

(Referring back to Part 2 of this series, in Fireworks Tips newsletter #92, 21 ounces of BP mill-dust, including dextrin, was set aside from the second ball-mill batch. This could be used as part of the above prime. To this 21 ounces, 9.9 ounces of potassium nitrate, 1.9 ounces of airfloat charcoal, 1.5 ounces of sulfur, and 0.7 ounces of dextrin, would be added and screened into the mill-dust to make the prime.)

Divide the stars into five lots, about 23 ounces each lot.

Divide the prime into five batches, 7 ounces per batch.

Put one lot of the stars into the star roller.

Small Star Roller

(This is assuming that I'd be using my smaller, stainless-steel pot roller. If I was using my larger, cement mixer roller, I would experiment with priming 2 or 3 of the 23 ounce lots or even all of the stars at one time.)

Out of one of the batches of prime, take 1/4 cup of the prime powder, place it in a paper cup, and add 2 tablespoons of water to it, stirring to mix up a thin prime "slurry."

Start the star roller with the 23 ounces of stars in it, and dump the slurry onto the rolling stars, using gloved hands to thoroughly coat the stars.

Slowly add the remaining dry prime powder out of the 7 ounce batch, 1/4 cup at a time, working the stars with the gloved hand to keep them separated, and spraying with water as necessary, until all the prime has been taken up by the stars and they have a nice, solid, "crusty" looking coating of prime on them.

Dump that batch of stars onto a drying screen.

Prime the remaining 4 lots of stars in the same manner.

The disadvantage of this method, from the viewpoint of this project, is that it takes 24 hours for the stars to completely dry. If I had that extra day, I would employ this method for the star priming.

Stars Primed with Slurry in Cement Mixer

10:00 am - 12 noon Take a little break and let the stars and spolette meal powder dry completely.

12 noon - 12:30 pm, Make Spolettes.

I'm making spolette time fuses for these shells, rather than using commercial time fuse, because I want to make the shell completely from scratch, using only a couple of chemicals.

Note: From Traditional Cylinder Shell Construction, Part I, Pyrotechnica IX, by A Fulcanelli, "The spolette is the oldest and most versatile type of shell fuse. It consists of a small-bored and relatively thick-walled tube, charged partially with pure commercial meal powder."

Pyrotechnica IX and XI contain the complete "Fulcanelli" series on this type of shell construction, and those of us who are familiar with this resource can't recommend it highly enough.

I have found that my homemade BP meal powder, such as that which was derived from the corned pucks above, works very well in spolettes.

My spolette tubes, which I've had for awhile, are 3/8" ID, 1/16" wall, 2.25" long, parallel wound tubes. (Skylighter sells some nice spolette tubes which are just a bit larger in OD.) I want 4 seconds of timing for the 8" shells, and based on Fulcanelli's figures, that ought to be about 1-3/8" of solid powder, plus 1/16" at each end for scratching back, for a total of 1-1/2."

First, I cover one end of a tube with masking tape and ram it with that amount of powder, using my 3/8" solid aluminum rod rammer, a little aluminum puck ramming base, my rawhide mallet and my 6x6 pounding post.

Ramming Black Powder in Paper Tube to Make Spolettes

I pound 1/8 teaspoon at a time, which produces 3/16" increments, until I have a solid powder column in the tube 1.5" long. Then I scratch both ends of the solid powder core with an awl to a depth of 1/16," and attach a piece of visco fuse with masking tape.

Spolette Ready to Test

Burning that spolette in a safe location, and timing it with my stopwatch, reveals a time of 3.2 seconds with this black powder. I recalculate the length of the powder core I'll need for 4 seconds, and arrive at 1-3/4," plus 1/16" inch on both ends for scratching back.

I make a spolette with 1-7/8" of powder, scratch the ends, burn it and time it, and get 4.1 seconds. Perfect. I then pound two spolettes with the 1-7/8" powder column (this takes 0.2 oz. of powder for each spolette) and scratch the inside powder with the awl. Note that the finished spolette has powder flush with one end of the tube and covered with masking tape, and leaves 3/8" of the tube still open and not filled with powder.

Note: A friend recently gave me a nice tool set for making spolettes. It is similar to what Rich Wolter makes and may have been made by him. It has been machined to work with the size tubes I am currently using. The grooves on the shaft of the ram, 1/4" apart, come in handy for gauging the height/timing of the powder column which has been rammed.

Spolette Tool Set and Tube

12:30 - 12:50 pm, Insert Spolettes in Shell Hemispheres.

I'm using commercially produced, Chinese, strawboard hemispheres for these shells.

My spolette has a 1/2 inch outer diameter. So, using my half inch steel punch, I knock a hole in two of the hemis, using my rawhide mallet and the 6x6 pounding post.

Punching Hole in Shell Casing

Note: Awhile back I purchased an inexpensive set of gasket punches at http://harborfreight.com/. These punches come in handy for punching holes in stuff like the shell casing above.

Harbor Freight Gasket Punches

Then I hot-glue the spolettes into the two hemis. This forms nice fillets of glue on both the inside and the outside. This allows 1" of the flush end of the spolette to stick out on the outside.

Spolette Glued into Shell Casing

I removed the masking tape to insert the spolette. Now I cover the outside end of the spolette with tape again, making a little "flag" with the tape for orientation during the pasting process.

On the inside of the hemi, I take a 5" x 5" piece of 40# kraft paper and make a passfire tube with three turns of the paper rolled up on a half-inch dowel. I then hot-glue the tube over the spolette tube. I've enlarged the dowel just a bit with some masking tape to make sure the passfire tube will fit over the spolette tube.

Sighting across the plane of the hemi equator, I use scissors to clip the passfire tube off flush with that plane. I then insert two pieces of black match, making sure they fit down into the spolette tube and are pressed against the scratched column of black powder, and sticking out of the passfire tube about 1/2." I then tie the end of the passfire tube with a clove hitch, and use my awl to punch a vent into the passfire tube below the string.

Black Match and Passfire Tube Installed, with Vent Hole

The clove hitch is the most-used and versatile knot employed in fireworking, and there are several ways to tie one. At one time, I spent some time sittin' in my La-Z-Boy chair, with a piece of string, and practicing the various ways of tying a clove hitch until they became second nature.

12:50 - 1:40 pm, Filling the Stars into the Hemis

I remove my stars from the dryer and try to pry the prime off of one of them. The prime is very hard and dry, and pulls off some of the star along with it. This indicates it is thoroughly dry and fully adhered.

I like to hot-glue my stars into the hemis with a small stripe of glue on each star, applied to the end opposite the primed end, beginning with the stars at the equator. I use four rings of 4" PVC pipe as stands for the hemis during this process.

Shell Hemisphere on 4" PVC Pipe Work-Stand

I glue the stars in about 1/8" below the equator because the angle of the hemi brings the inside edge of the stars just above the equatorial plane, where they will mesh with the stars in the other hemi.

Hot-Glued Stars around Equator of Shell

I then fill the rest of the hemis with stars, lightly gluing each one in.

Shell Hemi Filled with Stars

In a few cases I chip off edges of stars with a knife to allow a spot to be filled with another star. (I do this outdoors in a safe location.) Each hemi holds about 72 stars, for 144 stars per shell.

After filling all 4 hemis, I have 215 stars left over, enough for another shell and some rising tails. (I could have made 2/3 of the stars in the original batch if I wanted to avoid having these extra stars to dispose of. Maybe I can rustle up some more BP and make a mine or two.)

2:00 - 2:30 pm, Filling the Hemis with Burst and Assembling the Shells

I remove the burst powder from the dryer, line the stars in each hemi with tissue paper, and fill the tissue with the burst charge, clipping off the extra tissue paper with scissors. I allow the burst to project above the hemi just a bit. When I mate the two halves of the shell, I want to have to work a bit at doing so, so that, once they are mated, the shell contents are tightly packed in place.

Note: At some point, if you're like me, you'll say, "Heck, I don't need to keep that old burst powder separate from the stars with that tissue paper. I'll just dump the burst in on top of the stars and work it into the voids."

Yep, that's what you'll say, and that's what you'll try, and then, after you close the shell and continue to work on it, the burst will migrate further in between the stars, and the burst and stars will start to loosen up, and the contents of your shell will start to rattle around, and your shell burst will look asymmetrical and ragged, or else the shell will flowerpot on lift (break in the mortar when it is fired).

Then you'll say to yourself, "Well, that was a good experiment and a valuable lesson learned."

And, you'll go back to using the tissue paper. Yesiree.

Filling the Shell Casing with BP/Puffed Rice Burst Powder

I then close each hemi with a circle of tissue paper, hot-glued to the equatorial ring of stars. This paper disc is easily made by taking a square of tissue paper slightly larger than the casing, folding it in half, then quarter, then eighth, and so on, and then clipping the folded paper off to the right length, as shown.

Shell Hemi Sealed with Disc of Tissue Paper, Hot-Glued in

Note: There has been quite a bit of conversation in pyro-circles about the safety of using hot-glue when fireworking. The heat of the glue is not a problem, being well below the ignition temperature of the commonly used compositions. The problem can arise, if and when the hot-glue gun malfunctions, and possibly emits sparks.

Some pyros allow their guns to heat up, and then unplug them before gluing. The general consensus is that the most important safety precaution when using a hot-glue gun is to keep the gun on its stand, or sitting in a "garage," like a length of PVC pipe, when it's not in use.

Hot-Glue Gun in Its "Garage"

That also keeps its innards from getting gummed up with excess glue, a common cause of malfunction. If one lays the gun down on its side while it's being used, the excess glue ends up all over it, and some ends up seeping into its bowels.

My guns, when used this way are a mess. But when a gun is stored during use with the tip pointing down, either on its stand or sitting in a "garage," the excess glue just drips off the tip. The glue stays new, shiny as the day it was born, and not all gummed up inside. It's also probably a good idea to avoid using those "dollar-store," el-cheapo hot-glue guns.

Now it's time to mate the hemis by flipping one of them over quickly and onto the other one, and then setting them tightly against each other by applying pressure with my hand and lightly tapping with my rawhide mallet. Then the hemis are secured together with high-adhesion masking tape.

Completely Assembled Fireworks Aerial Shell Ready for Pasting

2:30 - 6:30 pm, Pasting the Shells

I know what you're asking, "Does this guy ever take a break or eat?" I am determined to get these shells pasted-in and in the dryer before dark and the beginning of the evening's festivities. And, no, nobody ever accused me of passing up on a meal.

"Pasting" a shell is the process of applying layers of reinforcing paper onto the exterior of the assembled shell hemispheres. I mix up some wheat paste (the good stuff from pyrosupplies.com) in my blender until it is about the consistency of yogurt. Wheat paste is the old-fashioned wallpaper paste.

I know, I know, how would you fellas who are reading this know what the consistency of yogurt is? Real men don't eat yogurt. Go buy a little tub of it and check it out. I like strawberry (no, you cannot paste your shell in with strawberry yogurt). But I digress.

I like to paste 8" shells with 1" x 9" strips of 40# virgin kraft paper. I have an 18" wide roll of this paper in a dispenser. I tear off twelve 9" long sheets, and do this four times, making 4 stacks of 12 sheets. I am going to use one stack of 12 sheets for each application.

I can only cut through 6 layers of the paper with my sharp knife (which I keep really sharpened). So I paste up 6 pieces of the paper on my cutting board. I apply paste to the cutting board; paste both sides of the first sheet and then lay down the rest of the sheets, feathering them as I go, and pasting only the top side of those 5 sheets.

Applying Wheat Paste to Kraft Paper Using a Paintbrush

Now, after marking my 1" widths with my marking screw-board (there are screws every 2," and I eyeball the intermediate cut marks), I cut the sheets into 1" wide strips.

Marking Pasted Paper and Cutting It into 1" Wide Strips

Now I pick up one stack of 6 strips at a time, and lay down 9 of the stacks on top of each other, feathering the ends as I go. Then I roll them up into a little roll.

Pasted Paper Strips, Stacked and Rolled

I do this twice for each cutting board batch, and there are two of these batches for the total of 12 sheets, so I end up with 4 of the little rolls of strips.

By the way, this paper and this method require no "breaking" of the paper. (Breaking paper, as described by Fulcanelli, entails crumpling it up to incorporate the paste and break the grain of the paper.)

Shell, Pasted Paper Strips, and Wheat Paste

The first thing I like to do is to brush some paste onto the shell and smear it around with my hands, preparing the shell casing so the pasted strips of paper will really adhere to it.

I like to apply the strips in the "9 axis system" described by Jim Widmann in his PGI Bulletin article, Bulletin #123, March/April 2001. This system uses the 3 main axes, x/y/z, as well as the 6 intermediate axes, which are rotated 45 degrees from each of the main ones. The little masking tape flag on the spolette is used to keep track of the axes as the pasting progresses.

Don't worry if this is not immediately clear. I lay awake for a bit on a couple of nights visualizing all of this until the light went on inside my head. The purpose of this system is to rotate the "poles" of the layers of paper, so that the final, consolidated wrap of paper has a consistent thickness and strength.

Applying the First Layer of Pasted Paper Strips to the Shell

As seen in the above photos, there are open spaces left at the north and south "poles" left after applying the 9" strips, and these poles are covered with torn strips of paper.

Each roll of strips is sufficient for one axis application, which produces 2 layers of paper on the shell since the strips are lapped by half over each other as they are applied. So, the 4 rolls are good for the first 4 axes, or 8 layers of paper.

As I apply successive layers of the paper strips, I keep the shell nice and wet with the paste, by applying a bit with the paint brush and smearing it around with my hands.

Shell, Wet with Paste, with More Strips Applied

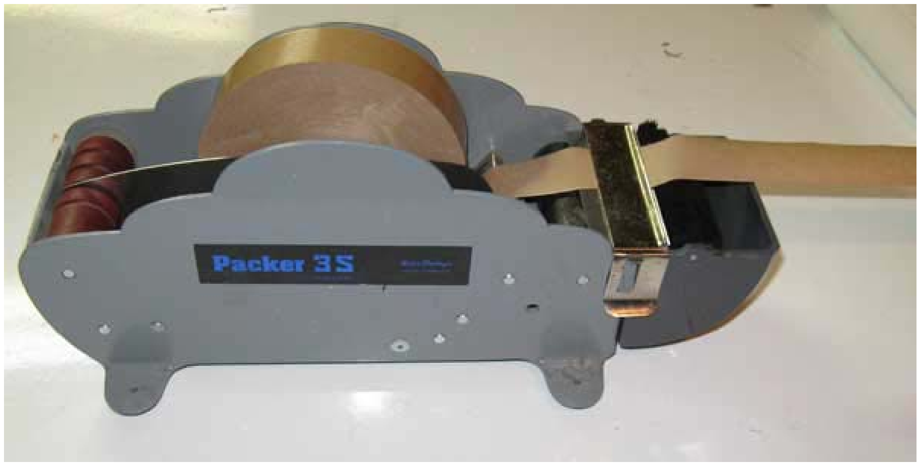
After applying the first 12 sheets/4 rolls/4 axes/8 layers of paper to the first shell, I place it in the drying chamber, with the shell resting on two strips of wood which lie across one of the drying screens. (The shells may be too heavy to rest directly on the screen, and I don't want them sticking to it.)

While the first shell is drying a bit, I apply the first 8 layers to the second shell. The first shell has taken about an hour to paste, and it dries for an hour while I'm pasting the second shell. Once this is accomplished, I switch the shells in the dryer and make the second 8-layer application to the first shell, then switch them again, and apply the final 8 layers to the second shell. Now I have 16 layers of pasted paper on each shell.

Sometimes, if I'm getting fancy, I apply a few drops of red or green food coloring on the shell as I'm applying the last layers of pasted paper. This results in uniquely colored shells.

"Christmas" Shells

Note: One alternative method for pasting the shells is to use gummed kraft-paper tape and a tape wetting/dispensing machine. The tape would be applied to the shells in similar lengths and fashion as the pasted paper above. I like to use 1-1/4" wide, 35-40# tape on 8" shells.



Using Gummed Kraft Paper Tape to Paste Shells

6:30 pm, Two Shells in the Drying Chamber. It's Miller Time.

The next and final chapter in this series will detail Sunday's lifting and leadering of the two shells. Then we can take them out to the field and put 'em up into the air!

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Tiger Willow Shells in 2-1/2 Days: Part 4 - Day 3

This is the final installment in a series of articles chronicling Ned Gorski's approach to producing two traditional 8", Tiger-Willow, paper ball shells, including handmade stars, burst powder, spolette time fuse, lift powder and quick match, all at a weekend pyro event.

The original series ran in 2007 in the Pyrotechnic Guild International's Bulletins #152-155. This is a somewhat revised re-issue of that series.

Materials Needed

- Aluminum rod or wooden dowel, 3/8" x 36"
- Awl (TL4002)
- Black match
- Black powder, 2FA
- Chipboard disk, 2" (DK2000)
- Cotton string
- Hot glue gun and glue sticks
- Kraft paper, #40
- Kraft paper, #60
- Masking tape
- Plastic bags
- Scissors
- Shell labels (MS1101)
- Tiger willow shells, unfused
- Tiger willow stars
- Tissue paper (MS1110)

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

You may want to review the project "How to Make Charcoal" which detailed the charcoal options for this project. It included the production of homemade charcoal to be used in the various components of the shells. The charcoal-making step of the process would occur at home prior to travelling to the pyro get-together.

In "How to Use a Ball Mill Safely and Effectively", ball milling materials, skills and techniques were addressed.

In Part 1, "Tiger Willow Shells in 2-1/2 Days, Day 1", production of the black powder (BP) shell burst granules, black match, shell lift powder, and charcoal tailed stars were begun. Options for star rollers, drying chambers, hydraulic presses, star plates, and homemade shell casings were also discussed.

And then in Part 2, "Tiger Willow Shells in 2-1/2 Days, Day 2", I addressed granulating the black powder, priming the stars, making spolette time fuses, and assembling and pasting the shells.

Now it's time to finish these shells up and get ready to put them into the air.

Sunday Morning

Well, the shells are dry in the drying chamber. Today I will "lift and leader" them, and tonight fire those babies up, two and a half days after starting this project.

9:00 - 10:00 am, Make Match Pipe and Lift Cups

Making Match Pipe

My 8" mortar is 42" long on the inside, so I'm going to want two quick match shell leaders about 48" long. The leader is the fuse which leads from the shell at the bottom of the mortar, up and out of the mortar (the "gun"). The leaders for large aerial fireworks shells are typically made of quick match, which is black match inserted into a paper tube called match "pipe."

To make match pipe for these leaders, I roll 3" x 34" pieces of 40# virgin kraft paper around a 3/8" x 36" aluminum rod (or you could use a wooden dowel), gluing the edge of the paper down with white glue. This will produce double wall pipe.

First, I tear a 34 inch long sheet from my kraft paper roll. Then, I fold the paper in 3 inches from the edge, make a crease, and slice it off in the crease with my sharp knife. I then make a fold the length of this strip, about a half-inch in from the edge. I lay the aluminum rod into that fold, then roll the paper around the rod, pressing and rolling it on my table a few times till the paper is snug around the rod. At this time, I glue the edge and press it down.

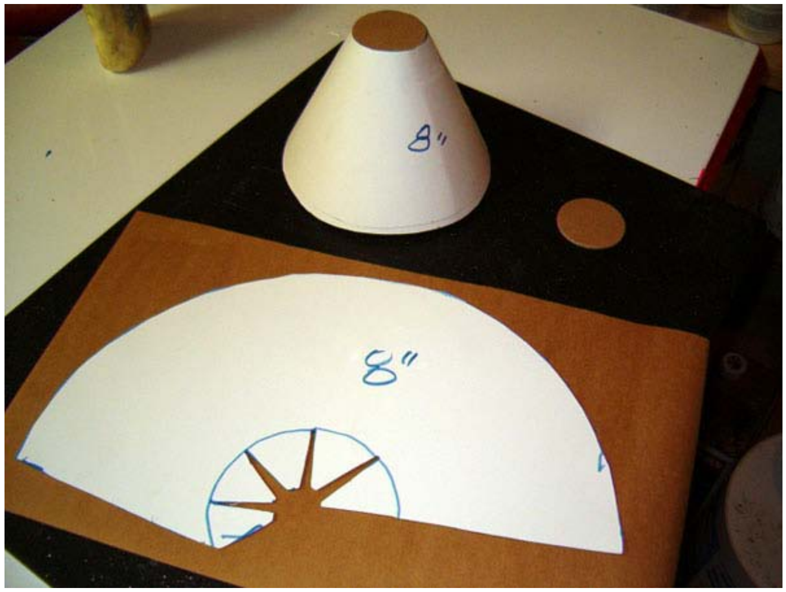
Cutting Kraft Paper and Rolling It around an Aluminum Rod

6 Finished Quick Match Pipes

Making Lift Cups

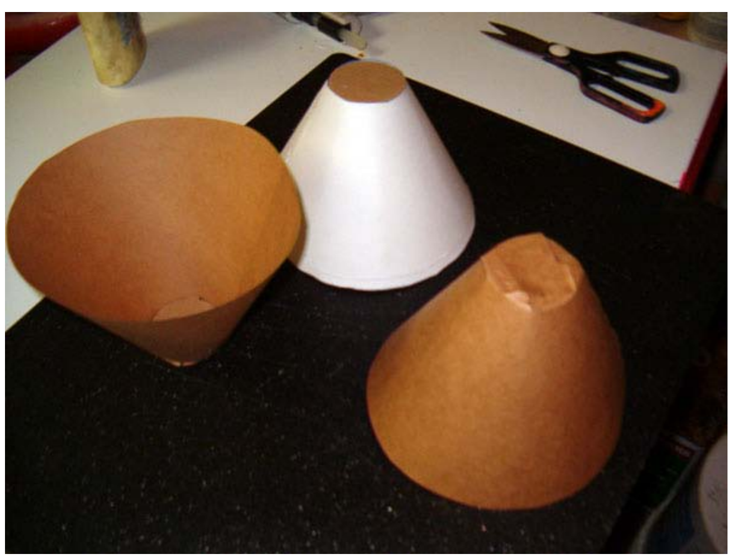
If you look at the bottom of a typical Oriental ball-shell, you'll notice that the shell lift powder is contained in a conical, paper covering called a shell lift cup.

I have made a little former and template to use in making the shell lift cups.



Former, Pattern, Disc, and Kraft Paper for Aerial Shell Lift Cups

These are based on the lift cups I have seen on some commercial shells. I use the template to cut out a pattern of 60# kraft paper. Then I stick a 2" chipboard disc on top of the former, wrap the kraft around it, and hot glue the kraft to itself and the disc, creating lift cups as shown.



Finished Shell Lift Cups

10:00 - 12 noon, Lift and Leader the Shells

Making the Quick Match

I want two 50" pieces of quick match for the shell leaders. I'll be using 1-1/2 pieces of the match pipe for each leader. I like to put two pieces of black match into each pipe to insure flame propagation past any potential weak places in the black match.

After gently unrolling the dry black match off the match frame, I cut four 54" pieces of match. First, I insert two of the pieces into a 34" piece of match pipe. Then I slide a 17" piece of the pipe onto the match, inserting the end of it about an inch into the longer pipe, and taping the joint well with masking tape. That produces a 50" piece of quick match with black match sticking out of each end.

Quick Match Shell Leaders

Lift Powder

Now I take the screen of 2FA black powder out of the drying chamber and dump it onto some kraft paper. The BP is divided into two 6 oz. amounts and put into two small plastic baggies.

One end of a quick match leader is inserted into the lift powder in the baggie, the baggie is gathered around the match pipe, and a band of masking tape secures the baggie closed. The extra baggie plastic is trimmed off with scissors and the first tape band is secured to the match pipe with another band of masking tape.

Now, on the shell, I mark the pole opposite the spolette. Holding the baggie of lift powder there, I hot-glue the leader to the shell down to the equator.

Baggie of Lift Powder, and Leader, Glued to Shell

Then I hot-glue a lift cup onto the bottom of the shell, covering the lift powder.

Lift Cup, Covering Lift Powder, Glued to Shell

Note: I am top fusing these shells because they use spolettes, which are more susceptible to pressure and blow-through than time fuse is.

Matching the Spolette

Black Match Hot-Glued and Tied to Spolette, after Scratching BP

After turning the shell upright, the masking tape flag/cover is removed from the end of the spolette, and the powder core is scratched in an X pattern with an awl. An 'h' made from 5 inches of black match is hot glued and tied onto the spolette.

Then the quick match leader is brought up to the bottom of the spolette where it is bent and then hot glued to the upper hemi of the shell and the side of the spolette.

I pierce the side of the leader above the spolette and cut a little 'door' in the side of the match pipe just above the top of the spolette. Then I insert an extra piece of black match as well as the upper leg of the spolette 'h' match into the leader pipe, and cover the junction with masking tape. This insures that a lot of fire is going to be transferred to the top of the spolette when the leader burns to that point.


Shell Leader and Spolette Match Joined and Secured

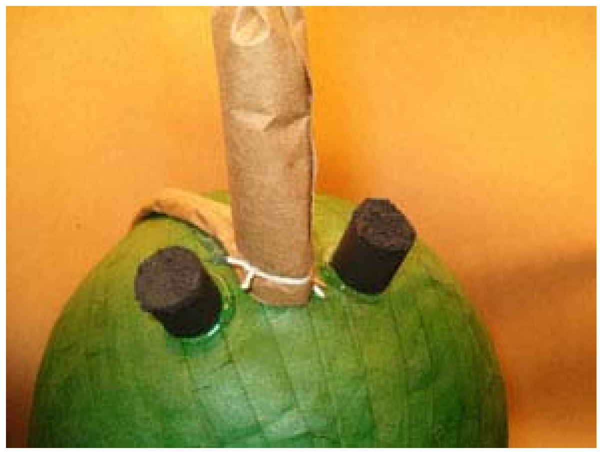
Then the whole leader/spolette assembly is covered with a kraft paper bucket, consisting of two turns of 40# kraft paper and tied with clove hitches at the top and bottom. I then tug on the leader to make sure it is tightly secured to the shell, since it serves as the lifting rope, which is sufficient for a shell weighing as little as this one does.

Paper Bucket Covering Spolette and Black Match

Finishing the Shell

The shell leader is 'S' folded back and forth onto itself to form a bundle. A band of masking tape, sticky-side-out, secures the bundle, and then the sticky side of that band is covered with a layer of masking tape, sticky-side-in. This forms an easily torn band which is not adhered to the leader. A piece of visco fuse is taped into the end of the leader.

Two of the tiger willow stars are hot glued on either side of the spolette to serve as rising tails. Then the tails are covered with rounds of tissue paper, which are tied on with clove hitches, and the labels are glued on.



Comet "Tails" Rising Effects, Attached to Shell, Covered with Tissue Paper

Note: This method of attaching the rising tails works well with my glitter comets, which are made of a composition which gets very hard when it is dry. The glitter tails stay attached to the shell very well.

The tails used above, being made from a higher-charcoal-content comp, were softer. I accidentally bumped one of them and it popped off. I then re-glued it, and also completely covered the sides of all the tails with a layer of hot-glue, right down to the glue attached to the shell. This strengthened the tails and ensured that they stayed on during the lift and ascent of the shell. Another approach uses masking tape around the comet, then little strips of masking tape going down the comet and onto the shell body.

12 noon on the third day of the process, and the shells are ready to drop and fire when it gets dark.

Finished Shells, Ready to Be Loaded and Fired

So, What Am I, Nuts?

After about 16 hours of work, I have two 8" shells. Similar Chinese ones could have been purchased for under $100 or so. Yeah, I guess I'm nuts, but there is something tremendously satisfying about being able to start from scratch, with no pyrotechnic materials, make a little charcoal, get some chemicals, add some paper and glue and string, and end up with these two shells.

I guess that's what I always wanted to know how to do ever since getting into this art almost 20 years ago. I also wanted to know if it could be done in a weekend.

The Shells in Action

One of the Tiger Willow Shells Performing in the Sky
(Photo by Stephen Lynch)

Acknowledgments

On the above note, I'd simply like to say that, although I've written about a few original techniques that I employ, there's really nothing new in this series of articles.

In my quest to learn how to make fireworks, there have been literally hundreds of generous folks along the way who were willing to share what they'd learned in their own experience. They've written books and articles, made videos, given seminars, posted to the pyro email-lists and club mailing-lists, made wonderful tools and equipment to use, made chemicals and materials available, and been willing to converse with, and tutor, fellow pyros eager to learn.

To all of them, I simply say, "Thanks." We all stand on the shoulders of those who have gone before us.

Checklist

- Homemade airfloat charcoal
- Potassium nitrate

- Sulfur
- Dextrin
- Wheat paste

Note: It is possible to make one's own dextrin and wheat paste from corn starch and flour, respectively. This would further reduce a pyro's dependence on outside sources of supplies. "Post-Apocalyptic Pyro" may be the way of the future.

- Block of wax
- Denatured alcohol
- Lampblack
- Water
- Puffed rice
- Pop-up tent
- Tables
- Chairs
- Generator
- Extension cords (3 or 4 100')
- 4 plug gang adapter
- Gas can - gasoline
- Ball mill
- Ball mill timer
- Ball mill sifting screen/buckets
- Plywood for barricades
- Digital scale
- Plastic tubs
- 5 gallon bucket of water/sponge
- Star roller
- Drying chamber and screens (plus wood strips to rest shells on)
- Possible humidifier
- Rubber gloves

- Spray bottle
- Hose/nozzle
- 12 to 24 strand string for black match
- Roll of 40# virgin kraft paper on dispenser
- Rough 40# kraft
- 60# virgin kraft
- Miscellaneous hand tools/toolbox
- Match drying frame/stand
- Match forming nozzle
- Measuring cups/spoons
- Dust mask/respirator
- 20 mesh screen kitchen colander
- 10 mesh screen kitchen colander
- 4/8/12 mesh sorting screens
- 40 mesh screen
- 12 ton hydraulic press
- Air compressor
- Grease
- Propane torch
- 4" comet pump
- Aluminum block to use under comet pump
- 5 gallon bucket/lid for mixing comp
- Star/comet plate
- Drywall knives/putty knives
- Meat tenderizing hammer
- Plastic baggies
- 6" x 6" x 4' pounding post
- Small paintbrush

- Paper cups
- Paper plates
- Paper towels
- Spolette tubes
- Shell hemis
- 1/2" hole punch
- 3/8" spolette ramming rod
- Small aluminum ramming puck/plate
- Rawhide mallet
- Hot glue gun/glue
- Tissue paper
- Blender
- Large paintbrush
- Plastic cutting boards
- Sharp kitchen knife
- Pasting strip marker
- Shell stands made of pieces of 4" PVC pipe
- 3/8" x 36" aluminum rod or wooden dowel
- Lift cup former
- Lift cup template
- 2" chipboard discs for lift cups
- Scissors
- Shell labels
- White glue
- Visco fuse
- Masking tape
- Thin string
- Hole punch

- Dust pan/broom
- Stopwatch
- Cooler or low table to paste shells on
- Light to work by if it gets dark (night or in rain)
- Plastic tarps to cover work tables

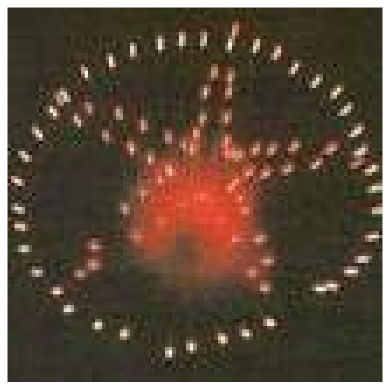
"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Making a Pattern Shell

By Ned Gorski

Introduction

A shell which bursts with a ring pattern, a smiley-face, or a star pattern can be a unique and creative addition to a fireworks display. Suddenly, after a procession of fairly typical full, spherical shell bursts, a simple ring of stars, or a display of four or five of them fired simultaneously, changes the focus of attention of the audience. "Hey, here's something different," they'll think to themselves.



Pattern Shell with a Star inside a Ring

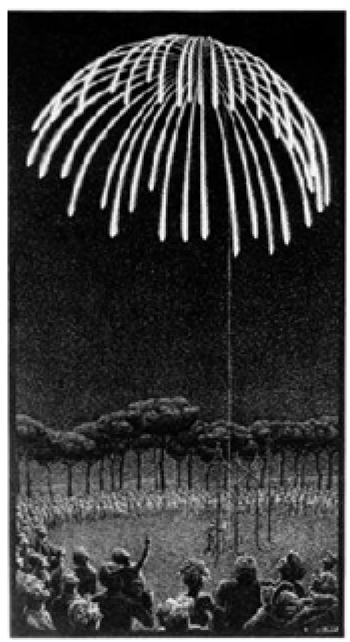
Pattern shells have some distinct advantages and disadvantages to their construction. They don't use nearly the quantity of stars that a fully loaded shell would use, so if I have a few stars of a particular size and color, they might come in useful in a pattern shell. Patterns can be chosen to coincide with a particular theme in a show, with blue stars in a patriotic section, or pink hearts in a romantic interlude.

On the other hand, it will be hit-or-miss when it comes to the pattern's orientation in the sky when the shell bursts. The smiley-face may display upside-down, or the ring may be seen on edge by a portion of the audience, looking more like a simple line in the sky. For this reason, most display designers choose to fire 4, 5, or 6 of the same or similar patterns at the same time. That will usually result in the audience in a particular location seeing at least 1 or 2 of them in the desired orientation.

Six Ring Pattern Shells, with only Three Oriented toward the Camera

If 6 ring-pattern shells of different colors are fired at once, the audience at one end of the field may see, say, the blue and red ones as true rings, and imagine all of them being the same shape.

Ring shells can use simple color stars, which leave no tail behind them, as in the photo above, or tailed stars can be employed, as below.



M.C. Escher's Lithograph, "Vuurwerk" (Fireworks)

This Escher print, "Vuurwerk," is on the cover of Pyrotechnica XI. It shows a pattern I would expect a ring shell of slow-burning, silver-tailed stars to display. It would have to be oriented so that the ring broke "flat" in order to display the "parasol" of stars just right. A small rising tail produces the "handle" to the umbrella.

An advantage to using patterns such as rings, stars, squares or triangles is that they can break in many directions that still have them look correct, as long as they don't break on-edge to the viewer. A smiley-face has to break in just the right direction to be recognizable.

The star-in-a-ring pattern shown above would look correct if it was rotated any number of degrees clockwise or counter-clockwise. It would also look fine if it was flipped 180 degrees front to back. The only way it would not show up well is if it broke on-edge to the viewer.

My friend, Mike B., made the heart-pattern shell shown below. While it did not break on-edge to the audience, unfortunately it did break almost upside-down. The fortunate thing about hearts is that they look good in almost any orientation, and the audience can make out what they are supposed to be representing.

Heart Pattern Shell

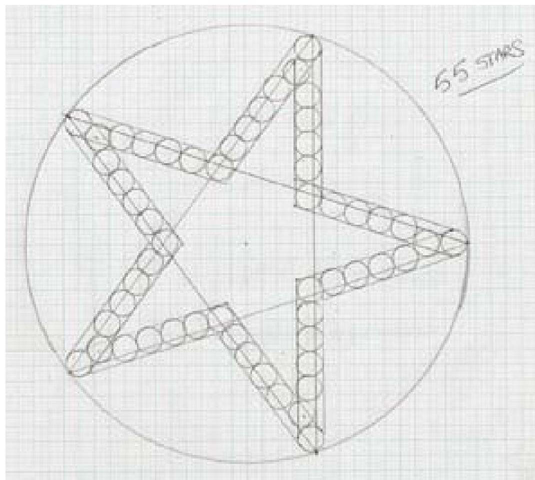
Making a Pattern Shell

I want to make a blue star-pattern shell. I don't want to make my stars much smaller than 3/8-inch in diameter, so that they burn long enough to allow the pattern to show up. Additionally, ball shells break more symmetrically than cylinder shells. For these reasons, I've settled on assembling an 8-inch ball shell for this project. With 3/8-inch stars, a smaller shell simply wouldn't allow the use of enough stars to create a nice star pattern.

The general construction techniques I'll be using when assembling and finishing this shell were detailed in Fireworks Tips #92, #93 and #94. I'll be using 1/4-inch time-fuse in this shell, though, instead of a spolette. The use of time-fuse was explained in Fireworks Tips #99.

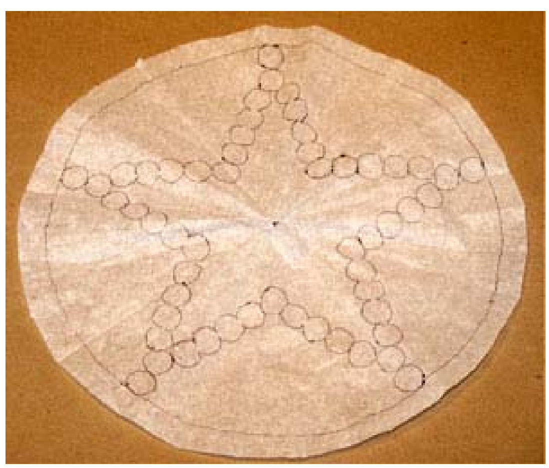
The first thing I did was draw a pattern of the stars that would fit the inside diameter of one of my 8-inch shell casings, which has an ID of 7.25 inches. 360 degrees divided by 5 gave me 72 degrees between each of the points of the 5-pointed star, which I measured out with my protractor.

My 3/8-inch pumped stars actually end up being about 7/16-inch in diameter once they are primed, so I drew lines of that size star on my pattern. Precision in these initial planning stages, right through the actual construction of the shell, will result in a more precise star-pattern in the sky when the shell bursts.



Star Pattern for an 8-Inch Ball Shell

I took a piece of tissue paper, cut a circle out of it about 1/2-inch larger in radius than my drawing above, and traced the star pattern onto it.



Star Pattern Traced onto Tissue Paper

Then I made some blue stars. Fireworks Tips #92 and #93 included instructions for making and priming pumped stars.

Although I didn't need a large number of these stars, it was important that all the stars were consistent in size. For this reason I used a 3/8-inch star plate to make a pound of the Shimizu blue star included in the table of formulas in Fireworks Tips #97.

Shimizu Blue Star Formula

Chemical	Percentage	16-ounce batch	450-gram batch
Potassium perchlorate	0.61	9.75 ounces	274.5 grams
Copper carbonate	0.12	1.9 ounces	54 grams
Parlon	0.13	2.1 ounces	58.5 grams
Red gum	0.09	1.45 ounces	40.5 grams
Dextrin	0.05	0.8 ounces	22.5 grams

I dampened this composition with an additional 10% water, and pumped and dried the stars. I primed them with the black powder "meal prime" which is also in that formula table cited above. I add an additional 5% of 200-mesh magnalium to the prime, which improves the ignition of perchlorate stars.

Constructing the Shell

As I said above, the shell was constructed in the standard fashion, except for the details below.

Once I had the time-fuse and passfire-tube installed in the shell casing, I hot-glued a 1.5-inch wide tissue paper ring inside each hemisphere at the equator. These bands served the purpose of locking the shell's contents into the hemispheres later on when I closed the shell.

Tissue Paper Bands Hot-Glued at the Equators of Each Hemisphere

Then I filled the fused hemisphere with black-powder-coated rice hulls, folded the tissue-paper band over onto the hulls, and hot-glued a tissue-paper disc onto the whole shebang to cover and seal it. As I loaded the hemi with the coated hulls, I packed them tightly one layer at a time to make sure the casing was solidly filled. I also filled the hemi slightly higher than the equator. This half of the shell held 29.4 ounces (825 grams) of the coated hulls.

Fused Shell Hemisphere Filled With Black-Powder-Coated Rice Hulls

Then I filled the un-fused hemi with coated rice hulls up to within about 3/8 inch of the rim. I made sure the rice hulls were tightly packed and very level. This filling was loosely capped off with the tissue paper disc which had the star-pattern traced on it.

Second Shell Hemisphere Filled to Within 3/8 Inch of Rim, and Capped with Star Patterned Tissue Paper Disc

Starting with the points of the star, blue stars were lightly hot-glued onto the tissue pattern. These stars only had a small dot of hot glue put on them where they touched the pattern. Just before the shell bursts, the tissue paper disintegrates and the stars are free to fly out in the star shape.

Hot-Gluing Blue Stars onto Tissue Paper Pattern

Then I filled in around the stars with more black powder-coated hulls, tightly filling all the voids and bringing the level of the rice hulls slightly above the rim of the casing. This hemi actually took about 35 ounces (1000 grams) of the coated rice hulls, for a total of about 4 pounds (1800 grams) in the whole shell. This was all capped with another hot-glued disc of tissue paper.

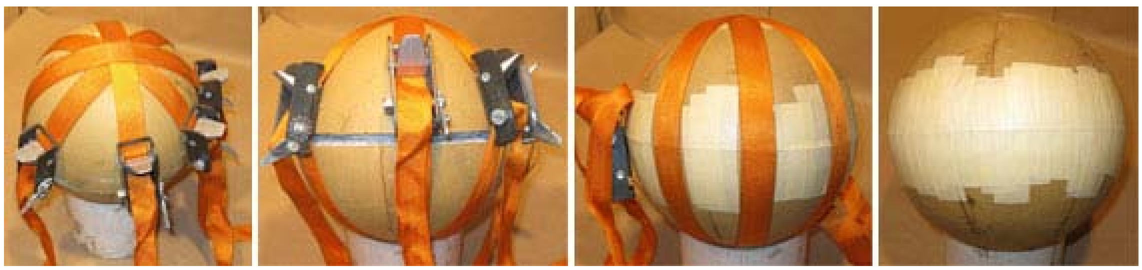
Black-Powder-Coated Rice Hulls Filled in around Blue Stars, Both Hemispheres Capped and Ready to be Mated

Because the tissue paper rings and discs were glued to the shell casing hemispheres, it was easy to flip one of the hemis over onto the other and close the shell up, ready for pasting, lifting and leadering.

With the blue stars sandwiched between the layers of tissue paper, with the rice hulls really packed in tightly and the hemis overfilled and slowly tapped and brought together, the star pattern was held firmly in place.

I've developed a nifty trick for bringing the stuffed hemis together at the equator. I use 4 strap-clamps, available at Home Depot or stores which cater to woodworkers.

As the clamps are slowly tightened, tapping the shell with a solid, heavy rod brought the two halves together and solidly packed the contents. Then the joint was closed with strips of masking tape. This method is so much easier than "lying" on the shell while tapping it in order to close it.



Closing an Aerial Shell Using Strap-Clamps and Masking Tape

Warning: I use a non-sparking, aluminum rod for tapping on the shell. But, the metal strap-clamp parts are not non-sparking. I'm working around relatively exposed black powder on rice hulls during this process. I'm very careful to avoid smacking the metal clamp ratchets, which could potentially cause sparks.

Then I pasted the shell, allowed it to dry, and lifted and leadered it. A small rising comet tail was attached to direct the viewer's eye toward where the shell will break.

Completed 8-Inch Star Pattern Aerial Fireworks Shell

When I shot this shell, it did indeed break a bit on its "side" relative to the camera, as shown in the photo below. There were viewers down and to the left of the shell-burst, and they said that the star really looked nice, big, and symmetrical.

Star Pattern Shell Bursting

(Click Image to Play Video)

Oh, well, maybe I'll get to see it next time. The video above shows the shell in action.

Final Thoughts

I enjoy making pattern shells. They offer a unique challenge in shell construction, and use less of the chemicals that go into stars. More black-powder-coated rice hulls are used than in a typical chrysanthemum or peony aerial shell, but these are the less expensive ingredients.

I think an audience enjoys the variety that these pattern shells bring to a display. The next time I make a shell like the one in this project, I think I'll add a red ring around the blue star pattern so the sky is filled a bit more when the shell bursts.

I'm working on my version of a way to at least have aerial shells burst with their equators level with the earth. This will allow rings, star patterns, etc, to display well for anyone underneath them. The method is one that I've heard about over the years, but have never seen, where a rope is attached to the bottom of the shell to produce drag on the shell's way up. This keeps the shell oriented with its "bottom" down on the way up.

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

How to Make Go-Getter Shells

By John Driver

Learn how to make "go-getters," animated stars used in aerial shells or mines that "swim" all over the sky.

Materials Needed

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- Acetone
- Aluminum (325 m, fine atomized) (CH0103)
- Ammonium perchlorate (CH5000)
- Calcium carbonate (CH8052)
- Calcium chloride or Damp Rid
- Copper carbonate (CH8087)
- Copper oxychloride (CH8098)
- Cryolite (CH8103)
- End plug: 9/16" (PC0600)
- Hexamine (CH8142)
- Kraft paper: 30 lb.
- Parlon (CH8210)
- Vinsol (CH8330)
- Saran resin (CH8248)
- Squeeze bottle
- Thermolite fuse
- Tube: 9/16" ID. x 1 1/2" long spiral-wound (TU2028)
- Xylene (CH8340)

"Go-getters" are an animated type of star, usually seen in aerial shells, sometimes in mines. Go-getters appear to "swim" all over the sky. The animated effect is similar to flying fish fuse, but much larger and brighter. Go-getters are the most consistent crowd pleaser of any aerial effect I have ever seen.

As far as we know go-getters were invented in the US by amateur fireworks makers in the early 1980's (if anyone knows otherwise, please correct me).

Go-getters were first described by Troy Fish in Pyrotechnica VII in 1981. In 1989 Dave Johnson published a booklet called "Go-Getters," which further developed the go-getter effect. Joel Baechle's 1989 book, Pyrocolor Harmony, contained a reference to a star formula which could make a good go-getter. Up to that point, most if not all go-getters used magnesium as the fuel.

This was the base of information that existed out there in the universe when John Driver decided to make go-getters. I first saw 6-inch blue go-getter shells that John had made in 1995 or 96 at a Florida Pyrotechnic Arts Guild (FPAG) event, and instantly fell in love with them. John first published his findings in the FPAG newsletter, The First Fire, and I went to one of his seminars on making them. Later a revision of the go-getter article appeared in American Fireworks News and Best of AFN IV.

John went on to commercially manufacture go-getter shells and inserts for a few years. He developed an array of colors and added metal spark trails to some of his go-getter shells. John and his long-suffering wife, Karin, drove all the way up from Florida to my place in Virginia for my Fourth of July party the year the go-getter article below was written. The go-getter shells he brought were THE hit of the party. I still hear people talking about them. He no longer manufactures his spectacular go-getter shells, but you can definitely do it yourself.

John's main contribution to the refinement of the go-getter effect was his adoption of atomized aluminum in place of the magnesium go-getter formulas originally prescribed by Fish and Johnson. Utilizing aluminum increased manufacturing safety and reduced costs. John's technique of using ball shells, different from traditional canister shell techniques, works very well and is much faster.

You can use either plastic or paper shells. (See my notes at the end of the article for a bit more information on shell construction and fusing.) He also greatly enhanced the range of go-getter colors and spark trails. Go-getters of all colors are now frequently seen in imported shells from China and Europe, just another example of the R&D contributions of American amateur fireworks makers to the craft of fireworks. Thank you, John, for all the work you did in furthering the development of go-getters and for so generously sharing your work with us.

The go-getter article below has been modified by me only slightly by removing the table of contents.

— Harry Gilliam

Ammonium Perchlorate/Aluminum Go-Getters

WARNING: THIS PAPER CONTAINS DESCRIPTIONS OF PROCEDURES WHICH SHOULD ONLY BE ATTEMPTED BY PERSONS POSSESSING AN ADEQUATE UNDERSTANDING OF THE CHEMICAL AND PYROTECHNIC PROCESSES INVOLVED AND WORKING AT AN ADEQUATELY EQUIPPED, LICENSED LOCATION USING ALL APPLICABLE SAFETY PRECAUTIONS.

Introduction and Original Formula

It all started several years ago when I watched a video of a PGI Convention. I observed a new-to-me effect; it looked like the stars were "swimming." After cleaning my glasses and viewing it again, sure enough, self-propelled stars. I already had Troy Fish's article entitled "Green and Other Colored Flame Metal Fuel Compositions Using Parlon" published in Pyrotechnica VII but didn't make the connection.

It all became crystal clear after obtaining a copy of Dave Johnson's book, "Go-Getters." Well, for one reason or another, the idea somehow got shuffled to the dark reaches of my mind. Although it did resurface from time to time, the final catalyst didn't come until the 1994 convention in Pennsylvania.

I witnessed some go-getter shells in the opening display by the CPA and particularly liked the blue ones. Next came the go-getter seminar by Dave Johnson and Mark Raitzer, which explained how to make the little critters. Unfortunately, the seminar only presented the same three colors that had been listed in Johnson's book, namely red, green and yellow. All utilized magnesium as the metal fuel.

Since I really like the color blue, the hunt was on. Inquires of several fellow pyros resulted in no answers for blue go-getters. The puzzle finally started to fall into place following a perusal of Joel Baechle's "Pyrocolor Harmony." Right there on page 34 was an ammonium perchlorate formula for violet with an interesting footnote stating "The violet with 10% aluminum and no hexamine is an excellent 'go-getter' composition." The original violet formula is as follows:

Original Formula

Ingredient	Parts
Ammonium perchlorate	50
Copper oxychloride	15
Aluminum, fine atomized	7
Hexamine	3
Rosin or Vinsol	5
Parlon	20

Having neither rosin nor Vinsol, I substituted Saran resin (I figured a little more chlorine donor couldn't hurt). Also, for the atomized aluminum, I used 325 mesh, 30 micron, spherical (KSI now Skylighter #007) aluminum. While this revised formula worked nicely in initial tests, I soon started observing bubbling and foaming in the tubes about one hour after they had been poured.

In most of the tubes the fuses disappeared completely, as they sank out of sight to the bottom of the tubes due to the agitation provided by the bubbling. The foaming was probably caused by the formation of acetone acids which reacted with the aluminum. In any case, the go-getters were useless since most of the fuses had disappeared and I didn't like the looks of them anyway.

In desperation, I tried something that shouldn't have worked quite as well color wise as the oxychloride. By substituting copper carbonate for the copper oxychloride, the foaming stopped and, judging by the comments I received at the PGI convention, the effect was quite well received.

The final formula is presented below, along with a formula for orange go-getters. If you want to shift the color more into the "pumpkin" range, eliminate the ultramarine and increase the calcium carbonate to 15%.

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Blue & Orange Aluminum Go-Getters Formula

Ingredient	Blue (%)	Orange (%)
Ammonium perchlorate	50%	50%
Copper carbonate	15%	
Calcium carbonate		14%
Aluminum, 325 mesh, 30 micron	10%	10%
Saran resin	5%	5%
Cryolite		1%
Parlon	20%	20%

Blue and Orange Formulae

All chemicals are run through a mixing screen a few times and, with the aid of a funnel, are poured into an acetone proof plastic bottle (I use an empty mustard squeeze-type bottle made of LDPE (low density polyethylene)). If you do not have access to LDPE containers, you must experiment to find a flexible plastic material that is not affected by acetone.

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

I find that, except for occasionally plugging up, the squeeze-type container works very well and gives more control over the flow of material than pouring from a plastic drink cup. Dave Johnson's book covers the construction of go-getters in great detail, so I will only point out the highlights and differences.

The Tube

I use a standard 9/16" ID. x 1 1/2" long spiral-wound, machine-made tube with a 1/16" wall thickness and standard 9/16" end plug. The end plug does not need to be glued in as the Parlon, once it sets up, is quite hard and will not blow the plug until the go-getter is almost done burning, if at all.

The tubes are then bundled into a convenient size package (I use bundles of nineteen) with rubber bands and set on plastic film (Saran Wrap), ready for filling. While go-getters made with these tubes go quite nicely, the tubes are still relatively heavy.

If you have the inclination, you might want to try hand-rolling some tubes from Kraft paper with a thinner wall to see if they fly better. Go-getters are end burners, so you should not have to worry about blowing out the tube.

The Solvent

A 90:10 mixture of dry acetone:xylene is used as the solvent. Both acetone and xylene are hygroscopic (absorb water) so it is important to use dry material. Fresh solvent is best, but if you have any doubts about the dryness, the mix may be dried in the following manner. First, the desired quantity of solvent mix is prepared.

Then a small quantity (an ounce or so) of drying agent (I use calcium chloride or "Damp Rid™" in Florida) is placed in an acetone proof plastic container (plastic two liter soda bottle), the solvent is added, the container is capped and shaken to allow the drying agent to absorb the water. CAUTION: be sure to release the pressure in the container by loosening the cap/lid from time to time.

Only a brief time is needed to absorb the water and then the mix is allowed to settle for a few minutes. Lastly, the mix is filtered to remove any solids by pouring it through a double layer of coffee filters and stored in an air/moisture proof plastic container and the drying agent is discarded (it's cheap). It is a good idea to dry only as much acetone as is needed for the batch of go-getters you are making.

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

CAUTION: acetone evaporates very quickly. The vapors are heavier than air and extremely flammable. Good ventilation and no sparks are a must.

The acetone/xylene solvent mix is added to the composition in the squeeze bottle at the rate of 35-45% by weight. Some experimentation may be necessary to get the proper viscosity of the mix with your chemicals.

The correct consistency is somewhere around a slightly thickened pancake batter (depends on your recipe). After placing the top on the squeeze bottle, squeeze out about 25% of the air (to allow for expansion of the acetone vapor), hold your gloved finger over the spout and shake vigorously for two to three minutes or until everything is thoroughly blended.

Depending on the size of the batch you are pouring, you might want to give the bottle a good shaking every once in a while just to keep everything in suspension (don't forget to squeeze some air out first). The tubes are then filled to the brim, ready for insertion of the fuse. It is a good idea to keep a toothpick handy to unplug the nozzle and some paper towels to wipe the nozzle and your hands.

The Fuse (The Secret)

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Black Match or any other potassium nitrate containing fuse probably should not be able to be used with aluminum go-getters like it can with the magnesium varieties. This is because of the ammonium perchlorate and potassium nitrate reacting to form the very hygroscopic ammonium nitrate, which may result in a wet interface between the fuse and composition.

The trick is to use Thermolite. The Thermolite will not react with the composition and provides a nice hot flame to light the go-getters. Cut (carefully) the Thermolite in about 1 ¼ inch pieces, remove as much of the fabric-wound outer layer as you can, bend the fuse into a narrow "U" shape and insert it into the go-getters, "U" end first, about half way, and lay them over against the side of the tube.

Make sure you prepare enough fuses to complete the job before you mix the slurry. Once you pour the go-getters, the stuff sets up rather quickly. After the fuse is inserted, set them aside to dry on a piece of plastic wrap until no odor of acetone is detected (about 3-4 days). As the go-getters dry, they will shrink back into the tube a little because 1/3 of the slurry, by weight, evaporates.

By having two ends of the fuse exposed to the expanding flame front within the shell, ignition of the go-getters is improved and more initial thrust is generated due to the two points of ignition.

Construction of a Six-Inch Round Go-Getter Shell

A round go-getter shell is constructed much like any other ball shell of comparable size with a few minor differences. The time fuse is cut to allow a delay of about 4 seconds between cross matching. A fuse extender made from three turns of 30 Lb. Kraft paper is rolled on a suitable former and only pasted on the last 1/4" or so of the trailing edge, just enough to keep the tube from un-rolling.

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The tube is then slipped over the cross-matched end of the time fuse and securely taped in place (remember, at this time you only cross-match the end of the fuse that goes inside the shell). The fuse is glued into the hemisphere and the fuse extender is cut off so that it just reaches the center of the shell.

Two or three pieces of thin black match are inserted into the extender tube to quickly transfer fire from the cross match to the center of the shell (just like building a regular chrysanthemum shell).

The Burst

There are two theories behind the burst charge for go-getter shells. The first is to use a relatively hard burst to scatter the stars and let them swim back toward each other. Since the stars are placed randomly in the shell, and they are not smart enough to know which way to go, the result is a big boom and go-getters scattered all over the sky, with the distinct possibility that some of them will be driven toward the ground hard enough that they will not burn out before impacting the earth.

My preference is to use a soft break, only strong enough to open the shell and light all of the stars. Meal powder on rice hulls works well for this purpose. A 3:1 or 3.5:1 ratio of meal to hulls works very well. Remember, they are self-propelled stars and don't need to be blown all over the place with your favorite "atomic" flash burst.

Putting It All Together

Two pieces of tissue paper are cut of sufficient size to line the shell hemispheres with enough left over to fold across the top of each shell half to hold the contents in the halves while assembling the shell. A hole is pierced in the center of one piece of tissue and the tissue is inserted over the time fuse and smoothed out against the inner wall of the hemisphere.

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The second piece of tissue is placed in the other half in a similar manner except for the hole for the time fuse. The go-getters are then placed against the inner wall of the shell about half way up the wall. Care must be exercised not to obscure any of the fuses. Burst is now poured in to fill all of the crevices between the go-getters.

At this point, just enough burst is used to fill the crevices and leave a thin layer over the already placed stars. Stars and burst are added in alternating layers until the hemisphere is full. Remember to keep forcing burst into the crevices between the go-getters as this is the only way to ensure shell integrity.

The extra tissue that has been hanging over the edge of the shell and getting in the way is now folded toward the center of the shell, secured with a couple of pieces of masking tape. The other shell half is finished in the same manner and the two halves are joined using your favorite shell glue.

As was discussed earlier, you do not need a hard break for go-getter shells. Consequently, you do not need to paste endless layers of paper on the shells. Four to six layers of 60 lb. Kraft paper will suffice. After pasting, the shell is finished in the normal manner with the final cross match, lift and leader. Good luck and SAFE SHOOTING!

More on Colored Go-Getters

Subsequent to writing the original article, I have done some additional experimentation as explained below.

Colors and Catalysts

I didn't realize when I first started making the blue go-getters that copper acted as a catalyst to increase the burning speed of the composition to make a livelier star. It is therefore quite easy to shift the color toward either purple or lavender by

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substituting the proper amount of strontium carbonate for some of the copper carbonate to achieve the desired color.

Other colors require a different approach since copper compounds are out of the question due to the blue tint imparted by them. The answer to this quandary may be found with the High Power Rocketry people.

More specifically, an article in the Journal of Pyrotechnics # 3 entitled "Ammonium Perchlorate Composite Basics" which discusses, among other things, burn rate modifiers which may be used to control the burning speed of ammonium perchlorate propellants (remember, these go-getters are baby rockets).

Due to time constraints, little research has been done by this author on the suitability of these catalysts, but red iron oxide seems like a likely candidate.

Fuse Alternatives

While Thermolite makes an excellent fuse for go-getters, its limited availability and high cost discourage its use in any but the smallest of projects. The most promising solution is to use an alternate form of fuse.

My first thought was to use an H-3 based fuse (potassium chlorate and airfloat charcoal). This is not a viable alternative due to the double decomposition reaction between ammonium perchlorate and potassium chlorate resulting in the formation of the rather sensitive ammonium chlorate (Lin Collins, private communication, September 1995).

The next logical choice would then be match based on KP burst (75% potassium perchlorate, 15% airfloat charcoal and 10% sulfur with 5% additional dextrin). Because the perchlorate isn't particularly soluble in water, you end up with a slurry which must be stirred from time to time while the match is being made.

Five strands of single ply cotton string works well for this purpose (you want a fairly small diameter match, like the black match used for cross matching). The slurry must be thoroughly worked into the string before it is drawn through the sizing orifice. When the KP match is dry, cut it into lengths of approximately 1 1/4" or so and insert them about halfway into the filled tubes as you would with Thermolite.

The final step is to prime the fuses to insure complete ignition. For this purpose, the go-getter (fuse end down) is dipped in an N/C lacquer solution and then dusted with meal powder (home made meal is entirely adequate). Since no moisture is involved, there is no worry of the ammonium perchlorate/potassium nitrate double decomposition reaction occurring.

References

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Fish, T. 1981. Green and Other Colored Flame Metal Fuel Compositions using Parlon.

Issue VII, Pyrotechnica: Occasional Papers in Pyrotechnics, Austin, Texas.

Sobczak, R.R. 1996. Ammonium Perchlorate Composite Basics. Issue no. 3, Journal of Pyrotechnics, Whitewater, Colorado.

Baechle, J. H. 1989. Pyrocolor Harmony, a Designers Guide.

Notes from Harry Gilliam

- The ammonium perchlorate is the 200 micron variety
- The uncoated atomized aluminum should be -325 mesh, average particle size 12-32 micron.
- Thermolite is hard to get but worth it if you can lay your hands on it. The last place I saw it for sale was from Coonie Coyle: Coonie's Explosives & Powder, 512 East Lea Street, Hobbs, NM 88240, (505) 393-0166
- Mix and dry the solvents EXACTLY as John has recommended. Do not skip the drying step. If you have any doubt that your solvents may have water in them, dry them before using. Removing the water from this composition is necessary for your safety. The presence of water in this composition could cause the mixture to heat up and spontaneously ignite. Removing the water will also help the go-getters to dry more quickly.
- I suspect you can substitute one of our flying fish fuses for a ready-made fuse, if you do not have Thermolite or don't want to make KP fuse. Try silver or crackling flying fish. I have not tried this, so consider it experimental.
- For a time, John was using plastic ball shells, pasted with several layers of paper. My guess is that you can use plastic shells, glued well, and then add 2-3 "X's" of fiberglass reinforced strapping tape across the equator of each shell. These shells do not have to break hard. So the extra compression added by the layers of paper may not be absolutely necessary.

Acetone is both flammable and poisonous. Use it outdoors or in a very well ventilated area. The acetone in your go-getter goo will dry out quickly while you're squirting the stars. Keep some more solvent on hand to add to the mix so that you can thin it as need.

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Consumer Fireworks

Planning a Consumer Fireworks Display

By Ned Gorski

Introduction

The Fourth of July is just around the corner, and many of us really enjoy producing a nice fireworks display to entertain our family and friends, and to show off our pyro talents.

In the past couple of newsletters we've discussed making small Cremora fireball pots for such a show, and electric matches to use when firing them.

For many years a buddy of mine has hosted a large party, with a hog-roast and a bonfire, which has brought in hundreds of folks. I've presented a fireworks show annually at this event to cap off the festivities.

There's nothing quite like putting in many hours of work and to have it result in that many people-adults and children-sitting in rapt awe as the show goes on, and erupting in joyful cheering at its completion.

I've had many folks compliment these small shows, comparing them favorably with the huge, commercial, downtown displays on the river. There's just something about a small, intimate, family-and-friends setting, ending up with a nicely planned pyro display, all resulting in a really memorable event.

In the end, this demonstration of our pyrotechnic creativity, talent, hard work, and experience, and the entertaining of others with all of it, is really what this art form is all about.

To insure a safe and successful consumer fireworks display, there are some topics which merit consideration in the planning process:

- What are the laws governing such a display in my particular state, county, or city? Is there a requirement to have insurance for such a show?
- What is the site like where the display is to be presented? What sorts of fireworks devices will be appropriate and safe at that site?
- What is the budget for the show? Who will be paying for the fireworks, and when?
- Will the display be shot with accompanying music or not?

- Will the display be fired by hand, electrically, or with a combination of the two?
- Who will be helping with the display?
- What will be the length of the show?
- What devices will be employed in the show, and how will they be laid out at the site?
- What safety precautions are necessary?
- Will there be any reloading of devices during the show?
- How can we prepare for inclement weather?

All of this might sound like a bit of "overkill" to some of you. Having been involved in the planning and production of many small "backyard" displays and large commercial ones, I have learned the value of planning and getting as much of the work done prior to the day of the show as possible.

It's quite amazing how much work there is to be done on the day of the show. If the above topics are addressed beforehand, and if enough work is done before the day of the show, then the chances of a safe, successful and enjoyable show are greatly improved.

Legalities

This ain't a fun subject, but it might be the one which can save you a lot of heartbreak and wasted money.

In the USA, there is no federal law regulating the use of consumer fireworks, only their production and sale.

But laws vary widely from state to state, and from locality to locality. In my state of Ohio, the display of all but "safe and sane" consumer fireworks is illegal. But around the Fourth of July many local law enforcement agencies look the other way unless they get a lot of complaints from neighbors.

In some other states anything goes. In others if you fire off a bottle rocket you'll end up in the slammer pretty quickly, have all your fireworks confiscated and perhaps your car and home as well.

Only you can research your state and local laws, and determine for yourself what you can and cannot do.

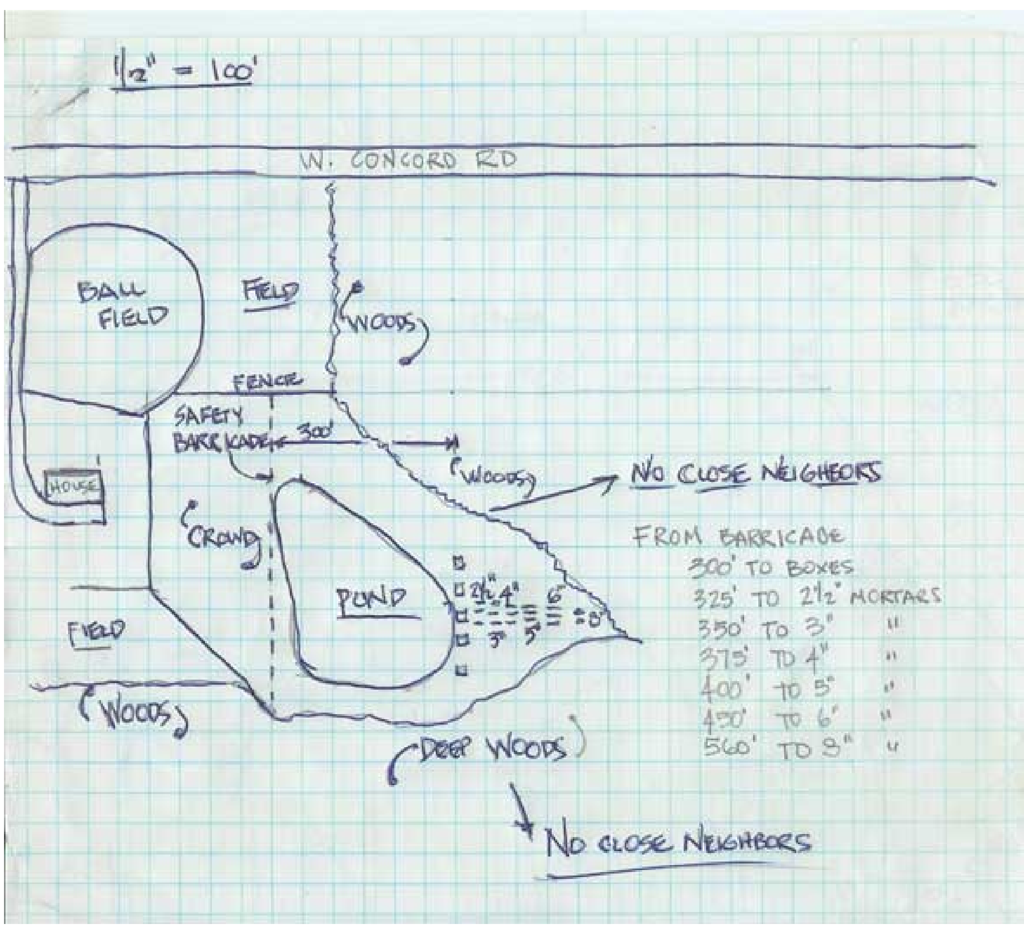
Here in Ohio, I've chosen to get my state fireworks display operator's license, to procure the necessary fireworks display permits, and to have a certificate of insurance for any display I produce. This gets the authorities-having-jurisdiction (AHJ's) on my side, and I avoid having to be looking over my shoulder and waiting for the cop cars to pull up during the show.

And, if God forbid, there's any property damage or injury, my permit and insurance are there to back me up.

The Display Site

Where will I be shooting the display? How big is the area; where will the spectators be; how close are the nearest structures and trees; how dry is the surrounding vegetation; and what sorts of devices will be safe to display there?

Some measurements with a measuring-wheel, and a simple sketch of the site can help a lot with the planning of the show.



Sketch of a Fireworks Display Site

On the sketch, I define the areas where the crowd will be. I show where I'm going to erect a barrier of stakes and caution tape, beyond which the spectators will not be allowed.

I also measure off the minimum distances needed to maintain safe separation between the crowd and the various fireworks devices. NFPA 1123 is the code which establishes these distances. These measurements not only insure compliance with the law, they also help insure the safety of the crowd during the display. These distances are as follows:

- 75 feet for ground display devices like fountains, strobes, small wheels, etc.
- 125 feet for large wheels with powerful drivers, and other powerful ground devices.
- 125 feet for smaller multi-shot cakes, and so on
- 70 feet per inch of tube ID for Roman candles, aerial shell mortars, larger multi-shot cakes, etc. (i.e., 125 feet for 1.75" artillery shells, 210 feet for 3" shell mortars, and so on)

I then determine the maximum size of the devices that I can use in a display fired at this site. I keep these limits in mind as I select the product for my show.

These separation distances assume that mortars, cakes, etc., are securely supported and/or barricaded. This protects the crowd from debris fallout and from a falling "dud" shell or device. If a mortar is not securely supported, falls over, and fires directly at the spectators, these distances will not insure their safety. Therefore, care must be taken to securely place and support mortars and cakes in the field prior to firing.

Skylighter Festival Ball Mortar Rack (#PL3175)

You'll notice that rockets are not mentioned in the above safe-distance specifications. Rockets are not typically used in professional displays any longer due to safety issues regarding the fallout of sticks and spent-motors. Rockets are used often in consumer fireworks displays, though.

Often the flight of a rocket is unpredictable even if it is fired from a secure, stable, and vertical launch support. I personally would not fire rockets in a show unless I could insure that the spent rockets absolutely would not be coming down on the upturned faces of spectators as they watch the show, or on parked vehicles. Injury and insurance claims are not on my list of "fun things" at a fireworks show.

You can see from all of the above that I take all of this seriously. Many of us see multiple examples every year of folks who have had a bit too much to drink, take some cakes and mortar tubes out to the back yard or into the cul-de-sac, have adults with kids standing in front of them about 30 feet away, and start firing away, whooping and hollering.

Most folks get away with this. Some do not. They either hurt themselves, or worse, some innocent bystander. And, as a result, fireworks get more of a bad reputation. Nothing would take the fun out of all of this more quickly for me than hurting some kid with my "hobby." I suppose I can't emphasize the safety aspects of this enough.

Show Budget

How much can I spend on fireworks for my planned display? Really! We've all gone into a fireworks shop, planning on picking up a couple of bags of fireworks for 50 bucks, and have walked out pushing two shopping carts full of brightly colored boxes after writing a check for $250.

Do you want your spouse to be talking to you on the day of the show, and sitting there enjoying your artistry, with the house payment paid in full? Yeah, sometimes all of this feels a bit like an addiction, but I have to balance it in with all the other responsibilities in my life, and I hate fighting with my wife.

It might be $200 or $2000, but the budget helps a lot when it comes to actually picking out the fireworks to be shot on the night of July 4th.

Will I be paying for the fireworks all by myself, or will some friends be pitching in? It is probably a good idea to get a commitment, and even the cash up front before the shopping trip.

Just a few things to think about. . .

Fireworks to Its Own Music, or a Pyromusical

It can be a lot of fun to record a soundtrack to be played during the fireworks show. On the other hand, sometimes it's nice to just shoot the fireworks all by themselves, enjoying their rhythm and beat, and playing the whistles, reports, soft fountain hissing, color breaks, and rocket whooshes one after another.

I like to shoot a show to music if possible. In the kind of show we are discussing, I'll simply choose some music based on the following criteria, and pick product that goes along with it. I don't try to get pin-point precision choreography. I'll save that for large, computer-fired shows.

Individual song download services like Napster and ITunes can be invaluable for finding and procuring great soundtrack songs.

One thing that I really think keeps an audience interested and entertained is variety. Folks are used to watching movies and television where there are ups and downs of emotion and action. Drama involves tension and relaxation, hard and soft, loud and quiet, slow build-up and climax. A good fireworks display will include the same.

We have found that, in general, 1-2 minutes of a particular song will keep an audience's attention. After that length of time, their minds will start to wander.

I think it's also important to keep the music recognizable. There are going to be loud fireworks going off which will obscure any music playing. I like to use a lot of hard-beats so folks can at least hear the beat of the song, and I also like to incorporate music in the soundtrack that folks will easily recognize and be able to follow along with.

Here are some possible musical themes to which appropriate fireworks can be choreographed:

- Patriotic songs: National Anthem, Taps, America the Beautiful, I'm Proud to be an American, etc. (Red/White/Blue fireworks, fountains, waterfalls, etc.)
- Kids' songs: Lion King's "Circle of Life," "Ghostbusters," "Linus and Lucy," theme from Charlie Brown, etc.
- Slow beginning beat: The beginning of The Who's "Won't Get Fooled Again" (strobes)
- Light, humorous songs: YMCA, disco songs, etc. (aerial shells, cakes)
- Soft operatic songs: "O Mio Babbino Caro," Andrea Bocelli's "Por Ti Volare," Israel Kamakawiwo'ole's "Over the Rainbow" (falling leaves cakes/shells, soft shells one at a time)
- Dramatic songs: "Theme from the Last of the Mohicans," Pirates of the Caribbean music, etc. (cakes and shells)
- Hard-beat finale songs: Hard Rock, Led Zepplin, Iron Butterfly, Queen, Black Sabbath's "Iron Man," and so on (hard-break and report finale cakes and shells, firecracker wall/tree)

There are, of course, too many songs and types of music to even begin mentioning them all, but the list above might suggest a place to start. One facet of a fireworks display which I really enjoy is the editing of a soundtrack which includes parts of 10-20 songs which I hope will entertain the crowd as fireworks go off to them.

I use Sound Forge audio editing software to cut, splice, and edit my soundtracks. I'm sure there are other programs out there, many of which can be obtained for free, with which we can assemble a fun soundtrack for our show. A final firing-script with firing times is used to fire the show.

Fired Electrically by Hand, or a Combination of the Two?

Large, precisely-timed displays are typically fired electrically, and often the firing is controlled by a computer program. This is a bit out of the range of most small display operators. But manual electrical firing can easily be incorporated into some or all of the show to improve the pace and the timing of the show, and to insure that particular devices are fired at exactly the desired moment.

The size of the firing system(s) will determine the number of cues (individual ignitions) you can incorporate into the display. If you only have a 12-cue system, there will be a maximum of 12 individual firings that you can have in the show, and the same goes for a 144-cue system.

Skylighter Electrical Fireworks Firing Systems (#GN6020, #GN6011)

But with creative fusing techniques it is possible, to greatly expand the number of devices and the duration of the display segment that is fired with each cue, though. We will be expanding on that idea in a soon-to-come Fireworks Tips article.

Skylighter Visco Fuses: Green American Visco (#GN1000), Yellow Chinese Fast Visco (#GN1100), Superfast Paper Fuse (#GN1205), Quick Match (#GN3001)

Some local fireworks clubs have yearly competitions in which a whole show is laid out on a sheet of plywood and the devices are fused together using various techniques for timing of the effects. The whole shebang is ignited using one fuse or firing cue.

Next week's article will focus on tips for wiring a display with various firing systems and include some tips for fusing devices together to expand the versatility of the electric firing cues.

If some or all of the display will be fired by hand, it's a good idea to have a scripted firing order and to have a firm idea of who will be helping to fire it.

Rehearsing the firing of the display with all of the shooters will insure a smooth display after dark.

Hand firing safety is greatly enhanced by the use of a flashlight and propane torch, or a road flare taped to a stick. Head or helmet mounted flashlights are great during firing and post-display cleanup.

Skylighter HDPE and Fiberglass Festival Ball Mortars (#PL3170, #PL3182)

If there is to be any reloading of artillery (festival ball, reloadable) shell mortars during the show, this needs to be thoroughly planned. Safe ready-boxes, which will contain the product to be loaded during the show, and their locations need to be planned. Segments during the show, when product is being fired in areas other than the area where the reloading is going on, are the only safe way to perform this operation.

Duration of the Display?

How long do we plan on having the fireworks show last? While it may be fun for us to take devices one at a time out to the shooting area and light them for hours on end, this may not be as entertaining for the crowd as it is for us.

Folks are used to being entertained for a half hour at a time with well scripted TV shows. A fireworks show that lasts 15, 20, or 30 minutes and has a lot of variety in it can easily keep folks entertained. Beyond that amount of time, you will probably start to lose folks' attention.

Of course, the length of the show will depend on your budget. It's a good idea to keep at least 25% of the product for the show's finale, which might last a minute or two. So scripting the rest of the affordable devices in an entertaining way, overlapping their durations just a bit to avoid unplanned "dark sky," will determine the show's duration.

One way to increase the duration of the show, yet not put much of a dent in the budget, is to choose long-duration devices like fountains, strobes, wheels, and waterfalls, which can fill minutes of the display for a minimal expense.

What Devices Will Be Fired During the Show?

This all leads us to a discussion of the actual product we will be firing during the display. All of this will be determined by the show's budget, site constraints, choreography, and personal tastes.

Sky Lanterns Can Be Used in Daytime or Night (#NV5000, #NV5020)

One fun addition to a show can be some pre-dusk firing of daytime effects. There is an increasing variety of daylight devices: smoke, Sky Lanterns, and streamer and parachute cakes. Kids love to run, chase, and try to catch the parachutes and streamers. Just make sure that the cakes produce fallout which is not still hot or otherwise dangerous for this kind of activity.

One really great way to pick out the product for a show is to attend the product demo at your local fireworks store. My friend Brian Lynch owns a store nearby in West Harrison, Indiana, Half Price Fireworks. Brian actually goes to China and hand-picks his favorite new devices for his shop. Often, these local, independent shops can give you the most bang for your bucks.

I attended one of Brian's product demos recently, and was handed a checklist/note-taking-sheet to use during the demonstration. Before the devices started to be fired, I organized my note-taking to include notes about these various aspects of the product:

- Height of device's display--low-medium-high (one cway to increase the variety in a show is to use various parts of the background (the sky): ground level, low sky, and high sky
- Loudness of the device (more variety can be planned if soft-medium-loud sections of the show are scheduled)

- Quality of the device, rated on a scale of 1-5
- Duration of the display of a device (I brought a stopwatch to use to record this time)
- Notes of the crowd's reaction to a device (laughter, WOW applause, quiet awe)
- Cost of the device, and its value for the money, (i.e. 12 seconds of a nice cake for $16, a line of soft-strobing fountains which last over a minute for $4)
- Based on all of the above information from the demo combined with the show budget, site limitations, and choreography, I now select my product for the show, getting the plan down on paper before strolling down the aisles of the shop.

One additional nice feature that many shops provide, including Brian's, is a label near each item which indicates the product's duration, effect, and often an actual photo of the device in action. This info can add to that which was gained at the product demonstration.

The layout of the planned devices can then be added to the sketch of the display site. Device variety, loudness variety, display height variety, and changes in durations and pace, all serve to keep the crowd interested in the show.

The safe use of some homemade devices, such as the Cremoras detailed in Fireworks Tips #101, can really enhance a display while only lightly impacting the budget.

Safety Precautions

If there is to be hand-firing during the show, safety gear such as safety-glasses, hardhats, gloves, long-sleeved cotton shirts/jackets, and hearing protection will be in order.

A five-gallon bucket of water for cooling off any possible burned hands, etc, is a good idea. Pump-up garden sprayers or a pressurized garden-hose/nozzle serve as fire extinguishers.

HAVE A FIRST-AID KIT ON SITE.

Small radios or walkie-talkies can enhance communications between shooters during the show. A barrier of caution-tape, stretched between fence posts, serves to keep the spectators in their designated areas before, during and after the display.

Thorough cleanup after the show, and a careful inspection of the site at daybreak following the display, serve to keep unfired devices out of the hands of children, who love to find and light or disassemble such items, often with disastrous consequences.

Planning for Inclement Weather

What are we going to do if it rains? A few years back I helped on a show worth tens-of-thousands of dollars. It was a hot, sunny July day, and the weather forecast predicted the same weather right through the evening. A half-hour before show time, a black, rolling wall of clouds formed on the northern horizon, and within 15 minutes the wind was howling and a hellacious thunderstorm rolled in.

In the wind, there was no way to use tarps or plastic to cover our mortars and cakes, and the long waterfall and the set pieces were completely vulnerable. We lost the whole show, and had stacks of wet aerial shells and box-cakes that had to be somehow salvaged or disposed of safely. A real mess!

These types of experiences motivate most of us experienced display producers to take precautions against the ravages of inclement weather, no matter what the forecast is. I like to say, "If you don't want it to rain, cover everything up. If you want it to rain, act as if it's not going to."

Rolls of plastic or aluminum foil, and plastic tarps, work well to cover racks of mortars. Large plastic bags cover up individual cakes, and rolls of plastic stretch-wrap can be used for mortar racks, lines of fountains, etc. It can be hard to cover and protect a firecracker wall or a waterfall or set piece, so sometimes it's best to leave them lying on the ground and covered with plastic until the last minute if there is a questionable forecast.

Conclusion

With planning centered around all of these subjects, a successful, relatively stress-free, safe, and fun fireworks display can be produced. Most folks will never know the amount of work that goes into a good show, but they also will never get to experience the satisfaction that comes from creating such a work of art and hearing the audience's cheers during and after it.

In the next few weeks, in Fireworks Tips articles, we'll be focusing more on the electric wiring and fusing of a display, the assembly of mortar racks and supports for wheels, firecracker walls/trees and waterfalls, and the actual layout/placement/assembly/support of a consumer fireworks show.

Fan Shaped Multi-shot Homemade Fireworks Firing Boards

By Skylighter staff

Learn how to make multi-shot homemade fireworks firing boards for pyrotechnic effects. These are like large firework cakes.

Materials Needed

- #5 mortar tube, 2" diameter (TU2200)
- Biscuit joiner or router
- Black match
- Circle cutter
- Drill press with spindle stop
- Electric skillet
- Hot melt glue chips (from Mercury Adhesives. 973 472-3307 Ask for hot melt #117)
- Ice pick or awl (TL4002)
- 3/4" thick particle board or MDF (medium density fiberboard) board
- Table saw or circular ("Skil") saw
- Tool grinder
- Visco fuse, green (GN1000)

Multiple shot pyrotechnic effects boards are a great way to add interest and variety to any backyard or professional public firework display. Although it is easy to pick from hundreds of Chinese-made multi-shot cakes for this same purpose, having the ability to custom tailor your own homemade fireworks firing boards is an advantage.

This article will focus on constructing the homemade fireworks firing board or "rack" in the manner commonly used by American manufacturers and not the methods favored by the Chinese. American pyrotechnic effect boards typically are made up using a heavy particleboard base and spiral wrap mortar tubes that are hot melt glued into the base.

These tubes are generally self-supporting and since they are separated from one another by an air space, in the rare case of a single tube self-destructing the remaining tubes will usually retain their integrity and continue to properly function. This is not the case with closely packed Chinese style construction methods.

While this article will not cover specifically how to load various pyrotechnic effects into the mortars, it will give a detailed description of what actual commercial production methods are used to manufacture these pyrotechnic effect boards. Covered topics are the layout and drilling of the homemade firework firing boards, gluing and setting in the tubes, a simple tube fanning technique, and methods for timing the shots (from slow-paced to several tubes fired simultaneously).

General Equipment Requirements

Circle cutter - Sometimes referred to as a fly cutter, it works by having a high speed steel cutting bit mounted in an adjustable arm that can be slid in or out to vary the cutting diameter. A pilot drill in the middle keeps the device centered in the work piece.

General Tools Mfg. Company makes an inexpensive model sold at home improvement stores. Make sure the one you buy uses a 3/16" cutting bit and either the 11/64" or 1/4" pilot bit. Closely follow all instructions printed on the package, especially the one about "Not for use in hand held power drill."

Drill press - The drill press needs to run slow enough for the safe use of the circle cutter (500 R.P.M.) and have a depth stop adjustment. It must be solidly bolted down or heavy enough to prevent movement when in use. For larger boards a 16" or larger model works well.

Tool grinder - In order to use the circle cutter, the end of the 3/16" high speed steel tool bit must be reshaped to cut a flat bottomed circular groove in the particleboard to receive the end of the mortar tube. The tool bit supplied with the circle cutter has an angled cutting end, which needs to be reground to a square tip, in order to produce the flat bottomed groove.

If thin wall mortars are being used the width of the tool bit also should be reground to produce a narrower groove. The width of the cutter should be about .030 - .060" wider than the wall thickness of the tube. For those not familiar with sharpening and reshaping tool bits, it is recommended that someone be found who has some knowledge in this area to avoid potential problems.

Electric skillet - Skillets, in conjunction with hot melt chips, are the best way to apply adhesive to the mortar tubes in order to secure them to the particleboard base. Glue guns can be used if only a few boards are going to be made up, but they tend to be very slow and do not give good, even coverage on the tube. Hot melt chips can be purchased in bulk at a much cheaper price than glue gun sticks.

Select a skillet with the highest wattage you can find (listed on the side of the box). 1200 watts works fine. Normally the hot melt chips' working temperature is about 350 degrees Fahrenheit. If the melted glue just barely smokes, it is at the right setting on the heat control. The glue must be run at the correct temperature without burning to give the best adhesion to the tube and board.

Too cool a setting will make the glue thick and less able to penetrate the pores of the materials being joined. After use, the hot melt can simply be left to cool in the skillet and re-melted at a future date. Glue that has been overheated and burned (it will be a dark brown color) should be discarded.

Biscuit Joiner - A biscuit joiner is a power tool used by cabinetmakers to form moon shaped slots in the edges of boards (wooden biscuit shaped inserts are glued in the slots to hold the boards together). The tool is useful for cutting connecting slots between tubes in the pyrotechnic effect boards. More on this later. It's great if you have one, but it is not absolutely necessary. A circular saw or router can also be used.

Laying Out the Pyrotechnic Effects Board

The first step is to determine the size and number of tubes you wish to use in your homemade fireworks firing board. Generally 3" I.D. tubes and smaller can be easily used. Since this can be a custom layout, don't be afraid to mix sizes also. For the sake of this article, we will use a 2" I.D. x 10" spiral wound tube (Skylighter #TU2200) with a 1/8" wall thickness. Nine tubes will be needed.

Using a table saw or circular saw, begin by cutting out a 12" x 12" square of 3/4" underlayment particleboard or medium density fiberboard. Plywood can be used but is harder to groove with the circle cutter and is more expensive. Do not use oriented strand board (OSB board).

On the surface of the board, lay out in one direction 3 parallel lines spaced 2-3/4" apart and centered on the pyrotechnic effect board. At right angles to this, lay out 3 more parallel lines, again 2-3/4" apart and centered. You should wind up with a grid of lines that intersect at nine points that are centered on the homemade fireworks firing board.

Set up the circle cutter in the drill press to produce a circular, flat-bottomed groove in your pyrotechnic effect board that is 5/16" - 3/8" deep. The groove should be wider than the wall thickness of the mortar tube by .030 - .060. The tube fit will be quite loose and there should be a gap between tube wall and the wall of the groove both inside and out.

Use scrap board while making the necessary depth and diameter adjustments. A WORD OF CAUTION: When securing the tool bit in the circle cutter it is absolutely imperative that the pilot bit starts cutting in the board before the tool bit does. The cutting end of the tool bit must be mounted 1/8" - 3/16" higher than the end of the pilot bit. Under no

circumstances should you attempt to use a circle cutter in any position other than perpendicular to the surface being cut. Failure to observe these points will result in the particleboard being forcibly thrown from the drill press.

Drill nine grooves in the pyrotechnic effect board by locating the pilot bit of the circle cutter in turn over each of the nine intersections previously drawn. Use a slow feed rate on the drill press, especially when the tool bit first enters the surface of the pyrotechnic effect board.

Clamping the pyrotechnic effect board to the table of the drill press is highly recommended when drilling each groove. Safety glasses are mandatory. When finished, you should have a 3 x 3 matrix of circular grooves with roughly 3/8" - 1/2" spaces between them. Starting at the lower right and ending in the upper left, label the grooves 1 through 9.

Using the biscuit joiner (or a circular saw or router) set the blade depth to 9/16" and center and cut slots between positions 7-8 and 8-9. These slots will be used to form a kind of "quick match" connection between tubes to allow instantaneous firing of three tubes in a row.

Imagine a kind of "underground tunnel" which goes from inside one tube position, under the bottom of the tubes, and comes up inside an adjoining tube. An alternate fusing method is offered in step #10 for those who do not want to try cutting these slots in the pyrotechnic effect board.

Setting the Mortar Tubes

Lay in a 2-1/2" long piece of black match in each slot cut by the biscuit joiner. The slots, where they cross the sections of circular grooves, should be slightly deeper than the bottom of the grooves to allow the black match to pass under the bottom of a seated mortar tube.

Take some lightweight paper (20#) cut roughly 1-1/4" x 3/4", fold lengthwise in half several times and force down into the slot on top of the black match with a narrow blunt stick. Center the paper in the slot. The paper keeps hot melt glue off the black match when gluing in the tubes.

Have the hot melt glue ready in the skillet. Position the pyrotechnic effect board (assuming you are right-handed) to the immediate right of the skillet with holes 9, 8, 7 at the back of the pyrotechnic effect board. Dip a tube straight down into the hot melt to a depth of 1/2", withdraw from the glue and scrape the bottom of the tube along the edge of skillet to remove excess hot melt.

Immediately position the tube over the required location on the pyrotechnic effect board - in this case, the upper left-hand spot, number 9. Generally it's easiest to fill the pyrotechnic effect board left to right, back to front. Since we are making a fan shape rack, this tube will be angled to the left about 10 degrees.

To do that, slide the tube straight down in its groove first and then angle to the left 10 degrees (you can cut out a 10-degree cardboard triangle template to lean the tube up against). Since we are not making any attempt to angle the groove into the board or cut the tube at angle, this angling method becomes limited as to the amount of fanning possible, especially with larger diameter tubes.

Continue filling the pyrotechnic effect board with tubes. Number 8 goes in perpendicular to the pyrotechnic effect board. A quarter twist of the tube as it is being seated gives a nicer bead of hot melt at the junction of the tube and the pyrotechnic effect board.

Tube 7 is angled to the right, 4 to the left, 5 straight up, and 6 to the right. At this point the inner row of tubes (4, 5, and 6) must be fused before tubes 1, 2 and 3 can be glued in place. Failure to do so now will make it impossible to fuse them later on.

After the hot melt has cooled, using the awl, punch visco fuse size holes between tubes 4 and 5, 5 and 6, 6 and 7. The holes should be located just above the hot melt bead about as low as possible on the tube. Holes should enter between the tubes at a 45-degree angle relative to the grid lines on the pyrotechnic effect board.

Cut visco fuse about 2-1/4" long and thread into the punched holes to connect the tubes together. Three pieces will be needed for this step. There is no need to run visco between tubes 7 and 8 or 8 and 9 since they are already fused with black match. If you did not use the "underground tunnel method of fusing, you will have to drill or punch larger holes between tubes 7 and 8 as well as between 8 and 9,so that short pieces of quick match can connect the tubes for simultaneous firing.

Finish gluing in tubes 3, 2 and 1, and continue to run visco between 1 and 2, 2 and 3, 3 and 4. Tube 1 also receives a leader piece of visco as a point from which to light the pyrotechnic effect board, a dab of hot melt on the leader will keep it in place.

You should now have a fan shape, 9-shot pyrotechnic effect 2" I.D. tube array. The fusing is arranged so that tubes 1-6 fire in sequence with approximately 3 seconds of delay between tubes. Tubes 7, 8, and 9 finish the sequence by firing simultaneously.

Frequently Asked Questions

Q. Can I use the pyrotechnic effect board over again after it has been fired?

A. Yes, as long as the tubes and glue joints appear in good shape, the pyrotechnic effect board can be used over again. The setup can be re-fused several times. However, the tube configuration must allow getting to each tube in order to be able to re-fuse it.

Q. The tube is only inserted 5/16" to 3/8" into the pyrotechnic effect board. Is that enough to adequately plug the tube?

A. Yes, since the tube wall is being held both inside and outside by the slot cut in the particleboard, this arrangement is more than strong enough to plug the tubes.

Q. I have some tubes that have walls thicker than 3/16". How can I use them if the tool bit is only 3/16" wide?

A. Easy, first adjust the circle cutter to cut the inside diameter on all the holes needed, then adjust the cutter bigger and go back and re-cut the holes at the new setting.

Q. Don't I have to glue in all the pieces of visco fuse:

A. No, only the leader fuse needs to be glued. The rest will stay in place just fine as long as the holes are not overly big.

Q. I don't have a tool grinder to grind and reshape the tool bit. Is there anything else I can use?

A. A belt sander with a good quality medium or fine grit belt can be used. When using this or a tool grinder it is very important not to overheat the tool bit. If the tip of the tool bit turns brown it has been overheated and will become dull quickly.

Q. Okay, now I have this great looking homemade fireworks firing board all nice and ready to go - what can I load it with?

A. Just about any idea is fair game, from shells, to mines, to comets. Even small-scale Cremora type or liquid type fireball projectors can be made.

Variations

Replace some or all the visco fusing with electric matches to create very precise electrically fired displays. Although the matches can be placed in the desired tubes by simply making a large enough hole in the side of the tube for the match head and protective shroud, a better method is to install them before the tubes are glued to the board. Here is a good technique:

First drill a 5/16" hole to a depth of 1/2" in the circular groove of the mortar tube in which you intend to have the electric match. Next, with masking tape, tape down the match and shroud so that the end of the shroud points at the small pilot hole in the middle of the; circular groove, routing the match leads down into the 5'16" hole and out again. Finally, glue the tube in place as usual.

The 5'16" hole allows the match lead to go down and under the tube lip, while the hot melt will seal everything in place making for a very tidy appearance. Do not use a bare match head installed in this manner! Loading a shell or comet in on top of a bare match head could set it off by impact. Even with the protective shroud in place, use extreme caution when loading effects.

Use fast visco (similar to the type used on class C re-loadable shells - Skylighter #GN1100) to fuse between tubes for a faster pace.

The technique of using a circle cutter and hot melt with skillet to produce tubes-on-a-base is very fast and versatile. Using simple drilling jigs to produce the hole pattern on the boards, a single worker can drill 500 to 1,000 boards a day. The technique is also good for making single shot baseboard and then cutting the strip into individual blocks.

Consumer Fireworks Display: Mortar Racks, Fusing Techniques, and Dramatic Wheel

By Ned Gorski

Introduction

I've discussed making small Cremora fireballs and electric matches to use in a consumer fireworks display, as well as firing systems and wiring techniques. I've also covered many topics which deserve attention when planning the show and purchasing devices for it.

This time we'll be looking at the construction of mortar racks from which to fire artillery shells during the show, how to construct a really nice wheel using fountains from the local fireworks store, and some techniques for using various fuses to attach devices together for the display.

Mortar Racks

Mortars are the tubes with plugged ends that fireworks shells, comets or mines are fired from. Mortars can be made of HDPE plastic, fiberglass, paper, or in some special cases, metal.

The mortars need to be secured in an upright and safe position. This can be done by burying the mortars (guns) about 2/3 of their length in the ground. Here are a couple of shots of some of the large guns that were buried for shows and competition at a recent Pyrotechnics Guild International convention.

Buried Mortars at a PGI Convention (photo by Mike Hrnciar)

Often, especially with smaller guns, the mortars can be securely held in place in racks, either perpendicularly or at an angle. The racks can be constructed of metal, wood, or a combination of the two.

PGI Convention Mortars, Set Up in Racks (photo by Mike Hrnciar)

Here are a couple of artillery shell racks made by Brian Paonessa at Skylighter, using Skylighter's PL3182 fiberglass mortars. One is a fan rack, and the other holds the guns straight up and down.

Fiberglass Mortars in Wooden Racks, One Fanned and One Perpendicular

Here is a shot showing some of the construction details of the fanned rack. Brian has glued and screwed the rack together.

Angle Rack Construction Details

Below is the angled PL3175 artillery shell mortar rack that Skylighter sells. The swing-out feet hold it in an upright position. When using this rack, I drill holes in the feet and drive spikes through them and into the ground to keep the rack from bouncing and falling over.

Skylighter PL3175 Mortar Rack with HDPE Guns

As you can see in the photo of the PGI racks above, wooden racks can also be held upright by attaching them together with lengths of wood 1x3s, or by pieces of plywood attached to both ends of them. In either case, screws or nails are used to keep the whole assembly upright and rigid.

Care must be taken to avoid driving fasteners into the mortars. In pyro this is known as a "bad-thing."

Typically, except in the case of fan-racks, racks are set up so that their ends are perpendicular to the front of the crowd. That way, if a rack happened to come loose and fall down, it would not be firing toward the crowd.

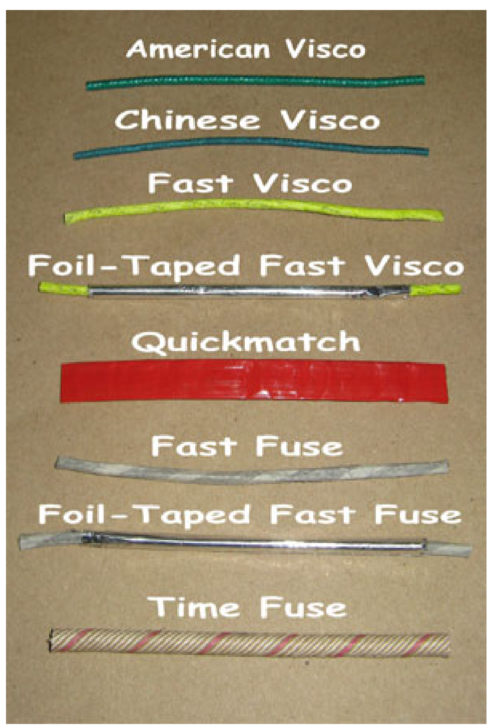
Here is another way to secure wooden racks. Screw-eyes are installed into the rack ends, and rebar pins are used to hold the racks in place. Both ends of the racks are supported in this manner, and racks can be erected end-to-end with only one pin between them.

Wooden Racks Secured with Screw-Eyes and Rebar Pins

No matter what method is used to erect them, once the racks have been assembled, they ought to be secure enough to withstand a healthy kick with a boot.

Fusing Devices in a Mortar Rack

In this section I'll be referring to and using the various kinds of fuse shown in the photo below. Each one serves its own purpose and has its own unique burn-rate. The burn rate of a roll of any particular kind of fuse can vary. So it's a good idea to cut 10 inches of the fuse off that roll and time it with a stopwatch as it burns to determine its exact burn rate.



Commonly Used Fireworks Fuses

Fuse Burn Rates

- American visco 2.5 seconds per inch
- Chinese visco 1.7 seconds per inch
- Fast visco 0.25 seconds per inch
- Fast fuse 0.1 - 0.15 seconds per inch
- Time fuse 2.2 - 3 seconds per inch
- Quick match Instantaneo us
- Foil-taped fast visco Instantaneous
- Foil-taped fast fuse Instantaneous

The foil-taped fast-visco or fast-fuse may be used as excellent substitutes for quick match, which is not shippable. I described how to make it in Fireworks Tips #99.

In the rest of this article, I will refer to quick match, and you'll know you can make substitutes for it with the fast-visco or fast-fuse as described above.

Hand Firing

So, I have filled 6 tubes in my rack with an artillery shell, comet, or a mine. If they are to be hand-fired, the shell-leaders (fuses) can simply be left hanging out of the guns, ready to be lit one at a time with a propane torch.

These shell leaders are fast-visco fuse, and I'd expect a burn rate of about 4 inches per second, which will produce about a 3 second delay between lighting the fuse and the shell launch.

A shell of this size will take about 3-4 seconds to rise in the sky and display its starburst. So if I light the next fuse immediately after the first shell has launched, and so on, I'll get a nicely paced series of bursts that lasts a total of 18-20 seconds.

If the shell fuse leaders are a bit on the short side and threaten to drop down into the mortars, they can be held in place with a little masking tape. Be sure the shells are all the way on the bottom of the guns, though, to insure proper height when they are launched. A shell that's not seated solidly on the bottom of its mortar can become a "low break," which, in turn, can cause fires or injuries.

Fireworks Shells Loaded in a Rack and Ready to be Manually Fired

Fast Chain Fusing

But, let's say I want all of these shells to launch at the same time at some point during the show or at the end of it (the "finale"). In that case I'll chain them all together with a length of quick match. Chaining shells simply means attaching their fuse leaders together in a series. If the shells are chained together with quick match, and then the end of the quick match is lit using a piece of visco or an electric match, once the flame hits the quick match the shells will all ascend skyward in quick succession.

This is done as follows:

Cut a length of quick match as long as the run of mortar tubes containing the shells, plus about a foot. Always use a razor blade or anvil cutters to cut fuse, never scissors.

Red, Waterproof Quick Match, GN3001

Pierce the quick match wall with an awl where each shell leader comes out of the top of the mortar, making sure that all the layers of match pipe are pierced and you can see the black match inside.

Punch a Hole All the Way Through to the Black Match

Put a fresh diagonal cut on the end of the shell leaders with a razor blade in order to expose the powder inside the leader. Insert the shell leader into the quick match for an inch or so.

Use masking tape or aluminum foil tape to secure the shell leader into the quick match. I really like the aluminum foil duct tape with the peel-off paper backing. The stuff sticks like crazy, will not gradually come loose over time, and is fireproof.

Cutting and Inserting Shell Leader into Quick Match

Use string to tie the fuse chain down to the rack between each mortar. I like waxed string for this purpose. It makes "threading the needle" with it a breeze. This prevents the first shell from yanking the chain as it is launched, which might pull the rest of the leaders loose from the chain.

Tie Fuse Chain to Rack at Each Mortar

Warning: In the past, some folks have used a staple gun to staple quick match chains to the tops of wooden racks. More than once, the stapler has created a spark which has ignited the chain and instantly sent shells skyward. This has killed or seriously injured some people. Don't use a staple gun to secure flammable fuse, nor use one anywhere near pyrotechnic compositions.

The nifty thing about this fusing method, and the following ones, is that they can be applied to fusing rockets set side-by-side in launch tubes, or to fusing cakes laid out in a field or on a piece of plywood. A whole show can be laid out, fused together with a combination of these methods, and fired by lighting one fuse or firing one electric match.

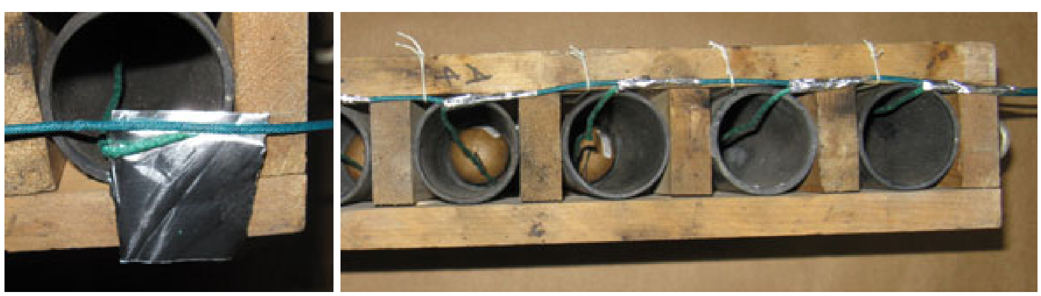
Delayed Chain Fusing

But wait, there's more! Maybe I want that nice 3-4 second delay between the shells' firing that I spoke about earlier. Maybe I want a different delay time, but I want to fire the shells in a chain as in the section above. How can I build that delay in between each shell in the chain?

Near the end of the Pyrotechnica XI article, Traditional Cylinder Shell Construction, Part II, "Finale and Flight Chaining" is addressed. This is a fascinating explanation of "old-time" chaining methods using quick match, paper buckets (rolled tubes of kraft paper), string, spolettes and regular time fuse. It's a valuable addition to my pyro library. In the photo above, there are about 3 inches between the centers of each mortar. If I run one of the visco fuses down the line instead of the quick match, and attach my shell leaders every 3 inches, then I will get 3 inches of delay between shots.

3 inches of the American visco will give me a delay of 7.5 seconds between shells. That's more than I want, but that might work in some cases. 3 inches of the Chinese visco will give a delay of 5.1 seconds between shots. That's more like it. I could go with that, although it's a bit more of a delay than I really want.

To use visco for a chain, simply tape the end of each shell leader alongside the visco fuse as it runs along the tops of the mortars. The two fuses must be parallel to and touching each other for at least an inch of tape. Then tie the chain down to the mortar rack as shown above. Don't try to run the shell leaders into the visco chain at a right-angle. You'll get poor or failed ignition that way.

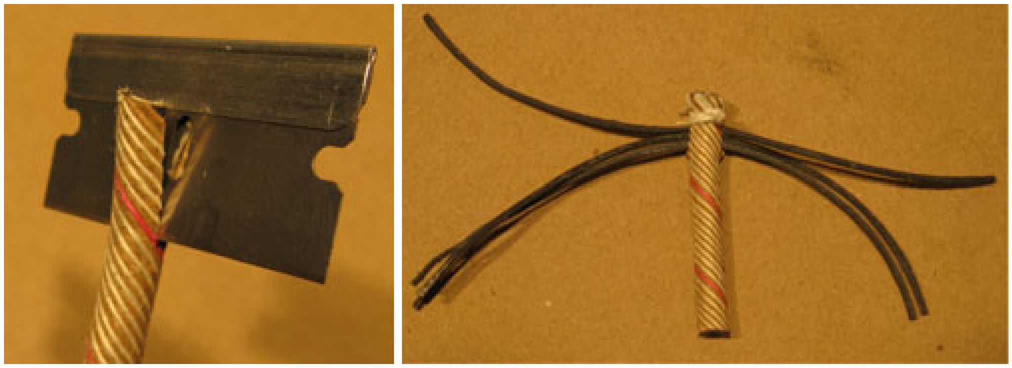


Tape Shell Leaders Side by Side to Visco Fuse Chain

There is another, more precise, way of incorporating delays into a chain of shell leaders, though. It incorporates sections of cross-matched time fuse, or the hand-rammed spolette fuses that I described in Fireworks Tips #93.

The roll of 1/4 inch time fuse that I have burns at a rate of 2.2 seconds per inch. If I use 1-1/2 inches of it between each shell in the rack, I'll get a 3.3 second delay between the firing of each shell. This is done as follows.

I want 1.5 inches of time fuse delay, and I'm going to split each end of the fuse 1/2 inch for cross-matching. So I cut five, 2-1/2 inch sections of the time fuse. I split each end 1/2 inch with my razor blade, insert three 2 inch pieces of the thin black match that can be found in the fast-fuse or quick match, and I tie each end of the time fuse closed with a clove hitch and overhand knot to secure each knot.

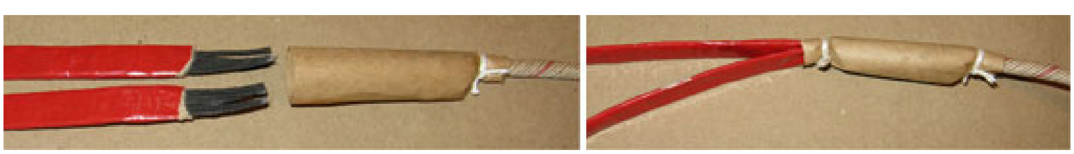


Splitting and Cross-Matching Time Fuse

Then I make "buckets" out of 3-1/2 inch x 3-1/2 inch pieces of kraft paper, rolled around a 1/2 inch wood dowel, with the edge of the paper glued down. I then tie a bucket on each end of the cross-matched time-fuse pieces, with the knots just to the inside of the pieces of cross-match. Tie the knots very tightly so that hot gasses cannot escape the bucket and transfer over to the next one before the time fuse has burned through.

Making Buckets and Tying Them onto Cross-Matched Time Fuse

Now it's just a matter of making a chain of these bucket time-delays, in similar fashion to the chains that were made above. The first bucket in the chain has a piece of quick match coming into it from the ignition source, and a piece of quick match coming out of it into which the first shell's leader is tied or taped. I don't want a delay before this first shell's fuse is ignited. This first bucket also lights the first time-fuse delay element.



Inserting Quick Match into First Chain Bucket

I bare the black match in the quick match for 3/4 inch before inserting it into the buckets. It's easy enough to clip the buckets a bit shorter with scissors as necessary. It's just important to avoid cutting into the cross-match with the scissors, and to leave enough bucket so that the knot can be tied without any black match protruding beyond it.

During the chain assembly, it can help to tie each delay down to the rack before assembling the next link in the chain. This helps to insure that the quick match pieces leading to the shells are long enough, and are routed away from each other and away from the mouth of a previous mortar, which would lead to a premature ignition.

6 Chained Shells with Time Delays between Each One

The chain shown above is designed to be ignited from the left end, to have 3.3 second delays between each shell, and to pass fire from the right end to the next device in the line if desired.

This same type of chaining using time fuse can be used to link box-cakes to each other. Let's say I start with the ignition of a cake that has a 30 second burn time, and I want to overlap the next box 5 seconds into the first cake's time. I'll put a 25 second delay time fuse and buckets at the ignition point of that second cake. On and on, this type of show can be assembled.

Consumer Fireworks Cone-Fountain Chromatrope (Wheel)

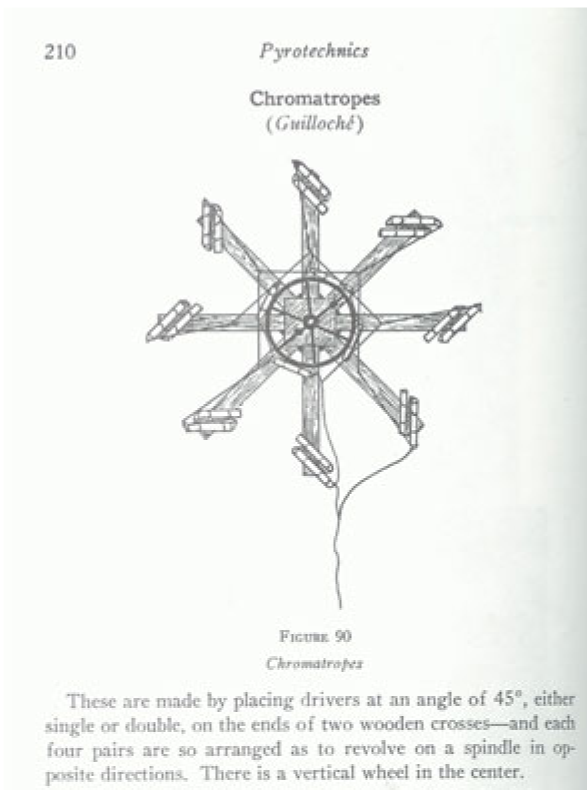
Chromatrope

Now for the added bonus section in this article. I find it to be fun and creative to take consumer fireworks items from the fireworks store, and assemble them into larger and more impressive assemblies. Fireworks cone-fountains can be hung upside down in a line to form a waterfall, and they can also be used as drivers in this large wheel. "Drivers" provide the force to make the wheel go round.

Chromatropes are a traditional fireworks display exhibition pieces. They are simply composed of two counter-rotating wheels, each of which is a basic assembly of wooden crosses with the drivers attached at the ends of each arm. They produce the kind of effect shown below.

The device shown above has 8 pairs of crossing fountain-sprays, or 16 drivers. This would be 8 drivers per wheel, and with 1 driver at the end of each cross-member, each wheel would have 4 cross-members. We'll build a simpler version, with two wheels, each having 2 cross-members and 4 cone-drivers.

Here is an illustration of a chromatrope out of Weingart's “Pyrotechnics.”


210 *Pyrotechnics*

Chromatropes
(*Guilloché*)

FIGURE 90
Chromatropes

These are made by placing drivers at an angle of 45°, either single or double, on the ends of two wooden crosses—and each four pairs are so arranged as to revolve on a spindle in opposite directions. There is a vertical wheel in the center.

You'll notice in both the photo and the illustration that the drivers are mounted at a 45 degree angle to the arms, and will shoot their spray out at that angle. This angle also diminishes the amount of force with which each driver will drive the wheel. I'm going to mount the cone-drivers at less of an angle to increase their force when turning the wheels, since the cones are not as powerful as handmade drivers.

Here's a very simple pictorial essay on this consumer fireworks model. The hubs that the bolt-axles go through are simply 3 inch long 3/8" threaded tubes/nuts/washers, available at a hardware store in the lighting department.

I have cut 1-Inch x 2-Inch x 8 foot pieces of lumber in half to produce 4 foot long arms, and I've cut steep angles on the ends of each arm.

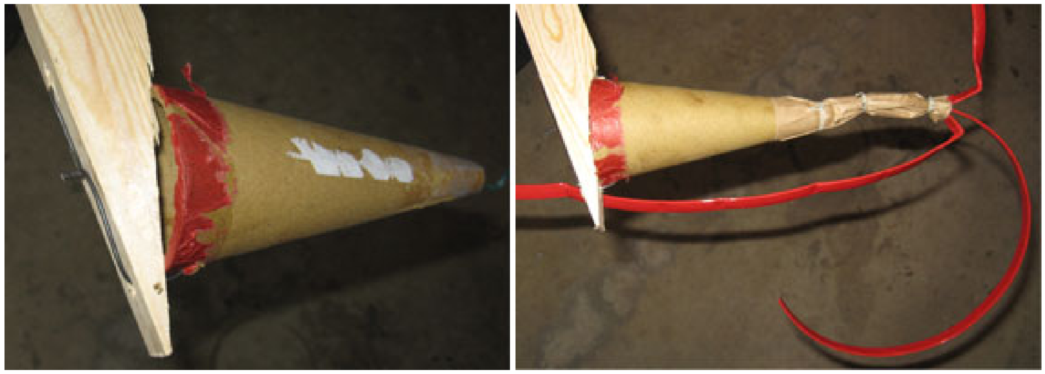
Then I drill 3/8 inch holes in the center of each arm, insert the threaded tubes, put some wood glue between the arms, and tighten the nuts and washers.

I've removed the wrapping paper from the cones and drilled some mounting holes in their hollow bases. I've also installed some extra Scotch Tape to insure that the fuses are secured in their tops.



Parts You'll Need for Your Chromatrope Wheel

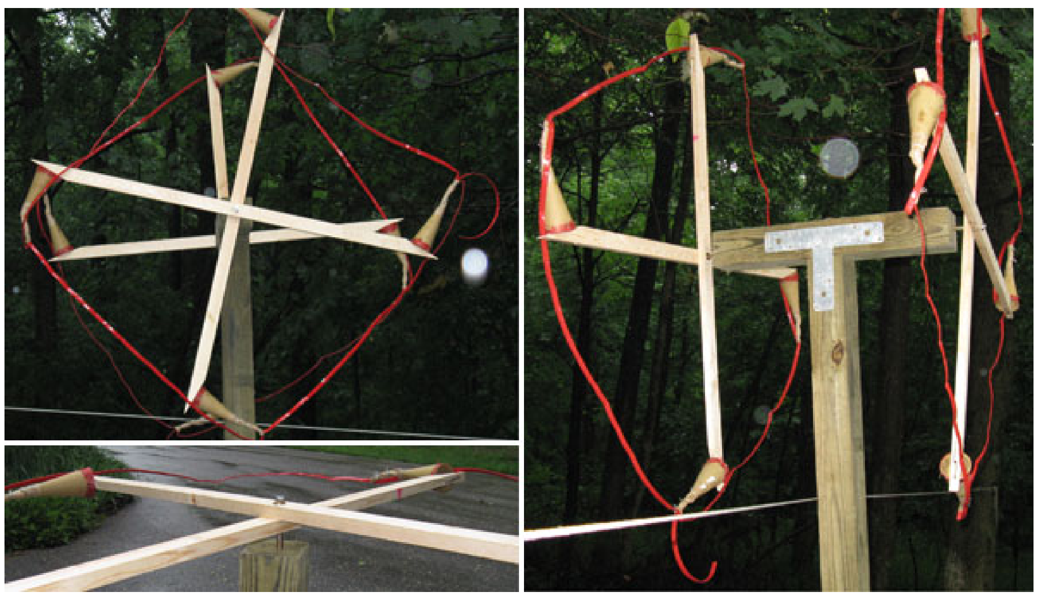
I then mount the cones to the arms with iron wire, and I install buckets and quick match to fuse them together. I have clipped the cone visco fuses on an angle to get fresh powder exposed, and I've glued and tied the buckets to the cones to insure that they don't slip off.



Mounting Cone Fountain on Arm of Wheel

I've assembled a T-support with 4x4 lumber and reinforcements. This insures that the wheels don't hit the vertical support during operation.

I've assembled the wheels so that they are driven and turn in opposite directions. You'd be surprised how easy it is to mess this detail up.



The Assembled and Fused Wheel

On the day of the show, I'll tie the two wheel ignition points into one leader so that both wheels will light at the same time. I always test at least one of the wheels with the cones you want to use to make sure that they are powerful enough to get the wheels spinning once they are lit.

Consumer Fireworks Display: Assembling a Cone Fountain Waterfall, Firecracker Wall and Tree, Star Set Piece, and On with the Show

By Ned Gorski

Introduction

In the past few Fireworks Tips articles, we've detailed the construction of Cremora fireballs and electric matches, and we've discussed the use of firing systems and wiring. Show planning and fireworks selection were covered, and then mortar racks, the use of various fuses, and the construction of a chromatrope cone-fountain wheel were all explored.

Now it's time to cover some final details, and demonstrate the set-up of the show.

Entertainment Prior to the Show

In the half-hour leading up to show time, I have some devices to shoot to entertain the kids, and to use to get the crowd ready for the main event.

I purchased some smoke cakes, which will look nice against the twilight sky, and a couple of parachute cakes which will give the children something to chase and collect. I've made sure that these parachutes do not come back to earth with anything hot attached to them, which could injure the kids.

I'm also going to launch some Sky Lanterns at dusk. These take a few minutes to launch and fly away, and the crowd always gets quiet and enjoys watching them float out of sight.

Launching Sky Lanterns Electrically

This proved to be more challenging than it sounds. Several of us have been working on methods to accomplish the electrical ignition and launching of sky lanterns.

The method I'm currently using involves priming 3 inches of a 4-inch piece of American visco with the following prime:

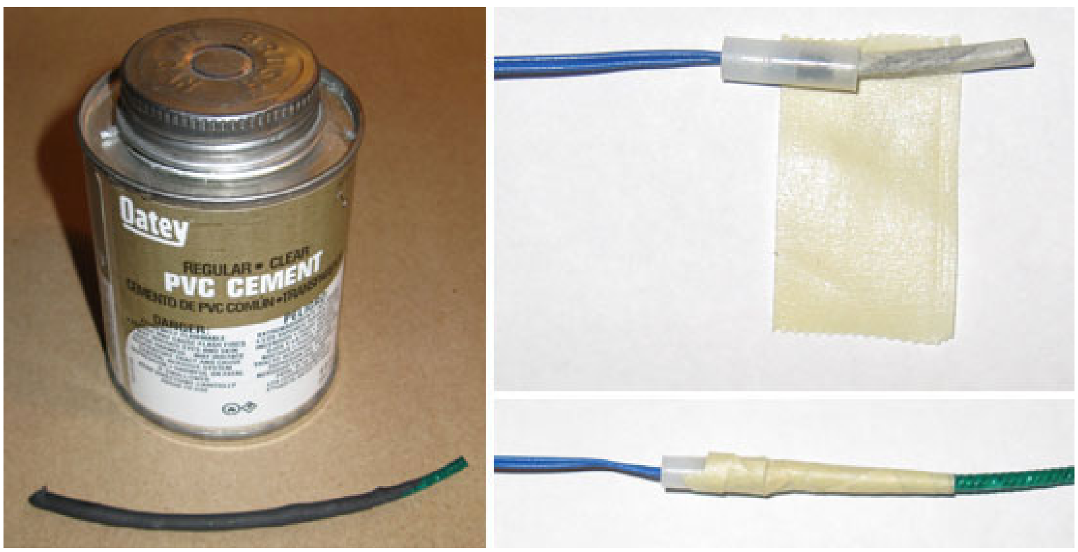
1. 1.0 ounce of black powder "green mix," which consists of 0.75 ounce of potassium nitrate, 0.15 ounce of airfloat charcoal, and 0.10 ounce of sulfur, all mixed by screening through a 40 mesh screen several times.

2. 0.2 ounce of titanium or magnalium, somewhere around 100 mesh

3. 1.3 ounces of PVC glue (Thanks to John Miller for the idea of using PVC glue in items like this.)

I put all of this into a paper cup and stir it thoroughly to create a slurry, into which I dip 3 inches of each piece of visco fuse. I then let these primed pieces dry for a day or so.

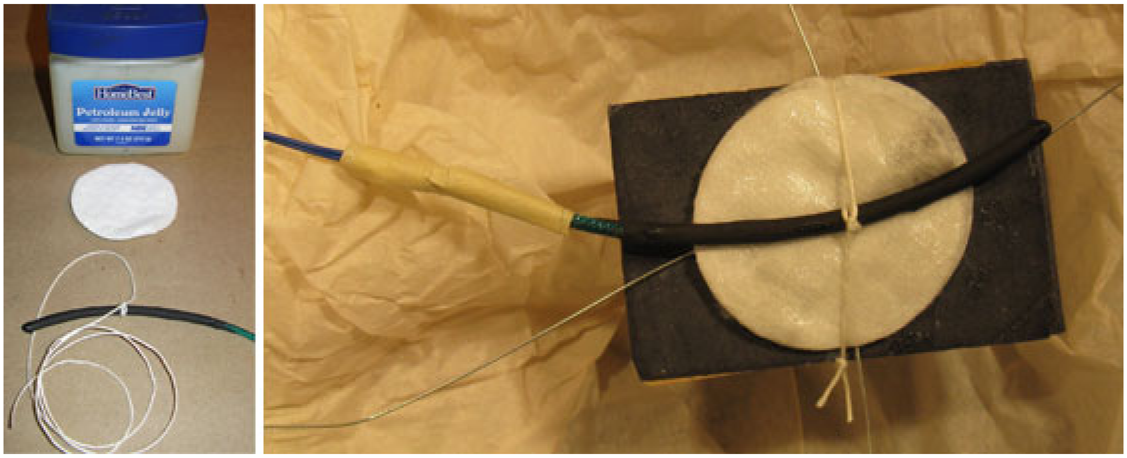
To electrically fire the visco, I tape a one inch piece of fast fuse (Skylighter #GN1205) into the end of an ematch, and then tape the fast fuse to the visco.



Visco, Primed and Ready to be Electrically Fired

Now I take a small, round cosmetics pad (stolen from my wife, Molly) and smear a very thin layer of petroleum jelly on both sides of it. This pad is placed on the top of the sky lantern burner (the fuel pad)--that is, the side of the burner facing the inside of the lantern.

I tie a piece of string around the midpoint of the visco fuse priming, and tie the fuse to the top of the jellied-pad, with the string going around the lantern burner. This string-tie keeps the fuse from coming loose from its position if the lantern moves in a breeze, or when the igniter fires.



Fusing the Sky Lantern Fuel Pad

To erect the sky lantern in the field, ready to be fired, I stick a rounded-top pole into the ground. This stick is just long enough to hold the sky lantern fully stretched out with the bottom hoop just resting on the ground. The rounded top of the pole helps prevent it from tearing through the fragile tissue paper. The lantern is now ready to be ignited and sent aloft electrically.

I have also recently used only the primed visco fuse stuck between the layers of the burner assembly. This has worked consistently for lighting the burner, but it takes a bit longer for it to really get burning. There is room for more R&D in this process.

Sky Lantern Launch Pole and Ready to be Launched Electrically

The Script and Layout of the Main Show

Now that the pre-show festivities have been covered, it's time to move on to the main show. I've intentionally kept this show simple, small in size, economical, and employing only relatively small and quiet devices.

I have also edited a simple soundtrack to be played on a boom box in front of the small crowd of family and friends during the show.

I've actually laid out on the ground the various fireworks devices that will be in the show. I've organized them in a line in the order I want to fire them, starting with some slow, smaller items, working through some smaller cakes, firing a waterfall and set piece, shooting some comets and rockets, displaying a consumer wheel and the hand-made cone-fountain chromatrope, then some 500 gram cakes, and ending with some chained artillery shells, a firecracker tree, firecracker wall, and some large Cremora pots.

There is a lot of variety in this lineup. Small and large items, low and high items, slow and fast-paced items, lots of different kinds of devices, building up to the bigger stuff, and then a loud and impressive finale.

Laying this lineup out on paper, I've overlapped quite a few of the items' display durations by 5 seconds to avoid dark sky except in the few instances where I want that dark sky to display rockets against.

The show script then looks like this:

Timing	Firework	Music
5,4,3,2,1	Fire (Start stopwatches at "Fire")	
00:02	Strobing fountains	The Who's "Won't Get Fooled Again"
00:30	Mine	
00:33	Mine	
00:37	Mine	
00:43	Comet	
01:00	Line of cone fountains	
01:16	Comet	
01:20	Purple Ball cake	"Are You Ready for This?"
01:45	Excellent Trip cakes	Disco/Upbeat music
02:10	Squealing Pig cakes	
02:40	Photo Flash cake	
03:05	Going in Circles cakes	
03:50	3 fanned comets fire	
03:55	Waterfall	"O Mio Babbino Caro"
04:15	Star set piece	
04:28	3 comets fire	
04:32	Rocket volley fires	

04:45	PyroWheel lights	Lion King's "Circle of Life"
05:03	Chromatrope lights	
05:35	My Favorite Martian cake	
05:55	Horsetail Barrage	"Somewhere Over the Rainbow"
06:15	Gold Lightning	
06:50	Timed-chain shell rack	
07:05	Quick-chained shell rack	Golden Earring "Radar Love"
07:10	Firecracker tree	
08:55	Firecracker wall	
10:00	Five-gallon Cremora pot	
10:05	Five-gallon Cremora pot	
10:10	2 Five-gallon Cremora pots pots	

As I lay the devices out, and wire them to the firing system, I'll make a note of the firing cue number to the left of the firing time so that I know which cue to fire at that time.

Note: Since I'm igniting the existing visco fuse on the various devices after clipping off a bit of it, I'm "pre-firing," by two seconds, comets, mines, and other devices that I want to shoot at a particular time. This gives the visco a couple of seconds to burn before the device is supposed to display.

Soundtrack

With this firing script nailed down, I can assemble and edit the soundtrack using my Sound Forge editing software. I always start a manually-fired soundtrack with a countdown, 5,4,3,2,1, ending with "Fire", which is where I start the timers by which I fire the show.

Sketch of the Layout

I've drawn up a rough sketch of the layout of the show, as shown in Fireworks Tips #103. This shows my safe distances to the crowd, and the layout of the firing system and scab wire, too.

What I Will Need for the Show

Now, in order to keep it simple in my head, I envision the show, one step and device at a time, starting with the pre-show items, and create a checklist of all the items I'll need to set everything up and fire it all. This is especially important if I'll be shooting the show at a remote location.

Checklist

- Table, chairs, pop-up-tent shelter
- Food and drink

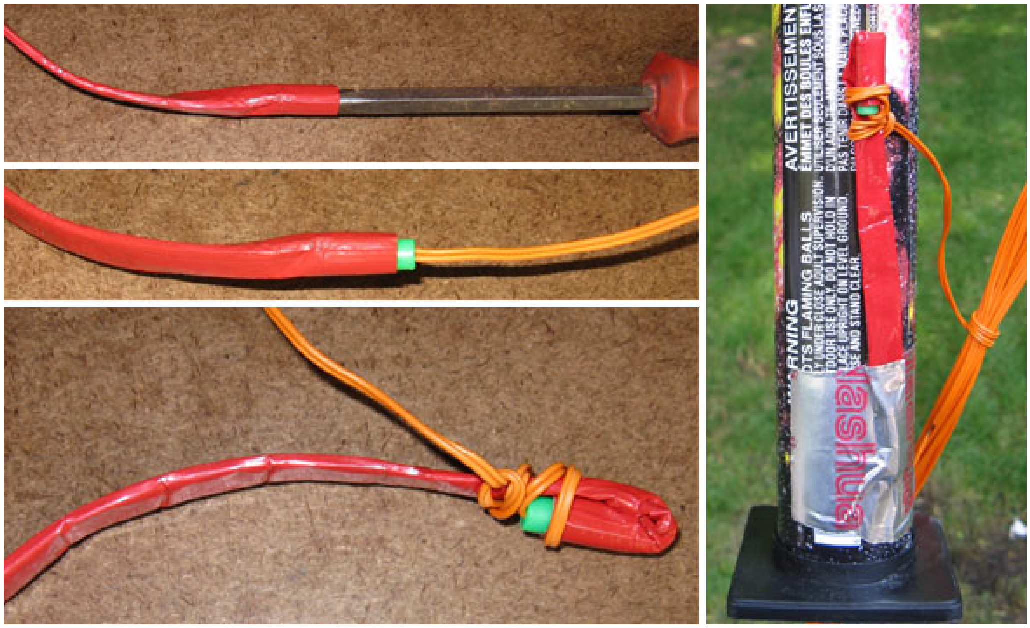
- CD player/batteries, 2 copies of soundtrack CD
- 3 copies of paper firing script
- 3 copies of layout sketch
- Caution tape and posts to use to erect a safety barrier
- Firing system (fully charged or with new batteries)
- Electric matches
- Scab wire
- Stopwatches
- Battery tester/multimeter
- Propane torch
- Fire extinguisher, garden sprayer (filled)
- Flashlight, headlamps
- First aid kit
- Sunscreen
- Bug spray
- Sunglasses
- Sledge-hammers
- Screw gun
- Screws
- Roll of iron wire
- Tool box, hand tools
- Spikes for strain relieving wires
- Kraft paper to use to make "chain buckets"
- Elmer's glue
- Sky lanterns, launching poles, ignition supplies
- Concrete blocks, bricks
- Wooden stakes
- Rebar stakes

- Ready boxes for reloading shells
- Duct tape, masking tape, aluminum foil tape
- Plastic garbage bags, aluminum foil, tarps, rain protection
- Quick match
- String
- All of the fireworks product (Duh!!)
- Rocket launching tubes
- Camera
- Step-ladder
- Fence-posts, fence-post driver, fence-post puller
- Mortar racks, loose individual mortars
- Wood blocks
- Lumber to erect waterfall, cracker tree and wall, wheels, set piece
- Cremora buckets, Cremora, black powder, napkins
- Measuring scoops, weighing scale

Preparation of Fireworks Devices

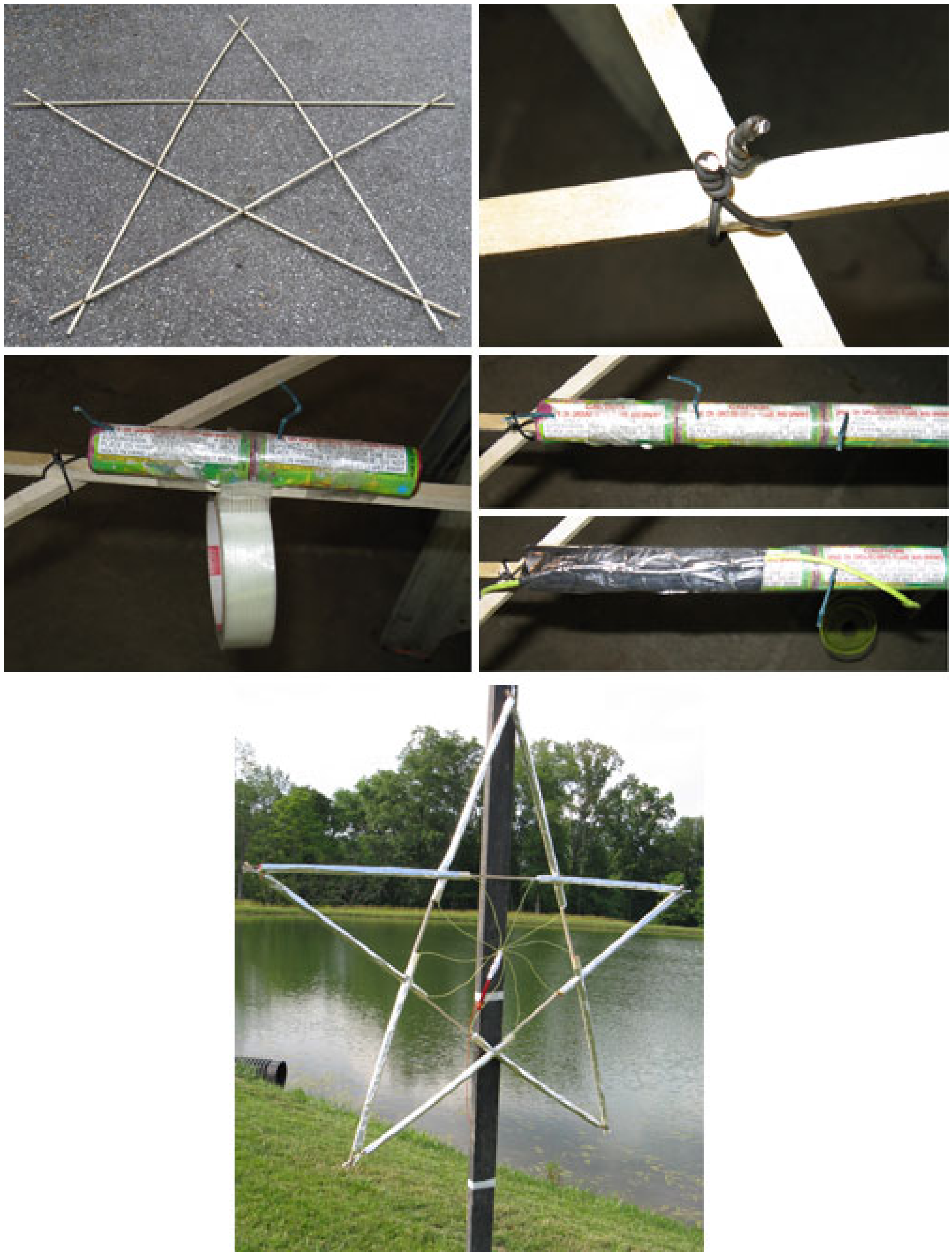
Before the day of the show, I prep the various devices that will be in the display. I install paper or aluminum-foil-tape buckets on all devices that will be chained together. I load and chain-fuse the shells that will be shot from mortar racks. I also have pre-assembled the chromatrope. See Fireworks Tips #105 for details.

I equip the cakes and other devices with ematches and quick match or fast fuse passfires.



Installing Electric Match in Quick Match, and Ematch Pigtail onto Device's Visco Fuse

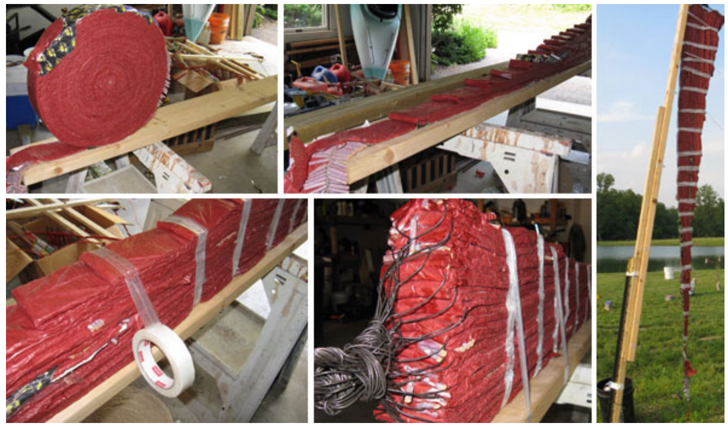
I assemble the set piece. My buddy Jeremiah Smith, winner of the Best Consumer Fireworks Show competition at the National Fireworks Association convention in 2007, developed and shared this method of using large Ground Bloom Flowers to create a consumer fireworks set-piece.



Star Set-Piece Using Ground Bloom Flowers and Fast-Visco Fusing

I sketch each support apparatus that will be used for the waterfall, wheels, and firecracker wall and tree, and I make a list of lumber that I'll need for it all.

The firecracker tree has been pre-assembled using two, 8000-firecracker rolls.



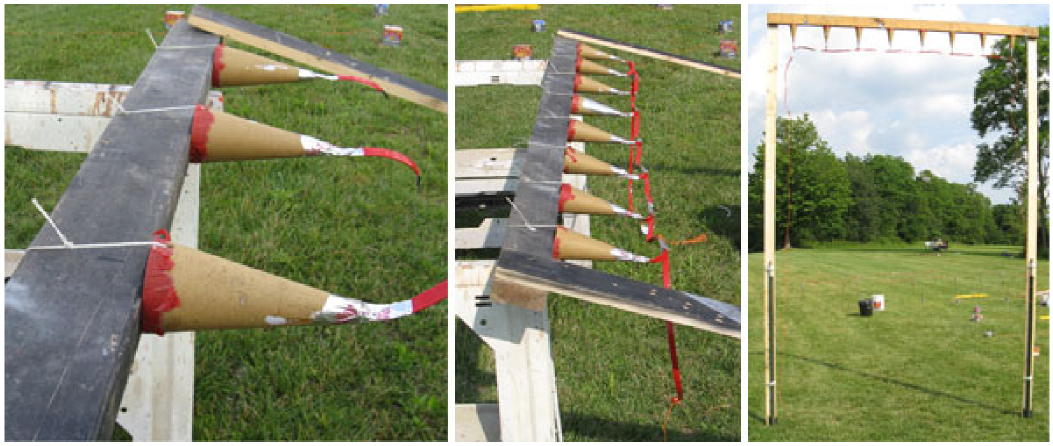
Assembling and Erecting the Firecracker Tree

The Day of the Show

So, now it's time to load the truck and head out to the shoot site. Rebar pins, wood stakes, or large barn spikes come in handy for erecting strobes, fountains, cakes, etc. I use quick match to connect all the strobes or fountains in a line.

Quick Matching a Strobe Line, and Anchoring Cakes with Barn Spikes

I assemble and erect the cone-fountain waterfall.



Cone-Fountain Waterfall

Then the rocket rack and firecracker wall go up.

Chain Fused Rockets in Rack, and Firecracker Wall

Everything else is set up and wired to the firing system, with each firing circuit checked with the multimeter. See Fireworks Tips #104 for details on wiring and firing systems.

The Complete Show Set-Up

If I was shooting this show on a paved parking lot, I'd assemble self-supporting frames for each device, and I'd support the fountains and cakes with concrete blocks and bricks. Naturally I don't use this method for anything powerful which might blow up and send pieces of brick flying toward the crowd.

Supporting Devices with Concrete Blocks or Bricks

Naturally, many of these details will vary from show to show, from site to site, and from device to device, but hopefully all of this information will serve to whet your creativity and imagination.

Post-Show Notes

I brought some leaf rakes to the site the next day to clean up as much of the paper debris as possible. I thoroughly checked the site in the daylight for any dud devices or live product.

Thinking back on the show, the best crowd reaction came when the chromatrope functioned, when the star set-piece lit and when the cracker-wall did its thing, and, of course, when the 4 Cremora pots shot their hot fireballs into the air.

For a simple, 10 minute "backyard display," the audience really enjoyed it and offered grateful responses. It's always fun to see families, folks, and children get together, romp around tossing Frisbees and baseballs until dark, and then sit around a fire and enjoy a little fireworks show.

It makes the hours and hours of work that go into the show worth it.

How to Make a 30-Shot Fireworks Mortar Rack for Festival Balls

By Harry Gilliam (source Lyle Jaegler)

Learn how to create mortar racks for "Class C," consumer fireworks festival balls using milk crates and HDPE mortar tubes.

Materials Needed

- Festival balls
- Mortar tubes, HDPE (PL3170)
- Milk crates
- Wood, 2x4
- Visco fuse, fast yellow (GN1100)

Here's How

Here's a great tip from Lyle Jaegler. Festival balls are those class C, 1.4G Chinese shells, about 1-3/4 inches in diameter that come with reloadable mortars. First, go to Wal-Mart or Staples and buy yourself one of those plastic milk crates like we all used to steal from grocery stores.

If you want to use these crates more than once, cut yourself a piece of 3/8 inch plywood or OSB the same size as the inside bottom of said milk crate, and lay it down in the bottom of the crate. Then, as fast as you can, drop 30 of our HDPE festival ball tubes right in. That should take you about 30 seconds. Et Voila! A fine new mortar rack!

Now, cut yourself a length of 2 x 4 so that it is the same length as the inside of said plastic crate. Lay it in the bottom of another crate. Then cut another piece of plywood and lay it inside on top of the 2 x 4. Then, fill the carton with HDPE tubes as before. You will now have a bunch of pipes standing up crooked, right? Wrong! They aren't crooked. They are angled mortars!

Make two of these angled racks. Now set them up in your back yard. Place the straight up and downer in the middle and put an angled rack on either side of it, 15-30 feet away. Fill them up with festival balls. Now, fuse them all together with fast yellow visco. Cross-fuse them, so that once they go, they will all go within a few seconds of each other.

20-Tube Festival Ball (Reloadable) Mortar Rack

By Brian Paonessa

The Mighty Fourth is closing on us and you haven't even begun designing your fireworks display, right? "I've got plenty of time," you say. And every year, you think to yourself, "Man! I need to buy more racks." And every year you wait 'til the eleventh hour, and end up either reloading during the show, or worse, using the cheap cardboard tubes that come with your reloadables!

Well, why not invest an hour or two right now to get ready? Here's a nice little "do it yourself project" that you can finish in about an hour if you have everything ready to go. This year you can get started early and paint the sky with festival balls the night of the Mighty Fourth of July!

20 Shot, Festival Ball, Fiberglass Mortar Rack

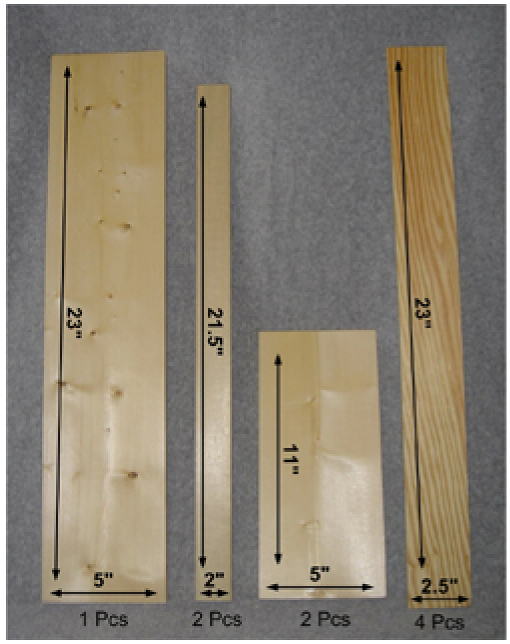
Materials Needed

- Baseboard: 1 pc. 1 x 5 plank, 23 inches long.
- End boards: 2 pcs. 1 x 5 planks, 11 inches long
- Center rails: 2 pcs. 1 x 2 furring strips, 21-1/2 inches long
- Side rails: 4 pcs. 3/8 inch thick plywood, cut
- 2-1/2 x 32 inches
- 20 fiberglass festival ball mortar tubes (PL3182)

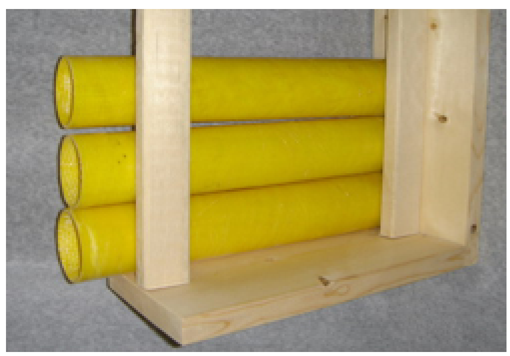
- 46 pcs. 1-1/2 inch drywall screws

Tools Needed

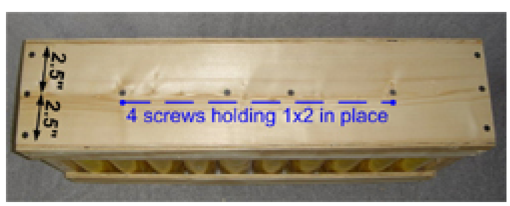
Wood saw (table-saw or chop saw if you cut your own wood pieces)



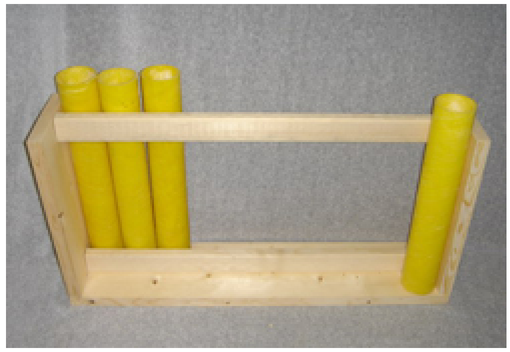
Assembly



Use Mortar Tubes to Support 1 x 2 Furring Strip Center Rails while Attaching to Base



Screw Placement for 1 x 2 Center Rail



Mortar Tubes Should Fit Flush with Each Side of the Baseboard in the Unfinished Frame

Placement of Lower Side Rail

Attach the end boards. Screw the two 5 x 11 end boards to the outside edges of the 5 x 23 base board. (Set your screws through the bottom of the base board into the each end board.)

Next, install the center rails. Place one of the 21.5 inch furring strips on its edge, directly in the center of this base. It's helpful to lay the base on its side and use several tubes as spacers to support this bottom center rail. Then attach the rail by screwing through the ends and bottom. Attach the top center rail frame screwing into it from the end boards.

Check your spacing. You should now be able to place mortar tubes on either side of the center rails with the edges of the tubes flush with each edge of the baseboard.

Attach upper and lower side rails. Stand your rack up on its base. Screw one of the 2-1/2 x 32 plywood side rails to the base and end boards. Once the lower side rail is screwed in place, attach one side of the upper side rail flush with the top corner of one end board. If the rack is not completely square, pull in the opposite end flush with the side rail to square the sides--attach that end. Flip your rack and attach side rails to the other side as well.

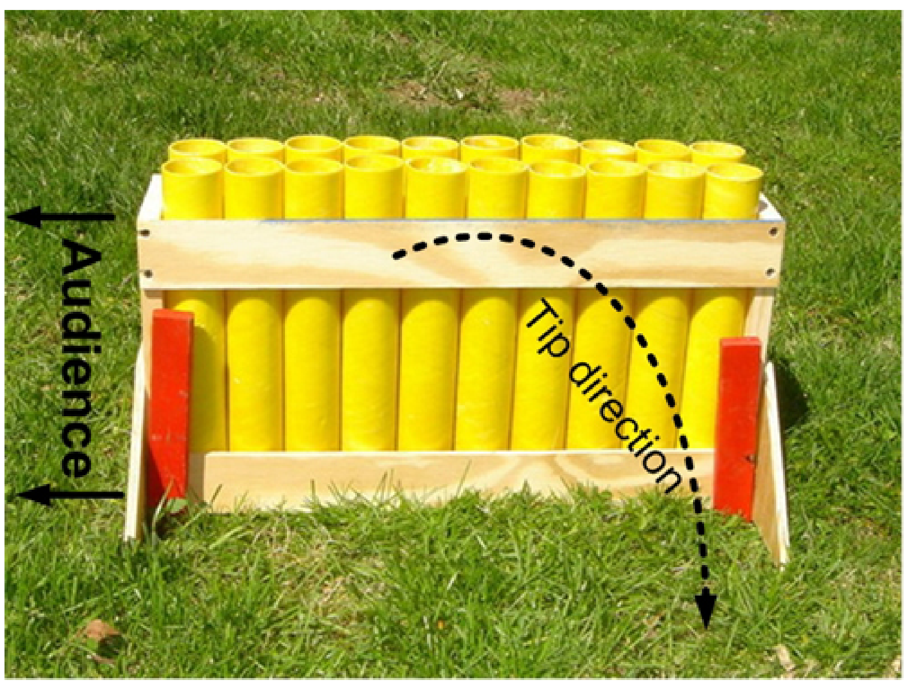
Test fit the tubes in the finished frame. They should fit snugly, but you should be able to remove them for cleaning later on.

Plywood Side Rails Screw Attachment

Safety

The rack you just finished may feel stable on a perfectly level, flat surface. But it will need to be supported when it is in use. This can be done by adding support legs or braces to the ends of the rack, or staking the rack in place, or screwing several racks together to form a larger footprint. It's not important how you secure your racks, just that you do secure them.

The orientation of your rack to the audience is critical to their safety. If a shell explodes inside a mortar tube, it will tend to blow out the weakest part of the rack. The weakest parts of this rack are the plywood side rails. And if the side rails are blown out, this could mortar tubes to fall over. So, it is important to orient your rack so that any falling tubes would be aimed away from your audience. This prevents shells from being fired directly into the audience, which can be very dangerous. Therefore, when you set up your display, orient your rack so one end board is facing the crowd. See photo below.



Safest Mortar Rack Orientation toward Audience--Perpendicular

Place rack perpendicular to the audience. In the event of a failure the tubes will fall parallel to your audience.

Note stabilizers on each end and stakes holding the rack in place.

8 Ways to Make Your 4th of July Backyard Fireworks Display Better

By Harry Gilliam.

Learn how to make a simple class C fireworks display even better using various fusing techniques as well as electrical firing.

Materials Needed

- Electrical firing system
- Electric matches (GN5050 / GN5040)
- Electric match tester (GN5005)
- HDPE tube, class C mortar (PL3170)
- Shooting wire (GN5010)
- Tube, paper class C mortar (TU2100)
- Visco fuse, fast yellow (GN1100)
- Visco fuse, green Chinese (GN1005)

Here's How

Come June, here in the good ole US of A, every Tom, Dick and Harriett is scrambling to put together his or her fireworks display for the Mighty Fourth. So, naturally, a lot of folks call with questions about how to do it around that time of the year.

Here are some of those questions and our standard answers. Some of the information below you will be able use, as you prepare for your next July 4th fireworks display. We hope your fireworks display looks better and is safe for you and your whole gang.

Question: I recently bought 50 reloadable mortars, but I don't have but one tube to fire them out of. Do you have extras I can buy? I was thinking about using PVC pipe from the hardware store.

Answer: First let us get something straight: a "mortar" is a tube from which a projectile is fired. That projectile, in fireworks, is called a shell. Shells are marketed as "artillery shells" or "festival balls." Got it? Mortars are tubes. Artillery shells are fired from mortar tubes. So what this customer really wants is more mortar tubes from which to fire his 50 artillery shells. So, yes, we have more mortar tubes.

Depending on the diameter of your artillery shells, you can use either TU2100 spiral paper mortar tubes, or PL3170 high-density polyethylene mortar tubes. Under no circumstances should you ever use PVC. When an artillery shell explodes in PVC pipe, the PVC splinters like glass or steel and can be very dangerous to anyone nearby. HDPE, on the other hand, shreds and tears, but does not create the dangerous shrapnel of PVC.

Question: I recently ordered 18 of your HDPE mortar tubes (PL3170) for artillery shells. Although my artillery shells have an outside diameter (OD) of 1.91, the mortar tubes you sent me have an inside diameter (ID) of 1.78. I was very happy with the quality of the mortars that you sent, and the speedy delivery. However, the mortars I received will work with less than half of the artillery shells that I have. What can I do?

Answer: Not to worry. This is a very common problem. The HDPE mortar tube ID's do vary some. This is because the pipe from which they are cut is actually made to have a more critical outside diameter than the inside one.

The artillery shell OD's vary as well. In a study I saw several years ago, Chinese artillery shell ODs varied from 1.68 to 1.91. There is, in fact, no standard.

Here's what you can do to get your shells to fit.

First, take a file or rasp and file the inside lip of the HDPE mortar tube down. All these HDPE mortar tubes are originally cut from 40' lengths. When they are sawn, often a bur is left on the inside, which decreases the ID. File this down.

Next, try to drop one of your artillery shells into the mortar tube. If it does not fall freely down to the bottom, place the artillery shell on its side on a hard surface, with the fuse down. Press down on the artillery shell hard with your hand and roll it back and forth across the surface. The objective is to flatten the visco fuse some, and press it into the wall of the artillery shell. This is a very common problem, even with class B (1.3G) commercial fireworks displays and mortar tubes. I use these same HDPE mortar tubes myself every year, and have to roll many of the artillery shells every time, particularly the newer, longer canister artillery shells.

Question: I can’t get quick match. What can I use as a substitute?

Answer: Use GN1100, fast yellow visco. It doesn’t burn as fast as quick match, but it can be shipped. It burns at a 1/2 second per inch. It’s yellow colored so you won’t make a mistake and use it for something requiring slower fuse.

Question: What is the best way to connect one fuse to another?

Answer: Basically, you hold them side-by-side, tight against each other and then use 3/4 to 1-inch wide masking tape to tie them together tightly. The objective is the have the visco fuse which is "giving fire" be burning right against the visco fuse which is "taking fire" for some length. It is generally a bad idea to connect your visco fuses at right angles, or end-to-end, this will result in many visco fuses not lighting.

Question: How can I use fuse to connect a lot of fireworks devices together, so I can get many of them to fire at the same time?

Answer: There are all kinds of ways to do this. Depending on the speed you want, we recommend you use either GN1005 Green Chinese visco (2.5 seconds per inch) or the quick burning GN1100 fast yellow visco (0.5 seconds per inch), or both.

Sequential Firing: Sequential firing will cause each device to fire after the previous one. First position your fireworks devices in a line or on a piece of plywood. Then cut a length of fuse long enough to connect all the devices. Then, one by one, use the masking tape method described above to connect them. What's important is that you first burn test the connecting fuse and time it. That way, you will have some idea how fast your fireworks display will go. You can cut the fuse so that the devices fire after each other with dark sky in between. Or you can use shorter timing so that the devices are "overlapping" each other-that is, one starts firing before the last one is finished.

Concurrent Firing: Use this method when you want to have a number of devices fire at the same time. First position your fireworks devices however you want them to be. After burn-testing your fuse timing, cut as many lengths of fuse as you have fireworks devices. Then, using the masking tape method described above, connect one piece of fuse to each device. Then join the other end of each piece of extension fuse to each other in a bundle. Use masking tape to tie these tightly together. When you are ready to fire them, just light the whole bundle.

Combinations: You can use both types of fusing above in combination to fire groups of fireworks in sequence, or when you have widely spaced fireworks devices. Get creative. Try different ways of doing it. Forget getting it perfect. You never will, but your audience will never know the difference. Meanwhile, you will learn from every fireworks display you shoot.

Question: Is there an easy way to fire a barrage of bottle rockets?

Answer: Yes indeed! There's a spectacular way. Get yourself a coffee or any tall can-even 12-18 inches deep would be good. You can even do this in a 5-gallon plastic pail. First punch a hole in the side of the can as close to the bottom of the can as you can make it. Insert a three-inch long length of visco fuse into the hole, about a half an inch deep. Leave at least 2 inches (5 seconds) sticking out. Put about half an ounce of black powder into the coffee can, or up to two ounces in a 5 gallon bucket. Then drop a bundle of bottle rockets into the can, with the sticks down and the bottle rockets up. If the fuses of the bottle rockets are inside the can, fine. You're ready to go. If the fuses are more than about an inch above the top of the can, break the bottle rocket sticks off, enough to get the fuses down into the can. When you light the fuse, get as far away as possible, because bottle rockets inherently fly erratically, and you don't want to be brought down before you finish firing the rest of your fireworks display. Keep in mind that the shorter the bottle rocket sticks, the more widely dispersed, and erratically flying your bottle rockets will be.

Question: When I connect 6 cakes together with one piece of visco fuse, they take too long to ignite. How can I speed them up?

Answer: I suggest you use GN1100 fast yellow visco.

Question: Is it feasible for me to fire my own firework display electrically?

Answer: Yep. You'll need the following items: an electrical firing system and electric matches. The way electrical systems work is by firing an electric match (or "ematch"), which ignites some part of a fireworks device.

Cues: A "cue" is one switched, firing position. A cue can be a single fireworks device being fired by an electric match. Or it can be a group of fireworks devices all fired at the same time by multiple ematches, such as a line of firework fountains.

Electric Matches: You can buy them or make them. However you are required to have an ATF explosives license in order to purchase them. Alternatively, you can make them yourself. For instructions and materials needed, read "How to Make Electric Matches Using Skylighter's Electric Match Heads". Alternatively, you can use Estes rocket electric igniters, which can be purchased at hobby shops, Wal-Mart, and elsewhere. Estes igniters do not require an ATF license, and although smaller, can be readily adapted to fire fireworks devices.

The Firing System: Skylighter carries three different firing systems.
(GN6011) consists of three parts: a battery-powered firing box, a 100-foot cable, and a "slat." The cable connects the slat to the firing box. The slat is on the fireworks end and the firing box is at your end, up to 100 feet away from your fireworks. Each slat will enable you to fire 10 "cues."
(GN6020) and (GN6021) consist of two parts: a 12-cue field module and a remote control.

Shooting Wire: Think of shooting wire (sometimes called "zip" wire) as ematch extension cords. You use shooting wire to connect your electric matches to the slat or field module. You also use shooting wire to help build multiple ematch circuits.

Ematch Testers: An ematch tester is a specialized circuit tester. It generates a low enough current to test the continuity of an electric match without actually exploding the match. Standard circuit testers will generate enough power to actually blow the electric matches, so don't use them. Although it is a good idea to test all electric matches before using them, if you make your own electric matches, it is especially important. Homemade electric matches are not as reliable as store-bought ones.

More Information on Electric Firing: We carry several videos on the topic. Read this to learn how to set up a show with GN6020 and GN6021.

How To Set Up a Display Electrically Using Firing System GN6011: This is a very simple explanation. Electrically fired firework displays come in all shapes and sizes from the very simple one described here, to complex firework displays consisting of many thousands of cues, choreographed to music, and costing hundreds of thousands of dollars.

A complete firing system consists of several parts that must be connected. First, the fireworks fuse needs to be set up so that it can be ignited. An electric match is attached to the fuse, typically using masking tape.

When an electrical current is forced into the ematch, it heats up a nichrome wire in the ematch almost instantly and becomes very hot (up to 2500 degrees F). That heat ignites the pyrotechnic composition on the ematch, and in turn ignites the firework fuse.

Each ematch igniter has two wires attached. These wires supply the positive (red) and negative (black) power to the igniter. These two wires as a unit are called "shooting wire." Commercial ematches come with two "leg" wires already attached. You may need to attach more shooting wire to the ematch leg wires, to enable you to attach the ematches to each other for a multi-shot cue or to be able to reach the slat.

The other end of the shooting wire is connected to two metal terminals on the slat. The two terminals are called a "cue" and they supply power to the shooting wire. Each slat has a number of cues on it (Skylighter’s GN6010 has ten cues). Other shooting wires running out to additional ematches and fireworks are connected to those cues.

The slat is the central connection point for power to fire all the fireworks cues. (If there is more than one slat, the slats are placed close to groups of fireworks or distributed evenly over the firing area. This minimizes the distance a firework is from a cue, which reduces the length of the shooting wires. Shorter shooting wires means less wire that has to be bought, stored, transported, and set up, saving you time and money).

The slat is then securely plugged into the 100-foot cable. The other end of the 100-foot cable is then plugged into the firing box. The firing box lets you decide which cue (or cues) will be "fired" (or have its power turned on) or tested. Once you have your display completely wired and connected, you will want to test each cue’s circuit.

First, you turn the power on to the firing box using the key provided with the system. Next you turn the red rocker switch to "Test" mode. Then turn the rotary switch to the #1 cue. Holding the black rocker switch down in the "On" position, you push the red Test button down. If the indicator light comes on, your circuit is good. Repeat the process for cue positions 2-10. If the indicator lamp does not come on for any circuit/cue, you will need to check your connections all the way out to each firework wired to that cue. Often, a wire has been pulled apart, and you simply need to reconnect it.

Once all cues have been tested, your firework display is ready to be fired. To get ready to fire the display, you switch the red rocker switch to "Arm." You then turn the black rotary switch to the desired cue (usually #1). To fire the cue, you hold the black rocker switch down in the "On" position, and with your other hand, press the red rocker switch to "Fire." This will fire all the fireworks connected to cue number 1.

Immediately turn the black rotary switch to the next cue (say, number 2), and wait for the firing box to recharge, usually 10 seconds or less if you are using fresh batteries. When the indicator light glows, you are ready to repeat the firing process described above. Always turn the rotary switch to the next cue as soon as you have fired a cue, so that the machine recharges and is ready to fire the next cue when you want. Since most consumer fireworks last longer than the recharge time, this will prevent you from experiencing any delays in your firing pace.

More Than 10 Cues: Using the very simple Skylighter firing system, you can expand your display from 10 cues to as many as you want by simply adding additional cable and slat combos. When you have finished firing the first slat, simply unplug its cable from the firing box, and connect the cable to the second slat. You can easily do this while the last fireworks are firing. Your audience will never know. Using this method, you can fire an unlimited number of cues.

How Many Fireworks Per Cue? The Skylighter system is powerful enough to fire up to 50 electric matches on a single cue. The best way to attach all those ematches together into a single circuit/cue is to wire them in series. Here's an example of how a simple two-firework series cue could be wired.

Say you want to fire two silver fountains at the same time. Securely attach an electric match to each fountain's fuse. Split the ends of the ematch wires into what we are going to call "left" and "right" wires. Take the right wire from the first fountain and attach it to the left wire of the second fountain. The take the left wire from the first fountain and plug it into one of the connectors for cue number 1 on the slat. Take the right wire from fountain two and plug it into the other connector for cue number 1.

Consumer Fireworks Festival Ball Artillery Shell Racks: Cautions and Advice

Learn how to use class C firework artillery shells with Skylighter mortar tubes and precautions to take when buying different sized class C artillery shells.

Materials Needed

- Class C artillery shells
- Mortar tubes, (HDPE) (Cardboard)

Here's How

After we offered the new HDPE class C festival ball artillery shell mortar racks last month, we started getting all sorts of questions and comments about various class C artillery shell sizes and firework mortar fits.

Will Kissel reports: "I work in a class C retail stand. We have 31 varieties of artillery shells. These range from 13/16 inch tube or gun bore to 1.875, with 1.5, 1.625, 1.75, 1.8125 inch and in between." He also expressed concern that smaller bore artillery shells used in larger bore firework mortars could produce dangerously low breaks.

Although our tests with smaller bore artillery shells in our firework mortars did not produce any low breaks, it is always possible with other artillery shells. And different makers and batches of artillery shells can have differing amounts of lift charge. So just for the record, our firework mortars actually have a 1.90-inch inner diameter. This tube should accommodate just about any Chinese class C artillery shell on the market. But you should test any class C artillery shells you are going to fire out of them first, just to make sure you get a good, safe burst height.

Will also points out that "using a mortar that is too tall for the fuse length on the artillery shell is a real pain. One B-Cat mortar is 18 inches in height. Our mortars are 14 inches tall, with about 12-3/4 inches of depth. Be sure your fuse is longer than 13 inches.

Will continues: "I mention these things because quite often I have to advise customers at the retail stand, who are buying several class C artillery shell kits of different mortar sizes, not to mix up the artillery shells and the mortar tubes." I think our firework mortar rack will help to solve that problem. You can mix class C artillery shells from different makers in these mortars.

"One last caution - if you can't hold your bare hand around the mortar tube at its base, it's too hot to drop a new artillery shell into, wait a minute or two."

How to Make Consumer Fireworks Festival Balls More Interesting

By Harry Gilliam

Learn how to make better use of your class C festival balls, what tubes to use, how to make mortar racks and how to fuse your artillery shells together.

Materials Needed

- Drill bit, hole cutter
- Glue
- Masking tape, 3/4" wide
- Mortar tube, paper (TU2100)
- HDPE mortar tube (PL3170)
- HDPE mortar tube rack (PL3175)
- Milk crate
- Quick match (GN3001)
- Razor blade knife
- Scissors
- Visco fuse, American (GN1000, GN1001, GN1004)
- Visco fuse, fast yellow (GN1100)
- Wood, 2x4

Here's How

It has come to my attention that the Chinese are making bigger and bigger assortments of festival balls (or "artillery shells" or "reloadables") but still supplying just one or two measly little mortar tubes for them. This leaves you with a lot of artillery shells to reload, which can be slow and boring. So it is critical that I point out to you several items for you reloadable artillery shell junkies.

Artillery Shell Size: Those artillery shells come in a variety of dimensions and shapes.

Consumer Fireworks Shells are Sold as “Festival Balls,” “Artillery Shells,” or “Reloadables”

There is no standard-sized Chinese festival ball artillery shell. They typically vary from around 1.67 inches in diameter, all the way to 1.88" or more. You might be asking yourself if you can get extra mortar tubes from Skylighter. And if you are, you need to know which mortar tube to look for. So, measure the outer diameter (OD) of the largest of your reloadable artillery shells. Measure the "widest" part, where the fuse goes around the artillery shell. Write that dimension down.

Mortar Tube Options: If you make/scrounge your own mortar tubes, PLEASE DO NOT USE PVC pipes. PVC becomes dangerous shrapnel when it shatters. These artillery shells can and do accidentally explode in mortar tubes. You would not believe how brittle and sharp PVC can be when it is exploding at you at 500 miles an hour!

To get artillery shell mortar tubes from Skylighter, you have two basic options: cardboard or plastic. If your artillery shells are less than 1.74 inches in diameter, and you want to spend the least amount of money, you can use our TU2100, festival ball mortar tube, 1.75 inches inside diameter, 10 inches long. Your artillery shell has to be smaller than 1.75" so it will slide down the mortar tube freely. Your other option, and your best one, in my opinion is to use PL3170 high density polyethylene (HDPE) festival ball mortar tubes. These are industrial-strength, professionally made, wooden-plugged mortar tubes, which should last you a lifetime. You can fire any size artillery shell out of these things.

I got all these mortar tubes from you. What do I do with them? Let’s look at your options one at a time. But before you make anything, make sure your artillery shells fit your mortar tubes. Try several. They should drop down the mortar tube freely, by just lowering them holding the fuse. If any are just a little snug, you can often roll the fuse side of the artillery shell against something smooth like a counter top, pressing down on the artillery shell as you do it.

Try and press the fuse a little flatter. Then try and drop the artillery shells into your mortar tubes. When you load your mortar tubes, be sure the artillery shells go all the way down to the bottom. If an artillery shell does not go all the way to the bottom, you will either get a low break, possibly injuring someone or starting a fire, or even a flowerpot.

A flowerpot occurs when the artillery shell doesn't lift out of the mortar tube, and explodes in it. Both conditions can be dangerous. So make sure, when you load your mortar tubes, that all artillery shells are firmly seated on the bottom of their mortar tubes.

Make a cardboard mortar tube rack. TU2100 mortar tubes don't come with plugs in them. Forget using plastic bases-most of them blow apart the first time you use them. And no, our paper caps and plugs aren't made for this. Here's what you do. Get yourself an adjustable hole cutter/drill/bit. Then get yourself a piece of 2 x 4 about as long as you want. Cut round holes in the 2 x 4 about 1/2 inch deep that are just wide enough to hold one mortar tube.

They can be holes or grooves. Either will work. Your mortar tube should fit into the hole snugly. Cut as many holes as you want. Using white/carpenter's/Elmer's glue, glue your mortar tubes down into the holes. Let them dry for a day. Et voila!

You have a mortar tube rack. If you want to reuse your mortar tube rack next year or after, first dip/roll your cardboard mortar tubes in an oil-based varnish and let dry. This seals them up, and keeps moisture from causing them to unravel.

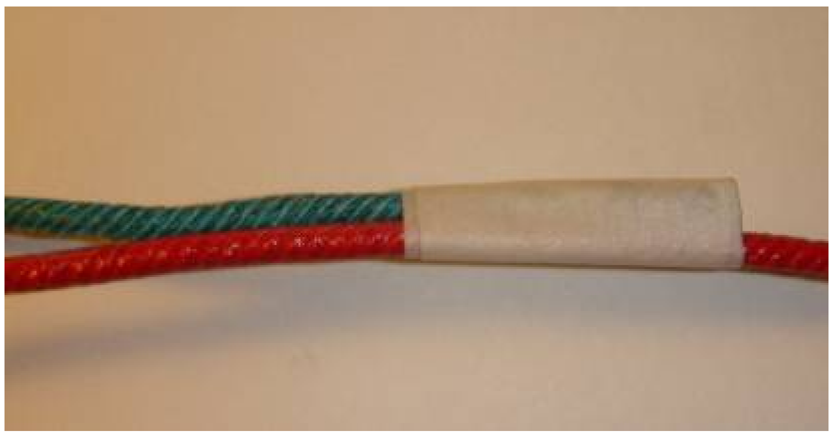
Make a milk carton plastic mortar tube rack. Read the article, "How To Make a 30-Shot Festival Ball Mortar Rack" for details on how to make a quick artillery shell mortar tube rack using HDPE mortar tubes. These make an awesome display. Milk cartons can be had at Staples and Wal-Mart. They come in different sizes and can accommodate different numbers of mortar tubes, but 20-30 of our PL3170 mortars tubes is typical.

Milk Carton Mortar Tube Rack Using PL3170 HDPE Mortar Tubes

Buy a ready-made mortar tube rack. We have an incredibly well made wooden mortar tube rack, which holds 6 HDPE mortar tubes in a fan shape, PL3175 festival ball mortar tube rack. They have folding stabilizers on the ends to keep them from tipping over, even if the ground is uneven or on a slight slope. They are the best for spreading your artillery shells all over the sky.

How do I fuse my artillery shells? I thought you'd never get to that question. This answer has two parts.

How to connect fuses: This is an easy answer. Just tape your two fuses side by side. In the picture below, 3/4" wide masking tape is used. The important thing is to have the fuses touching each other inside the tape. The type of fuse shown is called "visco" fuse.



Connecting Two Visco Fuses

How to chain fuse artillery shells using visco fuse: Chain fusing is simply connecting a number of devices together so that they fire one after the other in some intended sequence. You chain fuse artillery shells when you want to fire more of them at the same time, or if you don't want to light them all individually, or because you want to create some visual effect in the air. Or you could chain a mortar tube rack of artillery shells so that many of them would fire within a few seconds for a finale to your fireworks display. The possibilities are limited only by your imagination. So, let's see how a milk crate mortar tube rack might be chain fused. We'll use different colors of visco fuse so you see which fuses do what.

Using the milk carton mortar tube rack, shown in the picture above, notice there are 4 rows of 5 mortar tubes, and one row of 4. You can make each row different kinds. Here's what they would look like using red visco fuse for the main fuse. The green visco fuses all go to artillery shells.

The centers of the mortar tubes are 2.5 inches apart, so in this example, we'll make a simple chain with artillery shells chained at 2.5-inch intervals. First cut a length of visco fuse about 2 inches longer than your row of mortar tubes. With a magic marker, starting at one end, make a mark every 2.5 inches. Tape the artillery shell fuses at each mark. The finished chain looks like this.

Artillery Shell Fuses Chained to Visco Fuse

How to make a faster burning chain: The chain we made in step 2 above is relatively slow burning. But suppose we want to make the artillery shells fire almost all at one time, using visco fuse. Here's how. Just join the ends of all the fuses, octopus style. Tape them together really tightly. Then insert a 6-inch length of visco fuse into the middle of the bundle like this. Use another piece of tape to securely attach the 6-inch visco fuse to the octopus bundle.

Joining 5 Artillery Shells in One Place

Five Artillery Shells Fused and Timed to Go Off at the Same Time

When you lower this chain into the mortar tubes, you'll find that the artillery shells don't go all the way to the bottom of some of the mortar tubes. Don't worry. When the fuses burn past the taped connection, they will drop to the bottom of the mortar tubes before they fire.

How to chain fuse artillery shells using quick match: Quick match burns almost instantaneously. The artillery shell fuses in this chain will all light at the same time. These artillery shells will all leave their mortar tubes within a half second or so of each other. First, cut a length of quick match using a razor blade knife the same length as you made the main visco fuse in step 2 above. (Do not use scissors to cut quick match, as their friction has been known to ignite quick match! Instead use a razor blade or anvil clippers.)

Then attach a two-inch piece of visco fuse to the end of the quick match, using masking tape to attach it securely. Using a razor blade knife or scissors, make an incision in the quick match about an inch or so from the attached visco fuse, making sure that the black match inside can be seen.

Cut a Slit in One Side of the Quick Match

Then, insert about an inch of the artillery shell fuse into the quick match, with the end of the artillery shell fuse pointing in the direction your fire will be coming from (toward the visco fuse). This is important: because fire travels down quick match so fast, you want that fire to hit the exposed end of your artillery shell fuse, rather than travel past it, if it's facing the wrong direction.

Insert fuse in Quick Match toward the Fire

Use masking tape to securely attach the fuse to the quick match securely. You should be able to pick up the whole finished chain, and no artillery shells will come loose.

Use Several Wraps of Masking Tape

When your chain is finished, it should look like this.

Quick Match Chain. Note Visco Fuse on Right Side

You can either fire artillery shell chains individually, or chain your chains together. Here's how they look chained together using fast yellow visco and loaded in the milk carton mortar tube rack. All that's needed is to light one fuse.

Artillery Shell Rack Loaded with Chained Artillery Shells

Wiring Devices and Firing Systems in a Consumer Fireworks Display

By Ned Gorski

Materials List

- Digital Multimeter (or Ematch Tester, GN5005)
- Electric Matches (GN5050 & GN5040, if not premade)
- Firing System (GN6020, GN6011)
- Shooting Wire (GN5012 or GN5010)
- Stakes
- Wire-Cutters

Introduction

In recent Fireworks Tips articles I've discussed making electric matches with which to ignite devices electrically, and the construction of Cremora fireballs which can be impressive additions to any show. I've also looked at the issues involved in thoroughly planning a consumer fireworks display.

Now it's time to discuss using those electric matches in conjunction with an electric firing system and shooting wire, and hooking devices up to them out in the field.

Using these methods together can result in a nicely timed display, and will also enable you, the display designer, to sit back and enjoy the show with the rest of the crowd.

Shooting Wire

"Scab wire" or shooting wire is the wire that is used to connect the firing panel to the electric match. It essentially extends the length of the leads of the ematch, or connects multiple igniters in one firing circuit. It is important to know the wire's resistance for a known length of it.

Scab wire usually comes in rolls that have "duplex" wire on them, which means that the wire is two-conductor wire. Two insulated wires are attached to each other, side-by-side.

Two-conductor, copper, 22-gauge, yellow-insulation wire is probably the most commonly found scab wire out in the field. There is also copper-clad, aluminum, orange-insulation wire that is being imported and used.

Short Pieces of Shooting Wire, and the Tools for Working with It

I cut the wire with the wire-cutters (dykes), split the insulated wires apart with the same tool, or the razor knife, or with my fingernails, and strip the insulation with the dykes or with my fingernails. If I use the dykes to strip the insulation, I'm careful to avoid damaging the wire itself, which is easy to do. I therefore prefer to strip the insulation with my fingernails.

The most important thing to know about the wire that you are using is its resistance. This is listed as "ohms per 1000 feet" in wire data tables. It's easy to determine this for yourself, though.

Digital and Analog Multimeters to Use on Electric Circuits

All you need is the wire and a multimeter, which measures voltage and resistance. A digital meter like the one on the left is a good investment because it will be used in this step and also in future testing of firing circuits. The analog meter on the right is good for testing batteries and can be used to check resistance, but it is not as accurate as the digital meter.

Note: In a circuit which contains ematches, I only use the digital meter to check resistance. The analog meter can fire ematches, which is NOT something you want to happen!

To determine the resistance of my shooting wire, I take 50 feet of my duplex (two conductor) wire, bare 1 inch of both wires at one end of it, and twist those ends together securely. I then separate the wires at the other end for 3-4 inches, and bare 1 inch of those ends. Now I set the dial on the multimeter to the setting for measuring resistance (ohms) and wrap one bared end of the shooting wire on one of the meter's probes, and the other end of the wire on the other probe.

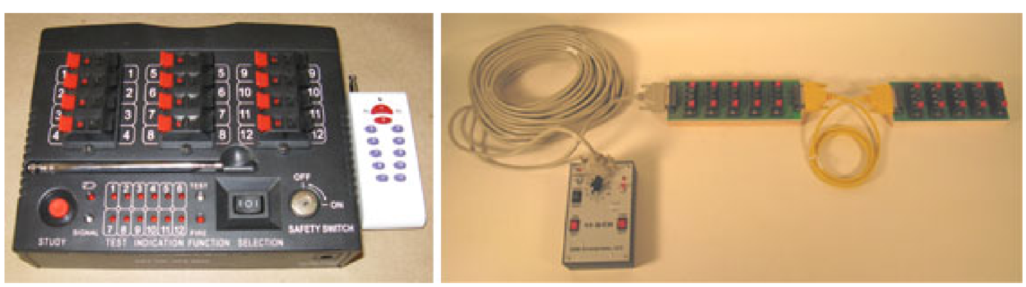
I'm actually measuring the resistance in 100 feet of the single-strand wire since the measurement current is going out 50 feet to the twisted ends, and then back 50 feet to the meter.

I should get a reading between 1.6 ohms for the 22 gauge copper wire, and 3 ohms for the copper clad aluminum wire. This exact reading will depend on the actual wire you are using. I then multiply this reading by 10 to get the resistance in ohms per 1000 feet of the wire.

The yellow wire I've described has a resistance of 16 ohms per 1000 feet, and the orange wire's resistance is about 30 ohms per 1000 feet.

Electric Firing Systems

I have a few different firing systems. I have a new Skylighter 12 cue wireless system (GN6020) which puts out 4.5 volts. Then there are my older model 8 and 12 cue wireless panels which put out 12 and 18 volts. I also have a hard-wired 144 cue system which sends out 24 volts, and I've recently seen the 10 cue capacitive discharge, hard-wired system (GN6011) at Skylighter which fires with higher voltages.



Skylighter Wireless 12 Cue, and Hard-Wired 10 Cue Firing Systems

To determine the firing voltage of my systems, and to check the batteries in the panels before use, I simply set a multimeter on DC voltage, hook it up to one of the firing cues, and fire that cue. The meter will read the voltage that is being sent to that pair of connectors by the firing panel.

Before the show, I use the meter to check the batteries in my firing system, both in the transmitter and receiver. I always have spare batteries for the multimeter and for the firing system in my kit of spare stuff that I bring to a display.

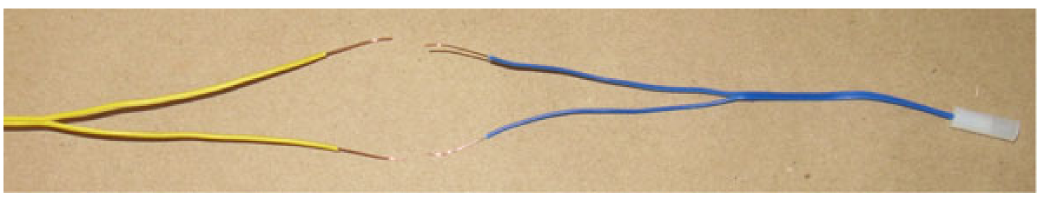
Hooking Devices Up to an Electric Firing System

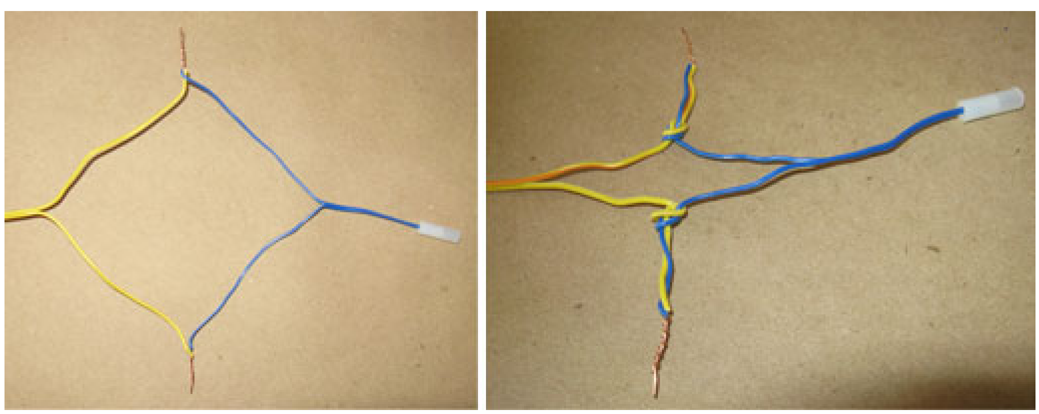
This subject sounds like the simplest thing in the world, doesn't it? But, believe me, there may be no quicker way to insure failure with a fireworks display than to ignore some of the "rules" of electric wiring that I'm about to relate.

If you keep these tips in mind electric firing can really be an incredible enhancement to any display.

Attaching an Electric Match to the Scab Wire

Nope, I don't need electrical tape, masking tape, or wire-nuts to do this. I start by separating the two wires at the end of the scab wire and at the end of the ematch. Then I strip 1 inch of insulation off of each of the 4 wires with my thumbnail.

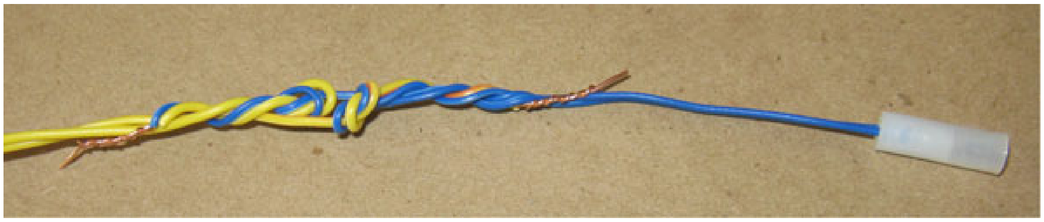




Two Pairs of Wires Tightly and Completely Twisted Together

An overhand knot is tied in each pair of wires.

The ematch wires and the scab wires are then pulled in opposing directions, the knots come together, and the twisted pairs of wires are wrapped around the main wires on opposite sides of the knots.



Yellow Scab Wire Attached to Blue Ematch Leads

This results in ematch wires that are securely attached to the scab wires. The knots prevent the connections from being yanked apart in case someone trips over a wire. The wires wrapped in opposite directions prevent the two bare-wire connections from coming in contact with each other, which would prevent the ematch from firing when it is supposed to.

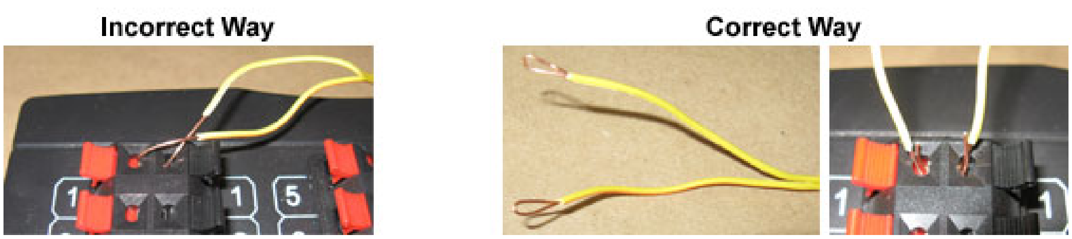
Attaching Shooting Wire to the Firing Panel

Warning: When connecting ematches to a firing system, have the system turned off and the safety key removed. Make sure all personnel are clear of the devices that are being wired up. If there are thunderstorms in the area, keep the wiring disconnected and the bare ends of the scab wire twisted together (shunted).

Once again there are right ways and wrong ways to attach wires to the firing system. First, I separate the insulated wires for about 3-4 inches, and strip the insulation back for 1 inch on each wire.

If I just stick the bare wires into the panel's connectors, there's a good possibility they can be pulled over and into contact with each other. This would short this circuit out and prevent the electric match from firing, as shown in the photo on the left below.

So, instead, I double each bare end against itself, insert those doubled ends halfway into the connectors, and then "pinch" the connectors toward each other to insure that the wires are really crimped into their connections.



Incorrect Way and Correct Way to Connect Wires to Firing System

You'll notice that I've only inserted the doubled-ends into the connectors halfway so that I can visually insure that the connector is not clamping down on insulation instead of the wire. I have also not inserted the wires so far that the clipped ends of the wires are down inside the connector. This could make removal of the wires difficult at the end of the show, and possibly damage the connector.

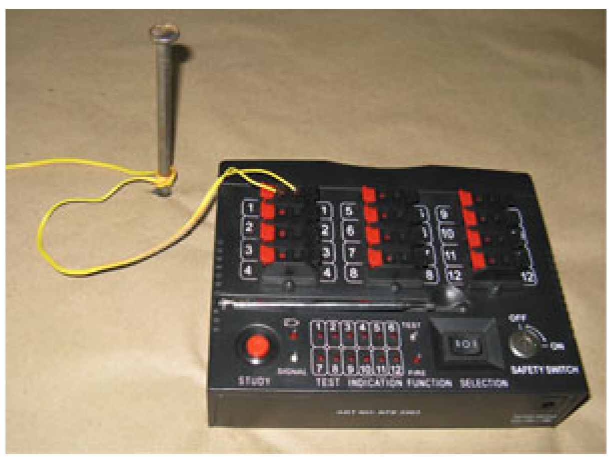
Strain-relieving the Wiring at the Firing Panel and at the Device

So, on the day of the show, it's getting late and dark, folks are becoming tired and are stumbling around, and there are lengths of shooting wire lying all over the shooting site, connecting the firing panel to the various devices.

At this point in the show setup, folks need to be reminded to walk carefully and avoid the wiring. And as soon as I do that, I'll sure-as-shootin' trip over a wire myself, yanking it loose from the panel, or worse, pulling way too hard on a fireworks cake fuse or a shell leader. One simple procedure can prevent a lot of problems in the above scenario: strain relief.

Simply put, anchor your shooting wire and/or ematch leads to something solid near the devices and near the firing system. Often, the ematch leads can be tied off to a mortar-rack. But, if there is not something nearby to tie the wire to, I'll simply drive a wooden or metal stake into the ground and tie the wiring to it with a clove hitch.

I place these wire-knots down the stake, near the ground so that if a wire is tripped over it won't pull the stake over too far.



Strain-Relieving Shooting Wire

Attaching the Electric Match to a Fireworks Device

Near the end of Fireworks Tips #102, Making Electric Matches, I described one way to attach ematches to the safety fuse on fireworks devices, using fast fuse and masking tape. A length of quick match can also be used, as described in an article by Brian Paonessa which can be found in the Project Plans section of the Skylighter.com website.

Wiring Calculations

I now know how to securely connect my wires to each other, to the fireworks devices, to the firing system, and how to safely strain-relieve them. But, how much wire can I actually run between the firing system and the electric match?

Each ematch needs a minimum of 1 amp of electric current to run through it in order for it to fire. Because of the wire resistance which I described above, if too much wire is used between the panel and the ematch, less than 1 amp of current will flow in the circuit. We then run the risk of having the igniter fail to fire.

Ok, here it is: a formula. Don't let it scare you off. I'll actually help save you from having to use it in a moment.

Resistance = Voltage divided by Current

I know the minimum amount of current I want in a firing circuit: 1 amp.

I know the voltage that my firing system puts out: 4.5 volts (in this example, using Skylighter's GN6020 firing system).

Resistance then equals 4.5 divided by 1 which equals 4.5 ohms. This amount of circuit resistance will allow a current of 1 amp to flow.

If I go above this maximum amount of resistance in my circuit, the current will drop below 1 amp. So, it's fine if I have less than 4.5 ohms of resistance in the circuit since that will simply increase the current above 1 amp.

The homemade electric matches that I detailed in the article cited above all had a resistance of 1.2 ohms. Commercial ematches will have typical resistances of 1.5 - 2 ohms. I'm going to assume we're using the 1.2 ohm matches for the purposes of this discussion. (But you should always test yours.)

Since my ematch has a resistance of 1.2 ohms, and I want a maximum of 4.5 ohms of resistance in this particular circuit, then 4.5 - 1.2 = 3.3 ohms left over for the scab-wire's resistance. I can now calculate the maximum lengths of the wires that I can use. For example: the yellow scab wire has a resistance of 16 ohms per 1000 feet.

(Using the 3.3 ohms left for scab wire) 3.3 divided by that 16 equals 0.206.

0.206 times 1000 feet equals 206 feet.

206 feet of this wire would have a resistance of 3.3 ohms. This is the maximum amount of this wire I can have in this circuit. Any more of this wire and my total resistance will be too high.

But, this is a maximum of 206 feet of the single strand wire, and my shooting wire has two strands: one out from the panel to the ematch, and one back from the match to the panel. So, in reality, I can only have a maximum of 103 feet of the double-strand shooting wire between my 4.5 volt firing panel and my igniter.

If I am using the orange (copper-clad aluminum) wire described above, which has a higher resistance of 30 ohms per 1000 feet, then I could only use 110 feet of the single strand wire going out and back, or 55 feet of the double strand shooting wire.

The table lists these figures for the two types of scab wire, the length of double strand wire between the panel and igniter, and for 4.5 volt, 12 volt, and 24 volt systems.

Max Resistance	Max ft. of Yellow Wire	Max ft. of Orange Wire
4.5 Volt Firing System (one igniter in circuit)		
4.5 ohms	103 ft.	55 ft.
12 Volt Firing System (one igniter in circuit)		
12 ohms	338 ft.	180 ft.
24 Volt Firing System (one igniter in circuit)		
24 ohms	712 ft.	380 ft.

Once again, these are the maximum lengths of the double strand wire I can use in the circuit. Now, it's easy to run a maximum of 103 feet of the yellow, two-strand wire, hook up one end to the ematch, and the other end to my digital meter, and check the resistance in that firing circuit. The resistance should not exceed 4.5 ohms, and should fire successfully with my 4.5 volt firing system.

The test circuit shown below, with 100 feet of the scab wire, read 4.5 ohms and fired as designed.

Ematch and 100 Feet of Shooting Wire, Reading 4.5 Ohms

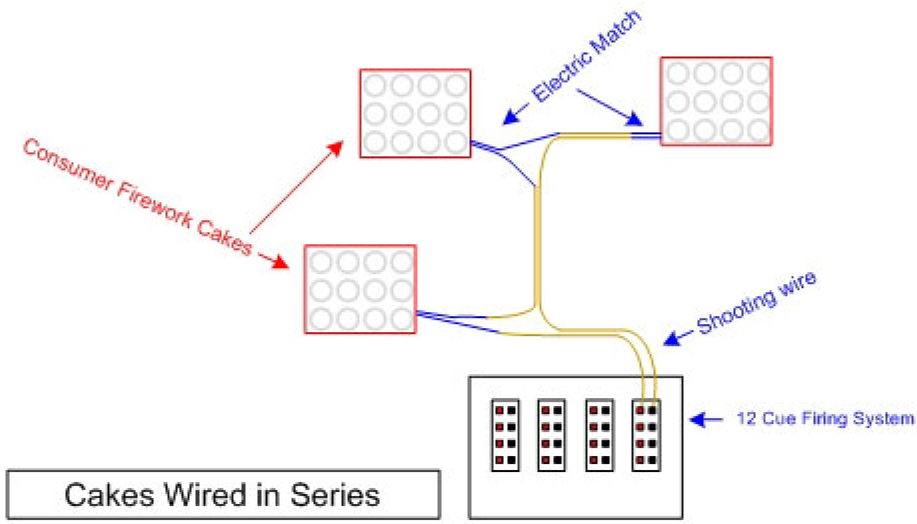
Firing More than One Electric Match per Cue

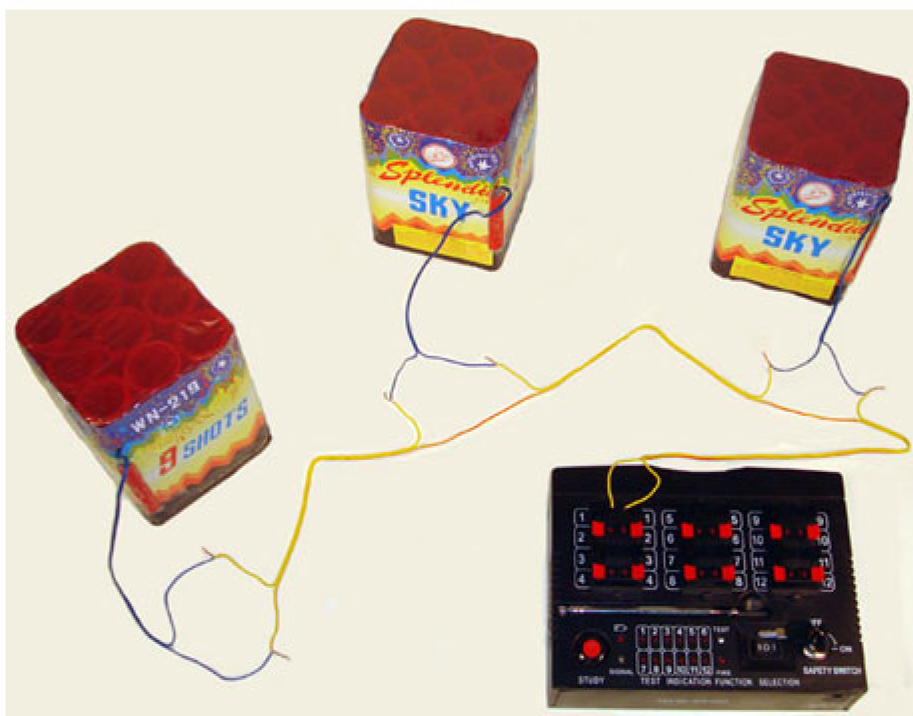
This introduces the last bit of complexity into the subject of electric firing. Each firing cue can indeed fire more than one ematch, but as usual we have to be careful when designing the circuit so that our igniters will fire as planned.

There are two basic ways to hook up multiple ematches to one set of connectors on our firing panel: in series and in parallel.

Series Wiring

Series wiring has the ematches hooked up one-to-another, so that the current flows through the complete line of igniters, one after another.





Three Igniters Wired in Series and Connected to the Firing System

A significant advantage to series wiring is that, since the current has to flow through all the ematches before it returns to the panel, the test lights on the panel will test all of the igniters at the same time. If there is a bad match, the test light will not go on.

Also, with a typical amount of shooting wire in such a circuit, series wiring requires less current to fire the igniters, thereby allowing longer lengths of the scab wire to be used reliably.

In the field, most pyros use series wiring, with few exceptions. Serial wiring is counter-intuitive to some people. They assume that if 2 or more electric matches are serially wired to each other, that when the first match fires, that first ematch will break the circuit and prevent the remaining ematches in the circuit from firing. But in practice, the current flows so quickly that all the ematches in any given serial circuit will fire at the same time.

In this series circuit, the resistances of the ematches are added together to obtain their total resistance: 1.2 ohms plus 1.2 ohms equals 2.4 ohms of resistance for two matches.

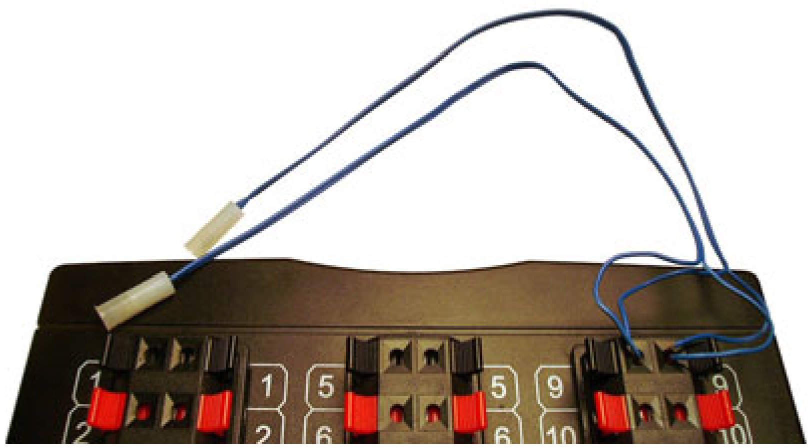
We still only need one amp of current in the circuit, though, to fire the matches. So, using the 4.5 volt system, with my maximum resistance in the circuit being 4.5 ohms as determined in the example above, the maximum resistance of my shooting wire can be up to 2.1 ohms.

Thus, I can add a maximum of 66 feet of my double-strand-yellow scab wire, or 35 feet of my orange-double-strand wire to the circuit. This wire can be added anywhere in the circuit: between the panel and the igniters, between the igniters, or both.

Note: I always test my completed circuits to see if the actual resistance in the circuit is close to my calculated resistance. It is also important that all the matches in the circuit are the same type and have the same resistance. If one match ignites before the others do, because of differences in construction, then there is a good chance the rest of the matches in the series will fail to ignite.

Parallel Wiring

This type of wiring connects all of the igniters directly to the firing panel (none to each other), or to the main scab wire individually like the rungs on a ladder.



Parallel Circuit Connection (Both Ematches Wired into the Same "Cue")

A disadvantage to this circuit is that, since the current has more than one way it can flow, if even one ematch is good, the whole circuit will test "good" with the panel test light. A bad ematch will not cause the test light to remain dark!

Parallel wiring also will allow less scab wiring to be used out in the field. The circuit shown will only show an amount of resistance equal to the resistance of one ematch divided by two: 1.2 ohms divided by 2 = 0.6 ohms.

But, the circuit requires one amp of current for each igniter, or a total minimum of 2 amps of current.

So, with my 4.5 volt system, I can use a maximum of 50 feet of the yellow 2-strand wire, or 28 feet of the orange. The maximum allowable resistance in a circuit with two, parallel matches is 2.25 ohms.

Once again I always draw out a firing circuit, calculate how much resistance it ought to have, and check the actual resistance with my meter to check the circuit in actuality.

The Final Wiring Table

Here is a table which shows the maximum allowable length of each type of double-strand shooting wire, for 4.5 volt, 12 volt, and 24 volt systems, using either series or parallel wiring if multiple igniters are in a circuit.

# of Ematches	Max Resistance	Max Yellow Wire	Max Orange Wire
4.5 Volt System			
1 match	4.5 ohms	100 ft.	55 ft.
2 parallel	2.25 ohms	50 ft.	28 ft.
3 parallel	1.5 ohms	34 ft.	18 ft.
2 in series	4.5 ohms	66 ft.	35 ft.
3 in series	4.5 ohms	28 ft.	15 ft.
12 Volt System			
1 match	12 ohms	338 ft.	180 ft.
2 parallel	6 ohms	169 ft	90 ft.
3 parallel	4 ohms	112 ft.	60 ft.
4 parallel	3 ohms	84 ft.	45 ft.
2 in series	12 ohms	300 ft.	160 ft.
3 in series	12 ohms	262 ft.	140 ft.
4 in series	12 ohms	225 ft.	120 ft.
24 Volt System			
1 match	24 ohms	712 ft.	380 ft.
2 in parallel	12 ohms	356 ft.	190 ft.
3 in parallel	8 ohms	238 ft.	127 ft.
4 in parallel	6 ohms	178 ft.	95 ft.
2 in series	24 ohms	675 ft.	360 ft.
3 in series	24 ohms	638 ft.	340 ft.
4 in series	24 ohms	600 ft.	320 ft.

Redundancy

In the name of successful electric firing, I'd like to mention redundancy, and then repeat it. If I have a critical item in a display such as a set-piece that I simply cannot allow to fail to ignite, I'll actually run two firing circuits (cues) to it. If the first one fails, I have a backup.

If there is any doubt about the capacity of a circuit out in the field, I'll remove the match from the device and test fire that circuit before the display. Then I'll replace that ematch with a new one and reconnect it.

Often on items such as set-pieces, waterfalls, and firecracker walls, I'll have two igniters and ignition points, wired in series. I'll also have a length of quick match rigged up as an alternative manual ignition point in case the electric firing fails. I keep a propane torch by my side during the show, and will use it to manually ignite devices if necessary, and if it can be done safely.

Although some of these preparations may end up being unnecessary, they can save the day for you. With each display I have one shot at having it go off successfully. I want to do all I can to insure that it does.

4

Fusing and Electric Ignition

How to Attach Electric Matches to Visco Fuse

By Brian Paonessa

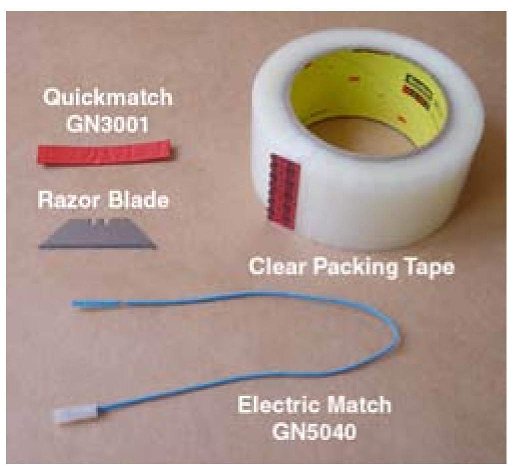
About this time of year we get lots of questions about attaching electric matches to consumer fireworks. That's because more and more people are using electrical firing systems to fire their 4th of July consumer fireworks shows, even at home. Here's how to do it.

The Problem

Electric matches made using Skylighter's electric match dip kit (GN5050) and electric match blanks (GN5040) put out a good amount of fire and can directly light visco fuse when connected end-to-end. Visco fuse is the green fuse used in most consumer fireworks (it is also called cannon fuse). But just taping the electric match to the visco fuse is not 100% reliable, so the connection technique you use is critical. Here's a little trick that works quite well for me when connecting electric matches to visco fuse and has given me 100% ignition so far.

Materials Needed

- Consumer fireworks
- Electric matches ("ematches")
- Roll of clear packing tape or masking tape.
- Roll of quick match (GN3001) or super-fast firecracker fuse (GN1205)
- Razor blade

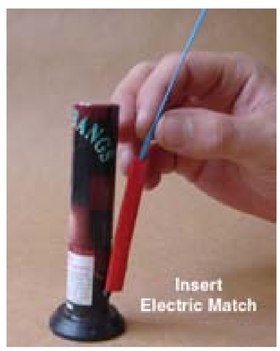


Materials Needed to Attach Ematches to Quickmatch

Assembly

Cut Visco Fuse at an Angle

Slide Quick Match over Fuse



Insert Electric Match

Tape Electric Match in Place

Cut visco fuse at an angle. Cut the firework's visco fuse on a sharp angle (as seen in the earlier figure). This will expose more of the fuse's black powder core. If your device comes with a long visco fuse attached, you may want to cut it down to about an inch to reduce ignition delay.

Create a quick match sleeve. Using a razor blade, cut a length of quick match about 1 inch longer than the fuse supplied with the consumer firework device.

It's best to cut quick match with a razor blade or anvil cutters. Quick match can ignite from the friction of scissors cutting through it.

Slide quick match over device's fuse. Carefully slide the device's fuse into the center of the quick match sleeve. Slide the quick match sleeve all the way down so it covers the firework’s entire fuse.

Insert electric match into quick match. Outside and away from people, hold the device so it is pointing away from you and any flammable material. Insert an electric match into the open end of the quick match to a depth of an inch. You may need to slide back the electric match's protective plastic cap.

Removing the electric match's protective cap may make inserting the ematch easier, but can cause ignition by friction. Insert the electric match's head slowly and gently.

Tape quick match, and electric match to device. Secure the electric match to the side of the firework with clear packing tape covering both ends of the quick match. Add a couple of extra wraps of tape to secure the electric match in place.

The tape serves two purposes:

1. It confines the burning gasses, increasing the burn rate.

2. It secures the ematch in place.

If you've never done an electrically fired fireworks display, just imagine people moving about in complete darkness with dozens of wires all around. It's inevitable that if you don’t completely secure each and every electric match someone will trip on "that" wire and pull the electric match free causing a misfire.

How Does It Work?

When the electric match fires, the ematch sparks for only an instant. If the ematch sparks and fire do not directly hit the visco's black powder core, the electric match may fail to ignite the firework device. The black match inside the quick match sleeve prevents this problem by carrying the fire forward, and increasing the amount of fire given to the visco fuse. This ensures that the slightest spark from your electric match will pass fire to the visco. The quick match’s outer paper wrap directs the fire downward through the tube like a flamethrower, lighting everything in its path, including the visco.

"But, I live too far away to pick up quick match..." Having quick match on hand does make this process faster, but all you need to make this work is black match and a homemade tube to direct the fire. Skylighter's GN1205 is a great source of black match, unless you want to make your own.

What is GN1205, Super-Fast Paper Firecracker Fuse?

Well it's our fastest, shippable fuse. It burns at 1 foot per second! It consists of 3 strands of black match with a light tissue paper wrapping. This tissue paper wrapping gives it a controlled fast burn great for chaining candle batteries, adding leaders to homemade festival balls, even chaining up your finale.

Remove Black Match from Super-Fast Firecracker Fuse

Insert Black Match into Tube

Now, harvest black match from GN1205. Gently peel the tissue paper off of the super-fast firecracker fuse.

Make a thin walled tube. You'll need a thin walled paper tube to hold the black match, visco and electric match all in place. For this cut a 3 x 3 piece of copy paper, and roll it on a 3/8th inch dowel or anything about that diameter (a Bic pen works well). Use glue or tape to keep it closed.

Insert black match into thin walled tube. Insert 6 strands of black match into a thin walled paper tube. If the black match is long, cut it flush.

Continue by following quick match instructions above.

Cross-Match Fuse Alternatives

By Harry Gilliam

Learn which fuses can be used for cross-matching.

Folks forever believe there is only one kind of cross-match fuse which is "right." In particular, there are people who think that the legendary, and now all-but-extinct Thermolite is the holy grail of cross-match fuses. And there is a peculiar breed of pyro who has been brainwashed that ONLY the cross-match fuse method they read about in such-and-such a book is right. Well, that isn't necessarily so.

When you've run out of now-impossible-to-get Thermolite, here are some possibilities for you, some of which, you may be surprised to read, you can actually purchase at Skylighter.

Quick match: Skylighter product #GN3001: the Chinese-made flat quick match fuse often consists of multiple strands of very skinny black match fuse which can double as cross match fuse. Its downside is that it's not very stiff. So you may have to make your time fuse hole a little larger to accommodate this variety of black match fuse. It also cannot be shipped, so you can only get it by coming by and picking it up or getting us to bring it to one of the club shoots we attend.

Cross-match visco: Skylighter product #GN1010: This is very thin green colored visco type fuse. It is commonly used as the central fuse to which strings of firecrackers are braided. It is stiff and easy to use. Downside is that it does not take fire as easily as black match fuse.

Paper firecracker fuse: Skylighter product #GN1200. This is actually a fairly stiff, paper-covered fuse used in firecrackers and other Chinese fireworks. The stuff that we get is actually two strands. It takes fire well, but not quite as easily as black match fuse and it's reasonably stiff.

Homemade black match: Easier to make fuse than most people think. Tom Perigrin's book, Introductory Practical Pyrotechnics, shows you how to make it. Use only pure cotton string, containing no reinforcing synthetics. It can be made fairly stiff.

The bottom line is that there are plenty of alternatives for cross matching. Any of the fuses above are within reach of the average US hobbyist.

Homemade, Field-Expedient Quick Match

By Harry Gilliam

If you don't have time to make black match, wait for it to dry, make paper tubes, etc. you can use this quick and dirty method to make your own quick match whenever you need it.

Materials Needed

- Black powder
- Kraft paper
- Masking tape, 3" wide

Here's How

You can do this in any length, but in this example, you would make a 5-foot long length of quick match fuse. First cut a 3-foot wide by 5-foot long sheet of Kraft paper. Fold the narrow dimension of the paper so that you have a 1-foot wide flap lying over the other 2 feet.

Tape a strip of 3-inch wide masking tape along the edge of the flap, making sure you tape exactly flush along the edge of the paper-don't let any tape stick out over the edge. Then, run a second strip of 3-inch wide masking tape over top of the first strip, so that exactly 1/2-inch is sticking over the edge. This is the part of the tape, which will be used to pick up the black powder. Keep this sticky side off of the paper.

Next run a trail of black powder (BP) on the 2-foot part. Just about any fine-grained black powder will do, FFg, FFFFg, etc. Now push the sticky side of the masking tape into the powder, so that it picks up a 1/2-inch wide strip of BP. Make sure you get as much BP to stick to the tape as possible. Then peel the tape off the paper.

Then fold the tape over lengthwise several times so that the BP strip is inside. Then fold the tape however many times it takes to end up with about a 1/2-inch wide length of homemade quick match. Thanks to Steven LeFaivre for this field expedient quick match.

How to Make Quick Match Paper Pipe

By Dr. Frank J. Feher, April 22, 1999

Materials Needed

- Brick, heavy
- Brush, foam, 3/4" to 1" wide
- Dowel, 1" wide, 4" long
- Glue or paste
- Metals rods, 1-1/4" wide
- Masking paper, 6" wide
- Paper towel
- Plywood, 3/4"
- Sponge, damp
- Spray oil

If you don't have ready access to ready made shell leaders or quick match, then making your own black match and the paper "pipes" for them may be necessary. Here is Frank Feher's approach to making the quick match pipes.

Here's How

There are several ways to make quick match pipe, but I personally favor the following method for making spiral-wound quick match pipe of fixed lengths. It is very easy to master, and the average individual pyro enthusiast can easily make an entire year's worth of quick match pipe in a single morning.

Step 1. Cut the roll of masking paper into thirds (2" wide rolls) using a band saw with a sharp blade. This is easiest to do if you first draw a circle around the roll using a paper band as your guide. Also make sure that the paper cannot unravel during cutting.

Step 2. Because I cannot easily provide a figure, I will describe the ideal arrangement of equipment by making reference to a right triangle. Place your metal rod on your work surface so that it is positioned lengthwise from your left to your right. This is one side of your triangle and it defines two points. Your paper holder defines the third point, and it should be placed so that the angle on the left side of your triangle is approximately 20 degrees and the angle on the right is 90 degrees. In practice, you will want to move your paper holder slightly further back and to the right, but you should get the picture.

Step 3. Pull a piece of paper from the holder and rest it along the end of your triangle. Cut or tear the paper from the roll and make sure the shiny side of the paper is facing up.

Step 4. Apply a VERY SMALL amount of glue along the far edge of your paper using the foam brush. Do not apply glue to the first 3" on the left side and don't use too much. You don't want the paper to get wet. You only want a thin (1/4" wide) band of dampness due to the glue.

Step 5. Place your rod on the lower left-hand edge of the paper. Then move the right hand edge approximately half way from its original position toward the paper holder. This positions the bar at a 10-degree angle relative to its starting position.

Now roll the bar away from you. Use your hands to guide the paper to be sure the quick match fireworks fuse match pipe rolls up smoothly. If all goes well and your rolling technique is similar to mine, the bar will rotate slightly clockwise and end up parallel to your working surface.

Step 6. If you have done everything properly, you should be able to slide the paper pipe off your metal rod. Allow your pipes to dry for about 15-30 minutes and then trim the ends with a pair of scissors.

Helpful hints and Other Comments

I have made fuse pipes up to 6 feet with this procedure, but 3 or 4-foot pipes are easiest to make. I have also made fuse pipe on a 1/8" aluminum rod with 1" wide paper.

Use a longer piece of paper so that the pipe extends beyond the rod. Then twist the end closed. This prevents the damp pipe from unraveling, and the excess is a convenient place to grab while pulling the pipe off the rod. Work quickly after you apply the glue. You don't want your pipe to get soggy or have your glue dry. If your pipe sticks, you probably used too much glue.

Give up on a soggy pipe. Unravel the pipe or scrape it off quickly. (The longer you wait, the harder the pipe is to remove.) Wipe the rod clean with a damp sponge, dry it with a towel, and then apply a very thin layer of oil by wiping with an oil-dampened towel. Some people don't like spiral match pipes because they cannot be easily torn to expose the black match inside the quick match.

To be quite honest, I actually like the fact that my match pipe is hard to tear. If you use spiral quick match pipe made by this method, two things will make your life easier. First, a little planning to make sure you have the proper amount of fuse exposed when you assemble your device in the first place. Second, carry a penknife.

It can be difficult to slide black match into spiral pipes if it has irregular edges which can get caught on the inside or if you have kinks in your pipe (i.e., you bent it at some point). Store your fuse pipes in a long tube and avoid kinking.

Super Simple Electronic Fireworks Ignition System

By Maj. Lewis J. Edwards (USAF, Ret.)

Learn how to make a simple fireworks ignition system using an electric fence power unit and dark flash powder.

Materials Needed

- Antimony trisulfide (CH8011)
- Battery operated, electric fence power unit
- Black powder, Meal-D
- Nitrocellulose (NC) lacquer (CH8198)
- Potassium chlorate (CH5200)
- Shooting wire (GN5010)

This works very well for a firework ignition system and does away with nichrome and/or bridge wire. It's easy. I first cut a 4 ft. length of Skylighter's shooting wire. Next, strip about 1/8 inch of insulation and squeeze the exposed copper conductors together and release. This should create a gap of about 1/64 inch. Then strip the insulation from the other end of the wires and attach to the positive and negative poles of the fence charger.

Flip the switch and you should get a nice blue spark between the tips of the exposed wires, sufficient to knock you on your keester if you hold the bare part. Disconnect from the charger. Then drip enough of the wet "dark flash" composition (potassium chlorate, NC lacquer, antimony trisulfide - see note below) to fill in the gap between the exposed copper conductors (where the blue spark occurred). Allow drying for a few minutes and then dip in the NC lacquer and coat with Meal D or fine black powder.

Dry for an hour or so and coat with the NC lacquer a second time to bind everything together. Attach the igniter to a longer wire (I've used up to 250 ft. of Army surplus wire) and insert the business end into whatever it is you want to launch. Connect back to the fence charger, apply power or flip the switch and the firework ignition system will light a fuse or lift charge.

Don't mix the dark flash composition until you have thoroughly read the instructions, else you may blow yourself to smithereens. See the article "How To Make Electric Matches Using Skylighter's Electric Match Heads" for the critical details on mixing the dark flash composition.

Making Your Own Igniter/Squib

By Harry Gilliam

Learn how to make electric matches (also known as squibs or igniters) using small pieces of circuit board, nichrome wire and solder.

Materials Needed

- Circuit board strips, copper clad
- Nichrome wire (GN5020)
- Shooting wire (GN5010)
- Sodium bicarbonate (CH8275)
- Solder

An electric match is a small device essentially consisting of a couple of wires attached to a small explosive composition that goes pop when you apply a current to the wires. The explosive power is not too much greater than a toy cap, but more than enough to ignite just about any firework device. They are designed to be used one time and then thrown away.

Several years ago, my friend Phil Martinez announced that he was going to start making electric matches commercially. He now gets orders for more electric matches than he can sanely cope with and it just keeps getting worse! His particular claim to fame is an electric match that generates a hotter flame than other electric matches do. He sent me this note along with a box of circuit-board looking strips:

"I have a quantity of copper-clad strips that I used when I first started experimenting with electric matches. I have approx. 600 pieces each measuring .4" x 4.5". What I used to do is spiral wrap the nichrome wire around the strips and then apply stainless steel soldering flux to one side and solder using the flank of the soldering iron tip. I would then flip the strip over and do [solder] the other side. This was followed by a flux-neutralizing bath of sodium bicarbonate in water.

The electric match chips can then be cut with a pair of scissors from the strip. All of the strips have a routed edge so that the finished product will have the nichrome wire spanning an unsoldered step on the tip of the chip (for better contact with the pyrotechnic composition).

There are 2 varieties of foundation board: approximately 200 pieces of a flexible board that is no longer available, and the rest using the conventional woven glass laminate material. The following flux works on nichrome wire:

"Oatey all-purpose Liquid Soldering Flux", Part #30106

Possibly available from:

Oatey Co.
4700 West 160th Street |
Cleveland, OH 44135
(216) 267-7100

You may be able to find it at Ace Hardware stores, Home Depot, Lowe's, or a plumbing supply store. It contains hydrochloric acid, ammonium chloride, and zinc chloride and as such requires neutralizing in sodium bicarbonate/water solution and a thorough wash in clean water afterwards! It's packaged in 4 oz. squeeze bottles and cost about $5.00/bottle or less. Let me know if you have any further questions."

So, in case all this escapes you, what you do is take small pieces of copper clad circuit board. We nabbed a roll of the same nichrome wire Phil uses to make his electric matches. You just diagonally wrap the little foundation board strips with the nichrome wire, coat the boards with solder, and then snip off little bits to make your electric match heads.

Solder a piece of our shooting wire onto the back end of the electric match head, one lead on each side. Finally, you dip the nichrome wire end of each electric match head into your electric match composition(s) layers, let dry, and you have a really cheap electric match. Such electric matches can cost as little as 5-10¢ each, vs. $0.75 and up for the store-bought variety.

Unfortunately the electric match foundation boards are no longer available from Skylighter. However if, after reading the above, you find you are either disinclined to make your own electric match heads or are truly one of life's solder-challenged relicts, you may want to consider buying electric match heads ready made.

There are no bridge wires to solder - they are already soldered in place. Just solder your lead wires on and follow the easy directions for making electric match composition and coating the electric match heads with it.

How to Make Ematches Using Skylighter's Electric Match Heads

By Harry Gilliam and Octavio Aguiar

Learn how to make electric matches, also known as squibs or igniters - using firework chemicals and electric match heads available from Skylighter.

Materials Needed

- Acetone
- Antimony trisulfide (CH8011)
- Battery, "AA"
- Black powder, Meal D
- Charcoal, airfloat (CH8068)
- Electric match tester (GN5005)
- Nitrocellulose lacquer (CH8198)
- Potassium chlorate (CH5200)
- Shooting wire (GN5010)

Here's How

Skylighter's electric match heads are made comparable to Davey Fire electric matches. Each has a thin nichrome wire wrap to convert electrical energy to heat. A minimum of 0.5 amperes will cause the nichrome wire to heat and then break open in a fraction of a second. Therefore an extremely heat sensitive electric match composition must first be applied to the tip of the electric match.

The electric match composition that provides this heat sensitivity is called a primer. WARNING: Primers burn and primers explode. Therefore it is important to use as little primer as possible, and then overcoat the primer with another electric match composition that is less sensitive but will take fire from the primer and give a flame spread to the electric match.

Here is a method for making electric matches that produces excellent results:

First twin lead wires should be soldered to the electric match head. Cut a piece of twin-lead shooting wire to length. Split the two leads apart and strip about 1/4 inch of insulation from each lead. Solder one lead on one flat side of the electric match head, and the other lead on the other side. Make sure you solder these to the back end of the electric match, the widest part. This leaves the narrow part, the tip; clear so it can be coated with the electric match composition.

Coat the electric match tip (1/32 inch to 1/16 inch) with primer using the formula below. Allow electric matches to dry approximately 1 hour.

Recoat with H3/NC or Meal D/NC, one half to two-thirds of the full length of the electric match. Allow drying overnight. NC is nitrocellulose lacquer. H3 is Shimizu's formula of 75% potassium chlorate + 25% charcoal, airfloat. Meal D is a very fine commercial black powder. High quality, ball milled black powder will work, too.

A final coat of 5% nitrocellulose lacquer is optional but is recommended.

Primer (also known as dark flash)

This formula is well known to be friction and impact sensitive. Therefore it is critical to make and use as little as possible.

Mixing instructions

To 5 grams of 200 mesh or finer potassium chlorate, mix a 5% nitrocellulose lacquer solution to achieve a syrupy consistency.

Add 5 grams of antimony trisulfide (200 mesh or finer) to this mix. Stir gently until a smooth homogenous mixture is obtained. Add more NC lacquer to maintain a syrup consistency. If it starts to harden or thicken, thin it with acetone.

We recommend testing 5% of each batch made, once your electric matches are dry. Use a "AA" battery to apply voltage to the electric matches lead wires. The finished electric match should give a small snap and then burst into flame, similar to a book match.

Also be sure to check the continuity of all electric matches with an electric match tester. This is a specially made low-voltage continuity tester that will tell you if your electric match will fire. A standard continuity tester will not work. It generates so much current it will actually fire the electric match.

The Skylighter electric match tester is roughly the size of a half-dollar. It has a 3-volt lithium battery, which should last five years or more, and a red LED light. The measured current through a typical electric match head and lighting the LED is less than 10 milliamps (mA).

Although well below the 50 mA maximum test limit, all precautions should be taken. All personnel should be distant from devices under test. Especially if you make your own electric ematches, you should always test your electric matches before attempting to use them.

How to Make Electric Matches

By Ned Gorski

Materials Needed

- Digital multimeter (or Ematch Tester, GN5005)
- Electric match dip kit (GN5050)
- Electric match heads (GN5030), if soldering yourself
- Ematch blanks (GN5040)
- Ematch tester (GN5005)
- Shooting wire (GN5010)

If Making Your Own Pyrogen:

- Antimony trisulfide, dark pyro (CH8011)
- Nitrocellulose lacquer (CH8198)
- Potassium chlorate (CH5200)
- PVC plumbing cement, optional

Introduction

Why would one want to fire some or all of a fireworks display electrically? First, it's safer to fire a device electrically than it is to light it by hand, especially if the item is in the middle of a field full of similar fireworks. Electric firing also enables the display operator to sit back and enjoy the show along with the rest of the crowd. Precision timing is also enhanced by shooting with a firing system.

Many of us are familiar with small firing panels and electric matches from our early days of experimenting with model rockets, since small versions of the igniters are used to remotely fire those motors.

What is an Electric Match?

From Wikipedia:

> *In pyrotechnics, an electric match is a device to ignite the end of a fuse under control of an externally applied electrical current. They are widely used in professional fireworks displays to control firing from a panel of manually operated switches, or from a computer interface.*
>
> *Electric matches typically consist of a pair of 22-gauge wires joined at the end with a smaller-diameter "bridge wire" that has been coated with a pyrotechnic initiator mixture formulated to ignite at relatively low temperatures.*

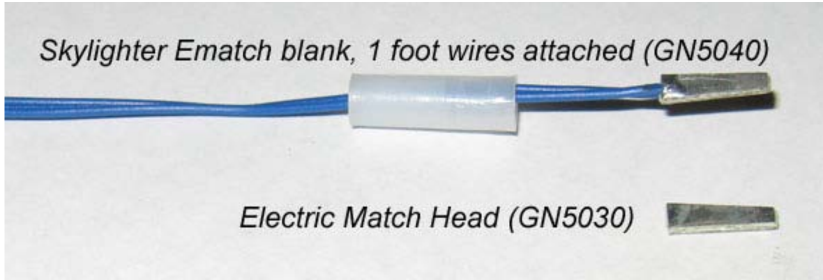
Quite a long time ago I made some electric matches using a kit which instructed me to just dip the bare ends of some wire into a composition that was dampened with some acetone, and then again into a finish coating.

I didn't have much luck with that system, and ended up firing the ematches with a high-voltage system just to get them to ignite. I was disappointed. Ever since then I've had access to commercially made electric igniters, since I am an ATF licensed display operator.

Commercial Ematches: One with Shroud Pushed Back to Expose the Match Head

But, you may not have access to commercial ematches. They are a regulated explosive and require an ATF license to purchase them. But making them yourself is legal and does not require an ATF license.

Now and then my curiosity has been piqued when I've seen some of the various methods for making electric matches. I've seen the match heads that you solder wires onto, and then dip into various compositions. Also, there are ematch blanks, which have wires already soldered onto match heads, ready for the application of the pyrogens (combustible compositions).



**Ematch Blank (top) and Ematch Head (bottom),
Both with Nichrome Wire Soldered across the Tip of the Head**

So, I figured that the only way I could credibly discuss these homemade ematches was to play a bit with them myself. Fortunately, I just recently spent some time in Virginia at the Skylighter facility, and was able to pick the brain of Brian Paonessa, who is one of the main Skylighter pyro experts, and who has experimented extensively with homemade electric igniters.

I assembled a kit of materials to bring home and play with.

Parts of a Finished Electric Match

The electric matches I'll be discussing have five basic parts:

1. Insulated, two-conductor, wire "leads" connected to the match head. The insulation is stripped back for about an inch at the opposite ends of the wires from the match head. These bare wire-ends are twisted together (shunted) to prevent a current from passing from one end of the wire, through the match head, and out the other end, accidentally firing the ematch.

2. The match head consists of a small chip of circuit board, which has a metallic conducting surface on both sides, separated by an insulating material.

3. An extremely thin (48-51 gauge) strand of nickel-chromium (nichrome) bridge wire is soldered to the chip, with one end soldered to each side, and with the exposed wire spanning the end of the chip and crossing over the insulated core.

4. Pyrogen: The tip of the chip containing the nichrome wire is dipped in pyrotechnic composition, in one or more coats, and then into a hard, smooth finish layer.

5. Finally, a plastic, protective-shroud covers the match head to prevent accidental ignition of the sensitive pyrogen as a result of friction or mechanical shock.

When enough current is passed through the ematch leads, the nichrome wire heats up and ignites the pyrogen, producing a flame, which will ignite the flammable materials that the ematch is in contact with. This happens in milliseconds. When it does, the nichrome wire burns through and is consumed, breaking the electric circuit.

If one can obtain circuit board blanks with conductive coating on both sides, Skylighter sells the thin nichrome wire so that heads can be cut to size and the nichrome soldered onto them. This is a very painstaking process. In the back of my mind, a future project would be to buy some copper-foil-tape from a stained-glass supply store, press the foil tape to both sides of a piece of cereal-box cardboard and cut match heads out of it. Soldering the nichrome wire onto those heads would produce homemade match heads.

Soldering wire leads onto electric match heads

If you go to the Skylighter (http://www.Skylighter.com) website, click on the Ignition Supplies under the Order Products heading, and scroll down to item number GN5030, Electric Match Heads, you can "click here" to see the instructions for this item. They detail the soldering of the wires onto the match heads, and then the coating of the match head with the various layers of homemade pyrogens.

At this stage, I like to work with short lengths of wire, so I cut about a foot of shooting wire, strip an inch of insulation from the wires at one end and lightly twist them together to shunt them, and strip about a quarter inch of insulation from the wires at the other end.

Soldering the wires onto the match head is easier if you "tin" the wires by coating them lightly with solder first. Then, the tinned ends are pushed together until they are just barely separated, and the match head is slid between the wires and gently soldered in place per the instructions.

A small "pencil" soldering iron and rosin-core solder come in handy for this process. You want to be careful to avoid overheating the match head during the soldering.

Soldering Wires onto Electric Match Head

The ematch heads do not come with plastic protective shrouds, which many of us consider to be an essential safety component of ematches. Rubber surgical tubing, of the appropriate inner diameter, can be cut to 1" lengths to use as protective shrouds on finished ematches.

Testing the Ematch Blanks

Whether I've purchased the pre-soldered ematch blanks, or have made them by soldering wires onto the match heads, I like to test the blank at this point. I do that two ways. I use Skylighter's ematch tester (GN5005) and make sure it lights up when the untwisted leads of the ematch are pressed to the sides of the tester.

I also use a Radio Shack digital multimeter to check the resistance of the match. All of the matches I've been working with have a resistance of 1.1 to 1.2 ohms. If the reading is significantly different, I discard the ematch blank.

Testing Ematch Blanks with Tester and with Digital Meter

This testing insures that the nichrome bridge wire is in place correctly, and is intact. It also proves that there is no excess solder bridging the two conductive surfaces on the chip, or between the wires.

It is important to use a digital meter to check ematches. Test it on a finished ematch first in a safe location. It has to have been proven to use a small enough amount of current that it will not fire ematches. My understanding is that the test current in analog meters with needle-readouts will accidentally fire ematches if that type of meter is used to test them.

Coating the Tip of the Match Head with Pyrogen

Now, with the tested ematch blanks, we have assemblies that are ready to have their ends coated with pyrotechnic compositions.

I am going to try some different ways of doing this.

The above cited match-head instructions offer specific directions for coating the tip of the match head with three different homemade compositions: a primer comp, an ignition comp, and a final protective coating.

Or, Skylighter sells the GN5050 electric match dip kit, which comes with all the necessary chemicals, materials and tools, and instructions (which may be seen by following the above cited links and scrolling down to the GN5050 dip kit listing and clicking on "click here for instructions on making electric matches").

These instructions include very complete safety precautions, which I am not going to repeat here, but which are necessary to understand before proceeding with the following steps.

The first thing I did was to remove the plastic shrouds from the match heads on the pre-soldered blanks.

Coating Ematches Using Skylighter Dip Kit

I used the Skylighter dip kit to coat some match blanks, per the instructions in the kit. I found that I had to add quite a bit of the thinner to the mixed first-coat pyrogen to get it thin enough to coat like the directions specify. Use a thin coat, which drips off one drop after dipping the match head into the pyrogen about 3/16".

I hung the bent matches on a piece of shooting wire strung between two wood posts and allowed them to dry for a couple of hours.

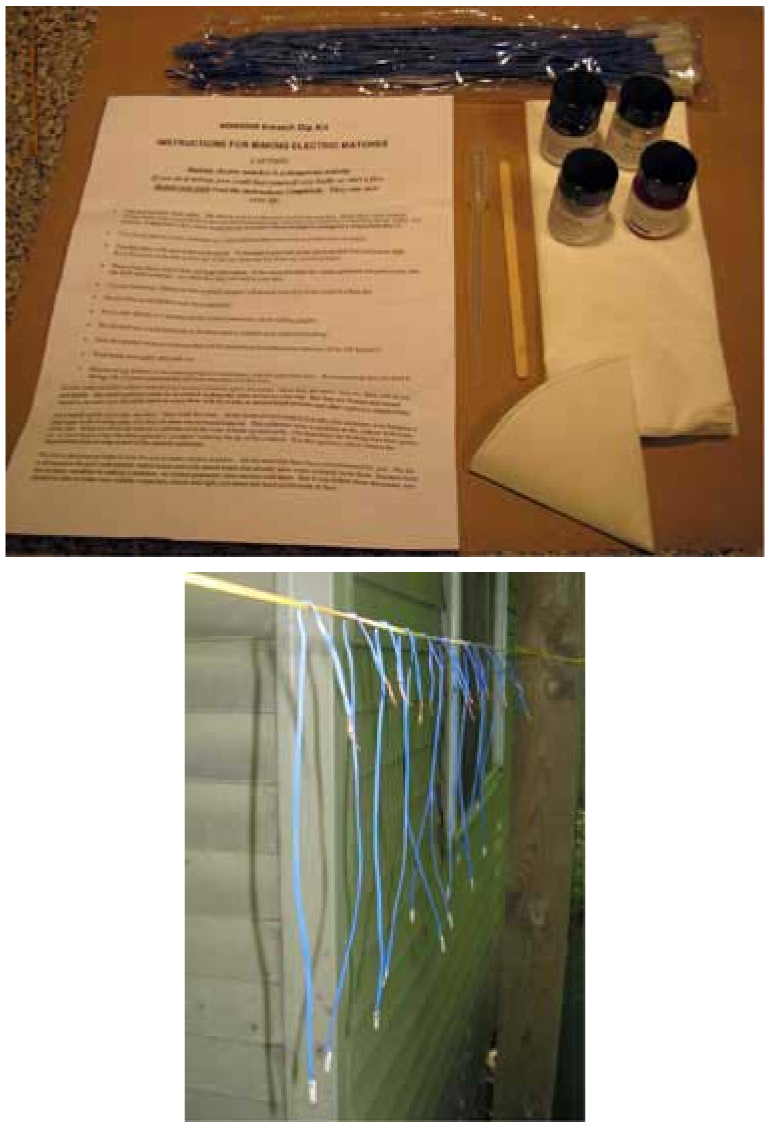
I decided to coat a dozen of the blanks and then apply the finish coat, and then test fire them to make sure the system I'm using is working.

This dip kit will coat hundreds of ematch blanks, so it's a good idea to prepare all the blanks you want to coat before starting the coating process. Once the pyrogen is mixed, it is uncertain how long a shelf life it has, and you have an explosive slowly setting up in a glass bottle. I recommend mixing it, using it relatively quickly, thinning any excess with more thinner, then pouring it on some newspaper and burning it.

As you are working with the wet pyrogen, don't allow any dry "crusties" to form on the edge of the bottle top. Push them back with your finger and stir them into the wet mix.

Brian says that the most common source of failure when using this dip kit is applying the pyrogen too thickly or too far up the match head. Make sure the mix is thinned as per the instructions, and that the heads are only dipped about one third of the way, or about 3/16". It's also very important to thoroughly mix the components, and then mix them a bit more. Under-mixing of the ingredients is another common cause of ematch failure.

The right consistency will cause one small drip off the end of the match once it is removed from the pyrogen, and a nice, smooth, slightly rounded match head will form.



Skylighter Ematch Dip Kit and Coated Matches Hanging to Dry

Once these matches were dry, I coated them about half way up the head, just past the first layer, with the red lacquer finish coating, per the directions.

Coating Ematches with Homemade Pyrogens

I wanted to try the dip-coating method described in the instructions for making ematches using Skylighter's match heads. This process details the mixing of two homemade pyrogen coatings, and then the final application of a nitrocellulose lacquer finish coating.

This process uses two sensitive compositions--dark flash and H3. The directions must be followed precisely to avoid accidents. These compositions are mixed in a wet state. I can't emphasize enough that these comps become very powerful and sensitive when they dry out. They must be worked with while they are wet. Any excess should be thinned and disposed of while it is still wet.

The "primer" coat is 50/50 potassium chlorate/antimony sulfide. Five grams of the potassium chlorate is screened through a 100-mesh screen. It is then mixed with 5% NC lacquer until a syrup is formed. Next 5 grams of the -325 mesh, dark-pyro antimony sulfide is mixed in. More lacquer can be added to thin the mix until it can be used as in the directions for the dip kit cited above.

Note: Skylighter sells nitrocellulose (NC) lacquer, which is a 25% solution of nitrocellulose in solvent. To make a 5% solution, weigh out some of the 25% lacquer into an empty, clean, one-quart paint can (from Home Depot or similar), filling it about one-eighth full. Then add four times as much acetone (by weight) into the can, close it, and shake to mix thoroughly.

Mixing this comp in an HDPE photo-film canister using a Popsicle or coffee-mixing stick (free at every 7-11) works well. I then dipped some ematch blanks into this comp and allowed them to dry completely.

This primer coating was then coated with the H3 composition. 7.5 grams of potassium chlorate was dampened, as above, with 5% NC lacquer. Then 2.5 grams of airfloat charcoal was added to that mix and stirred thoroughly. Then more lacquer was added until the thin syrup consistency was achieved. Then the ematches were dipped into this second-coat composition and allowed to dry once again.

Finally I dipped the dry match heads into 5% NC lacquer, completely coating all the pyrogen layers, up about half way on the match heads to create a protective final paint job on each match. Once again, the matches were allowed to dry completely (anywhere from a couple of hours if it is warm to overnight).

One More Experiment

Regular Plumbing PVC Cement

I've recently heard about a fellow pyro using regular PVC plumbing cement rather than nitrocellulose lacquer to dampen compositions. I decided to repeat the above process using the PVC cement instead of the NC lacquer.

Using this cement produced easy-to-use compositions and nice, hard, shiny, black match-heads when they were dry.

Testing the Finished Ematches

All three production methods produced nice, very hard, durable ematch heads.

Electric Match Heads Made with (Left to Right): Skylighter Dip Kit, Homemade Pyrogen/NC Lacquer, and Homemade Pyrogen/PVC Cement

I wanted to see how much electric current it takes to fire these 3 types of homemade electric matches, and also to see how effective they are at igniting a quick match fuse. I installed the plastic safety shrouds on all the matches.

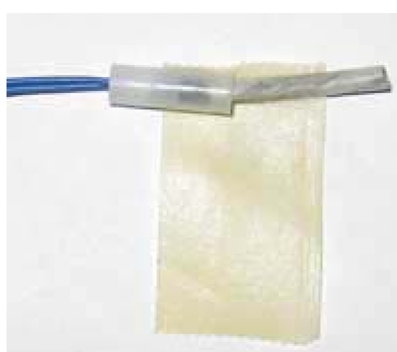
Using a little testing apparatus, I determined that the matches will begin to fire once 0.5 – 0.7 amps of electrical current is passed through them. This specification is similar to commercial ematches and a good rule of thumb out in the field is to maintain at least one amp of firing current in firing circuits.

The above info yields a simple rule of thumb out in the field when setting up the wiring for fireworks cues. Using a Skylighter 12 cue wireless firing system, which puts out about 4.5 volts with each cue, you'd want to use one ematch and a maximum of 100 feet of the double-stranded, yellow, copper shooting wire between the panel and the ematch, or a max of 50 feet of the new orange aluminum shooting wire. If you use a 12-volt firing system, maximum length of these "scab" wires would be 300 feet and 180 feet respectively for use with a single ematch. Using a Skylighter GN6010 electric firing box, which generates 300 volts, you can use a virtually unlimited length of firing cable.

I fired each type of ematch several times. The matches made with the dip kit really pop and throw out a fast flame, similar to commercial ematches. The matches made with NC lacquer and homemade pyrogens burn a little less violently and a bit longer and throw out quite a few orange sparks. The similar matches, made with the PVC cement, burned nicely, and even a bit longer, throwing out a nice flame for about a half second, like a regular safety match would.

I figured that any of these matches would effectively ignite quick match if they were installed in contact with the internal black match. I wanted to experiment with one additional step, which would really throw out a lot of flame and would reliably ignite the visco safety fuse on any cake or device out in the field.

I cut 1" lengths of the super-fast-fuse, which is similar to quick match, but which can be shipped. I then used 2" long pieces of one-inch wide masking tape to secure the fast-fuse into the ends of the ematch plastic shrouds. Then, with some of them, I installed a piece of visco fuse with the freshly-cut end in contact with the end of the fast-fuse, and secured with another length of masking tape.



Installing Fast-Fuse and Visco Fuse into End of Electric Match

All the different types of ematches performed flawlessly and ignited the visco fuse easily. I was very pleased with their performance and with the opportunity to learn more about how reliable electric matches can be homemade for one's own personal use.

5

Ground Effects

How to Make a Flying Fish Fuse Mine

By Skylighter Staff

Learn a fast way to make a simple fireworks mine using Skylighter's flying fish fuse.

Materials Needed

- Black powder. Almost any kind or size will do, even rough-mixed green powder. If you don't have any black powder, then the instructions below will tell you how you can make it using:
  - Potassium nitrate (CH5300)
  - Sulfur (CH8315)
  - Airfloat charcoal (CH8068)
- Flying fish fuse, various colors or Flying Fish Fuse Mine kit for 10 mines (KT0100) or
  - Mortar tubes, #0 (TU2053), 10 tubes
  - Plastic mortar tube bases, #0 (PL3001), 10
  - Visco fuse, Chinese (GN1005), 10 feet
- Glue, Elmer's or carpenter's
- Paper, 1-1/2 inch square pieces
- Razor blade

This is a great project you can make on just about any scale. This is perfect for doing with your kids or for your very first fireworks making project. Although this mine is a small, quiet one, suitable for use almost anywhere, you can easily scale it up to something more dramatic. It is fast and easy to do, and many of our customers have tried them. Here's what one customer said:

First, just what is a fireworks mine? Well, this is my definition, which is not necessarily the textbook one. A mine is a fireworks device that fires its effects from a ground-based tube up into the air. Usually the visual effects burn from the time they leave the tube until they burn out.

A mine is distinct from an aerial shell in that a shell is first launched, and then the effects are ignited after they achieve their desired height in the air.

Traditional mines most commonly function by simply propelling firework stars out of a ground-based mortar tube using a black powder charge. You place the charge in the tube, add loose stars or stars in a container, and ignite the lifting charge. The stars are lit, propelled out of the mortar, and burn out typically as they are rising into the air. Mines look like this.

A Bank of Mines Made from Colored Stars

In practice there are an endless variety of mines, traditional and non-traditional. What you can do with mines is endless. This project is basically a flying fish fuse derivative of the traditional star mine.

If you are not familiar with flying fish fuse, it is a variety of visco fuse, which, when cut in short lengths, is reactive enough to actually fly through the air on its own power. Very commonly used in Chinese consumer fireworks today, flying fish fuse comes in a wide variety of colors and effects. It's become so common that flying fish fuse is used in place of stars. And that is how it's used in this project: a quick and easy substitute for ready-made stars.

Here's How

Black Powder

If you already have black powder, use that. It's not critical which type or grain size. If you need to make the black powder, you can make a simple type of black powder called "green powder."

First, weigh out 150 grams of potassium nitrate, 30 grams of airfloat charcoal, and 20 grams of sulfur. Run the potassium nitrate and sulfur through a screen (20-60 mesh) several times individually to break up any lumps.

Then mix both them both with the charcoal by hand. Wear long rubber gloves. Once the color of the mixture is pretty much the same, then sift that mix through your screen three times.

Transfer the mix into a one-gallon zip lock plastic bag, the heavier the plastic, the better. Add enough water to the mix so that it will clump and hold its shape. How do you know you have it just right? When you can squeeze some of it in your hand and it will hold its shape, but no excess water squeezes out between your fingers.

Add water sparingly to the bag. Then work it into the mix thoroughly. Then add a little more, if necessary, until you get the right consistency.

Next, lay out several sheets of newspaper on a tabletop. Push the damp black powder mix through the screen onto the newspapers. Let it dry. You can speed up the process by setting a fan up and keeping air moving over it. Don't try and heat it up.

Moving air is all you need. If you can, sift out anything finer than 30 mesh. What you have left is called "green" or "rough" black powder. It is not the most powerful powder, but it will work fine for this mine project.

Assemble the Mine Mortar

Cut a piece of the green visco 2-3-in. long and set aside.

Next, apply a bead of white (Elmer's or carpenter's) glue into the groove of the plastic mortar base. (Hot melt works, too, but tends to come loose after you use your mortar a time or two.) Push the tube down into the groove and let it dry thoroughly.

Once it's dry, drill or punch a 1/8 inch diameter hole into the cardboard mine tube about 1/8th of an inch above the base. The diameter of the hole should be small enough that it will hold the fuse firmly. Insert your green visco fuse into the hole.

Cut Flying Fish Fuse to Length

Cut your flying fish fuse into 1/2 inch long pieces with a razor blade (never use scissors to cut fuse!). Mix the colors and effects together in whatever proportions you like. Make a bundle of flying fish fuse big enough to slide down into your mine tube. The flying fish fuse bundle should fit into the mine tube snugly. Set the flying fish fuse bundle aside for the moment.

This is our favorite method for making a really pretty flying fish fuse "star" mine. Cut 40 strands of yellow flying fish fuse and 5 strands of green falling leaf into 6-inch pieces and then group them together. This bundle should be tested to easily slide into your tube. If it does not, remove strands of fuse until it does. The fuse is then formed into a bundle and wrapped with 2 turns of tissue paper glued at the end. Once dry, cut the bundle into 1/2-inch long pieces using a razor blade and downward rocking motion.

Flying fish fuse has been known to ignite when being cut with shears. This is presumed to be because of the friction of the composition between the blades. An accident at the PGI was attributed to this. Using a razor also has the added benefit of keeping the powder core exposed.

Green and yellow fuses were used because of the color combo and the two-tiered effect of fast and slow moving fuses.

Assemble the Flying Fish Fuse Mine

This is close to real-time gratification and should take you less than a minute.

Step 1: Dump 1.5 grams of black powder into your mine tube.

Step 2: Shove the bundle of flying fish fuse all they way down into the mine tube. A magic marker or a dowel works great for this.

Step 3: Place the square of paper on the top of the mine tube. Using your magic marker or dowel, shove it as far down as it will go.

That’s it. You just made a mine. So, take that sucker outside and light it. Flying fish fuse will fly all over the place, so make sure you’re 100 feet or more away from anything you care about.

Mine Construction

By John Werner

Learn how to make firework mines, an effect that shoots firework stars into the air from a tube.

Materials Needed

- Awl or ice pick (TL4002)
- Base or plug for tube (PL3005)
- Black powder, 2FA
- Cardboard discs, 2" diameter (DK2000)
- Firework stars (1/4" to 3/8" diameter)
- Inserts: small whistles, firecrackers, dragon eggs, etc. (optional)
- Tube, spiral wound cardboard, 2" I.D. (TU2200)
- Visco fuse (GN1000, GN1001, GN1004)

A mine is a quantity of firework stars, small comets, inserts, etc., which are simply fired up into the air from a mortar tube so that their effect is immediately noticeable as they exit the muzzle of the mine mortar. The simplest mine is a single spray of colored firework stars. More complicated mine designs can exhibit several layers of color, or color with reports, whistles, spinners, or small shells. Mines are fast and easy to make, and provide a dramatic effect.

Mines are low-level fireworks and designed to work roughly in the same spatial parameters as roman candles and comets. Since their effect starts at ground level and goes up to only several hundred feet at most, they are a great way to visually tie together ground pieces, such as lancework and wheels, with aerial shells.

Mines can be constructed quickly and easily, and offer the beginner lots of opportunities to experiment with various types of firework stars and inserts, without getting into the intricacies of shell building. Mines are most effective when fired in multiples, and the individual mine tubes do not have to be large for the effect to be spectacular in a show.

I like to categorize mine construction into 2 basic types, which I call "drop-in mine bags" and "pre-loaded disposable mines." Drop-in mine bags are constructed similarly to a shell with a quick match leader and are designed to be dropped into a mortar at the shoot site and to be fired by lighting the leader protruding from the top of the mortar.

Traditionally this style is probably the most common way of using mines, at least for public displays. However, for the sake of this article, only the preloaded disposable method will be covered as it is somewhat simpler to make and can be readily used with multi-shot display boards (cakes). You can see exactly how these mines are made on Skylighter video #VD0060, Mine Construction.

Begin by making up several single-shot test mortars. A plastic base will work fine for 2" or smaller diameter tubes, but on larger diameters a wood base or plug is preferable. Once the correct amounts of lift and firework stars have been dialed in, you will want to make up some multi-shot mine boards too.

Next take one of the cardboard discs and punch with the awl (6 or 8) 1/16" diameter holes in it. (If you do not have disks, you can use 2 inch end plugs, #PC2000). You can also drill these holes if you prefer. The pattern of holes can be as neat or as sloppy as you like. Set the perforated disks aside.

Using the same awl, punch a fuse hole at the very bottom of the mine mortar so that when the visco is inserted it lies flat against the plug or base on the inside of the mine mortar tube. The fuse can be left unglued if the hole has not been made too large or the fuse can be secured in place with a dab of hot melt or white glue.

Place a level 1/2-tablespoon of 2FA Black Powder in the mine mortar (about 8 or 9g.).

Insert the perforated disc from step #2 into the mine mortar and slide it down flat to the bottom of the tube so that it rests on top of the black powder. Do not glue the disk. The disc should fit tight enough that it would not slide out if the mortar tube were turned upside down. Also, little or no black powder should leak out through the small holes in the disc if the mortar is inverted over a sheet of paper. The purpose of the disc is to ensure that that the black powder remains at the very bottom of the mortar, separate from the firework stars.

Measure out about 1/4 cup of firework stars to start and place them in the mine mortar on top of the perforated disc. For a mortar of this size (2 inch diameter), small firework stars, 1/4" to 5/16" diameter are preferable in order to prevent a thin or sparse pattern.

Finally, slide a solid cardboard disc down flat in the mine mortar to hold the firework stars in place. If the mine tube is inverted, the disc should be tight enough to prevent the contents from dropping out. Do not glue the disk.

Go outside and fire the device. Note the height and density of the firework star pattern. If it looks too sparse, increase the amount of firework stars slightly or decrease the black powder lift slightly. If the firework stars start to turn over and come back down, use more lift or smaller firework stars. Keep careful notes on quantities used for each size and type of mine constructed.

Adding Inserts with Firework Stars

The next step to take after getting a single-color firework star mine to work to your satisfaction is to try adding some simple sound or report inserts. Firecrackers are probably the easiest and can be simply loaded in loose on top of the firework stars.

However, a better method which results in more firecrackers getting lit is to bundle the loose firecrackers together with a rubber band until you have a bunch that is slightly less in diameter than the I.D. of your mine mortar. Insert the bundle, fuses down, into the mine tube on top of the firework stars. There should be no disk between the firework stars and the firecrackers. Slide down an un-perforated disc to hold everything in place.

Other inserts to try are crackling firework stars (dragon eggs), whistles, bees, small serpents, jumping jacks or combinations of these.

Layered Pattern Effects

Beautiful layered firework star patterns in which groups of firework stars arrange themselves in tiers are easily produced in mines. The only requirement is that firework stars of different shape and density be available. The layering is produced not by carefully arranging the firework stars in some particular order in the mine mortar, but by making use of the aerodynamic properties of various types of firework stars.

Round firework stars, for instance, will tend to travel higher than cut firework stars and therefore will appear to separate and rise above the cut firework stars as they exit the mortar. Similarly, higher density, heavier firework stars such as color firework stars will travel higher than lightweight firework stars such as glitter firework stars.

The greatest layering effect will be achieved by using heavy, dense, round firework stars and lightweight cut firework stars. Imagine throwing a golf ball and a Styrofoam cube up into the air at the same time. Obviously the golf ball will go much higher than the cube.

The principle is the same with actual firework stars exiting the mine mortar as the effects of air resistance and momentum cause the firework stars to separate and form a layered pattern. It is immaterial as to the order the firework stars are loaded into the mortar. Two and three layers can be achieved by careful selection of firework star types. Again, do not use a disk between layers.

Combinations of inserts as suggested above can be added to layered firework star patterns. However, don't overdo the combinations of colors and effects, as the overall look in the air can easily get too busy and confusing.

Using Color Changing Firework Stars

An alternate method of producing a layered look is to use round firework stars that change colors two or more times. As the firework stars leave the mine mortar tube they will be visible first as one color for the lower portion of their flight and then suddenly change to one or more different colors higher up in the sky. Visually the effect is somewhat different than the layering method described above.

Color changing firework stars made with a dark burning composition between colors give a very distinct rich looking pattern in the air as they first appear low to the ground, then seem to disappear half way up and suddenly reappear further up in the sky.

Again, don't forget to experiment with combinations of sound and noise along with color changers.

Comet and Firework Star Combinations

A very nice effect is a mine utilizing large comets and firework stars. In order not to overload the cardboard mortars, use comets whose thickness is roughly 1/2 their diameter. For this effect the comet should be just slightly less in diameter than the I.D. of the mortar. It should fall loosely into the mine mortar tube. Typically, the comet would be one displaying a long glitter tail for best effect, especially when used in combination with small color firework stars.

Loading order is as follows: Black powder, perforated disc, small color firework stars (1/4" to 3/8"), comet and solid disk. It is important to place the small firework stars under the comet and not on top, in order for the firework stars to light reliably.

When fired, the mine will display a low-level cloud of color with a large tailed comet rising up through the center of the cloud and continuing to a higher elevation.

Some Final Thoughts

Mines are a great way to enhance any type of pyrotechnic display. They are surprisingly effective even in small sizes and require a minimum of materials. Keep in mind that mines are much more impressive when fired in multiples rather than merely up-sizing up a single mine. Six or eight 2 1/2" mines placed 35 feet apart in a straight line and fired simultaneously will get much more response from your audience than one or two 6" mines.

Make sure you first thoroughly understand the principles of constructing mines in smaller sizes (1 1/2" to 2" tube I.D.) before trying to scale up to larger sizes. I have seen mortar tubes (HDPE) blown apart by people that thought that mine construction consisted simply of pouring firework stars and black powder in a tube and lighting the fuse. Large diameter mines can be very dangerous if improperly made. There are very few instances where mines over 4" I.D. are necessary or justified, especially when fired in multiples.

Frequently Asked Questions

Q: Do mines always have to be fired straight up?

A: No, fan shaped or angled arrays are a great variation. "V" shaped patterns of mines augmented with mortars firing tailed artillery shells straight up works very nicely. Layered mines containing comets whose effect matches the tail of rising shells are beautiful.

Q: Do I have to use 2FA black powder?

A: No, especially on small mines (1" to 2" I.D.), 4FA works fine. However, with smaller particle black powder there is more chance that the powder will migrate through the holes in the perforated disc and mix in with the firework stars. To prevent this, a piece of tissue paper can be lightly glued to the underside of the perforated disc.

Q: What is the best way to construct electrically fired mines?

A: Look up the article on making multi-shot boards. Go to the section on inserting electric matches in disposable mortar tubes. Do not attempt to load mines with a live electric match at the bottom of the mortar, unless the match has a shroud over its head. Always use extreme caution when using electric matches. THEY ARE VERY IMPACT AND FRICTION SENSITIVE!

Q: How much material can I put into any single mine tube?

A: Don’t fill cardboard tubes any more than 1/3 full with all mine contents including black powder, firework stars, comets, and inserts. If you do, the mine is likely to explode when ignited.

Q: I have heard that building up alternating layers of black powder and firework stars makes layered mines, similar in fashion to the method used for making double and triple petal shells. Will this work?

A: No.

15 Foot Crackling Mine Finale

By Griffin Behm

For reasons beyond my comprehension, peoples is forever calling up here and asking about making their own Chinese cakes. (A "cake" is a multi-tube repeating shot firework that shoots stuff up into the air.) I patiently explain to them that 1) they can buy these things reasonably at just about any fireworks stand, and 2) unless they ARE Chinese, that any cake they make will be distinctly NOT-Chinese. But they persist nonetheless. So here's a little project, sent in by Griffin Behm that can appeal to folks who want the satisfaction of making a repeating shot "cake." This is a perfect starter project for you newbies who have never ever made a fireworks device before, or for you dads who are looking for a project to help nurture your pyro kid's addiction.

This effect is sort of like a min-finale chain. As the effect really only goes about 15 feet high, it might not be suitable for a professional display, but for that backyard fireworks show you do every year, it can go a long way. Or perhaps you just have a craving for a loud pyro device? Either way this is a fun project.

Materials Needed

- 10 3-1/2 or 3-inch long pieces of 3/4 inch ID paper tube (TU1062 or TU2053)
- 1 1-foot length of 2 x 4 lumber
- Hot melt glue & gun
- 1/8" drill bit and drill
- Black powder
- 1.4g (Class C) Crackling Balls
- At least 10 inches of visco fuse (GN1000)

Obtaining Materials

Black powder. If you have access to real BP, then use it. If not, here's the 'poor mans' way to get it. Visit your local hobby show and pick up several C type Estes rocket engines. You will have to squeeze out the comp with pliers. I estimate you will need about 5-6 engines.

Crackling Balls. These are small 1.4g fireworks items sold around the Fourth. They are small green balls that are filled with a cracking composition (called dragon eggs). They are sold in packs of six, so just buy two. If you don't have a year-round fireworks store near you, consider ordering on-line if possible. The great thing is they come with a length of visco attached, meaning it's not necessary to buy extra visco for this project. If you are so inclined, you can make your own dragon eggs using one of the several dragon egg formulas floating around.

Visco. You'll be linking all these shots together, so you will need at least 10 pieces of visco. You could use one long piece (most reliable) or you can just be economical and use the fuses from the Crackling balls.

Procedure

First start by drilling fuse holes in all the tubes. To keep things simple, you might as well just drill an 'in' and an 'out' hole for each tube about 3/8 to ½ inch above the bottom of each tube. (The last tube doesn't need an 'out' hole so if you think you're slick, don't drill it.)

Next assemble all the tubes on the 2 x 4. You'll want to make sure all the fuse holes are aligned, as we will be pushing fuse through them in a straight line. Glue (white/Elmer's glue's best; hot melt will work) all the tubes to the board with glue on the base of the tube as well as around each one. You should leave about 1/4 inch to 1/2 inch between tubes. Do this for each of the remaining tubes. When finished you should have a nice arsenal of tubes lined up ready to be filled.

Now take your visco, and insert it into the fuse holes in a daisy chain fashion. If you have one long length just push it in the first 'in' hole on the first tube and then right through the other tubes until you reach the back of #10. If you're using short individual lengths, make sure that some of the powder core is exposed on all fuse ends. Attach the fuse by pushing it into the 'out' hole of a tube and then pushing it into the 'in' hole of the next tube. So on and so forth.

The next step is to fill the tubes with a lift charge. This is where the black powder comes in. You will probably have to experiment with the amounts, but if you were to use Estes fuel you're going to want to fill the tube 3/8 of the way full with 'rocket comp.' It's a good idea to measure the amount you're putting in as opposed to just randomly filling it. That way all the shots will be of equal height.

At this point add the effect, or the comp from the crackling balls. These will look like small round pellets (stars). You can just go ahead and dump the all the stars from each Crackling Ball into each tube (one Crackling Ball per tube). Now the tube should be pretty much completely full with BP and the effect.

As a final touch, cover all the openings of the tubes individually with foil in order to prevent premature ignition.

Firing

Place this impressive looking device out in the open somewhere. Fire/light the fuse and step back. You will hear a Whoosh and then a loud crackle of sparks. Just as the sparks are fading, another Whoosh and more loud crackles will be heard, and another, and another, and another, and another, and another, and another, and another, and then a final one. My! That was exciting, wasn't it!

Ghost Mines: How to Make Colored Fire and Fireballs

By Chris Spurrell

Learn how to make ghost mines, flammable colored flame projectors using firework chemicals. At night, this effect looks like a translucent green, blue, or red colored flame shooting into the air. You can use the techniques below to make liquid fireball colored flame projectors or simple colored flame lights burning in steel bowls.

Materials Needed

- Black powder, FFg
- Boric acid (CH8042)
- Calcium chloride (CH8091)
- Copper chloride (CH8091)
- Electrical firing system (GN6021, GN6020, GN6010)
- Electric matches (GN5050)
- Lithium chloride (CH8178)
- Methyl alcohol
- Methylene chloride (CH8193)
- Potassium iodide
- Sodium chloride (table salt)
- Shooting wire (GN5010)
- Steel pipe, 4" ID
- Steel wool
- Titanium, sponge or any other titanium powder (CH3080)

My experience with liquid fueled colored flame mines started small. A friend of mine, who is a professional storyteller, wanted to create some "atmosphere" at one of his outdoor gigs. He wanted some colored flames in the background to burn with an "eerie" light. Well, I had a bit of experience with colored flame mines with alcohol and thought I'd give it a shot.

Green mines are easy. You mix a teaspoon or two of boric acid in a gallon of methyl alcohol and you're set. The boric acid reacts with the methyl alcohol to give you methyl borate, which is volatile. The boron in the colored flame mine gives it a very pronounced green color. The colored flame mine can be burned in an alcohol lamp or in the open (a Sterno can sort of thing). My buddy used a stainless steel bowl placed in a dish full of sand. Of course, once he had green he wanted other colored flames. But, those were a little more difficult.

In order to get a chemical to make a colored flame, you have to get it into the flame itself. And, unlike the boron, it's either tough or undesirable to produce a volatile metal compound. We fussed with that awhile until we hit on the idea of a wick. A piece of steel wool in the bowl of alcohol did the trick. So now we could produce colored flame mines in a rainbow of colors.

The elements chosen are obvious, but the actual firework chemicals are a compromise among solubility in methyl alcohol, cost, and availability. Turns out that roughly 50 grams per gallon always works. In some cases it doesn't all dissolve, but with calcium chloride or sodium chloride, who cares?

Coloring Agents

- Red: Lithium chloride (actually any soluble lithium salt)
- Orange: Calcium chloride
- Yellow: Sodium chloride
- Green: Boric acid
- Blue: (nothing - alcohol burns blue)
- Violet: Potassium iodide

The next step was to go large. I had been firing gasoline fireballs out of some mortars I had. Starting with a half gallon, I had gradually worked up to blowing three gallons of gasoline out of a six-inch steel mortar using a charge of 40 to 120 grams of FFg black powder for lift. So why not shoot colored flames instead?

Several folks at the "Do-It" fireworks event had a chance to witness my first shots of the half-gallon fireball "Lampare Mines." Upon seeing a daytime video of these colored flame mines, Harry Gilliam coined the phrase "Ghost Mines."

I launched some of these at the Western Winter Blast XII using the following gear: Mortar: 4-inch inside diameter iron pipe, 2 feet long

Lift charge: Place 40 grams of FFg black powder, a pinch of sponge titanium, and an electric match in a very small zip lock plastic bag. Squeeze all the air out, and tightly wrap it with both clear packing tape and then masking tape to seal it against alcohol seeping in.

Fuel: One gallon of methyl alcohol with 50 grams of firework chemical coloring agent

Method: Fill mortar with alcohol and firework chemical coloring agent solution. Lower the black powder charge into the mortar. If the charge is tightly packed it won't float. From the friendly end of a 50-foot electric shooting wire, fire that thang!

Drawbacks: Typically there is some burning alcohol left behind in the mortar: HDPE and paper don't last too long.

Supplies: I get the methyl alcohol at the local lab supply, or fancy hobby shop, for $10/gal. Ethyl alcohol may work on some but the denaturing agent tends to give a yellow colored flame. I hear the boric acid doesn't work with ethyl alcohol.

No man's land: To get a really beautiful sky-blue colored flame, add six grams of copper chloride and 200 ml. of methylene chloride (chlorine donor) to the gallon of methyl alcohol. Great colored flame but it also makes a phosgene byproduct, something you might not want indoors. Any chlorine donor will do that. That is why I shied away from strontium and barium.

References: Unfortunately after pulling this stuff together I found out it was also in Weingart and in an early issue of Pyrotechnica. Well, at least when you reinvent the wheel there is some satisfaction in knowing that it came out round.

How to Make a Cremora Fireball

By Ned Gorski

Materials Needed

- Black powder, 2FA
- Coffee can
- Non-dairy creamer (Cremora)

Introduction

Ya know what's really aggravating? You put many hours of sweat and labor into producing a nice fireworks display, perhaps with some homemade aerial fireworks shells and fountains, and somewhere in the show you fire some of these simple and easy-to-make Cremora fireballs.

And after the show, do you hear much praise for the meticulously constructed shells that you slaved over? No! All you hear, especially from the kids, is, "Wow, we loved those big, fiery things! Whaddaya call em? They were hot!"

40-50 Foot Tall Cremora Fireball
(Photo and fireball by Noel Emge)

These fireballs are definitely crowd-pleasers and they couldn't be easier to make and shoot. The Bluegrass Pyrotechnics Guild has made and shot literally hundreds of the 5 gallon size fireballs in the displays we have produced for the Pyrotechnics Guild International's (PGI) summer conventions over the years. One time we wanted to replicate an atomic bomb mushroom-cloud in a show that had a World War II segment. We fired 13, five-gallon fireballs which resulted in this smoke cloud after the fire went out.

70 Foot Mushroom Cloud by Bluegrass Pyrotechnic Guild

In another show, we had a Wizard of Oz segment and wanted to have fireballs associated with "The Great Oz Has Spoken" soundtrack. Cremora fireballs provided just the right effect.

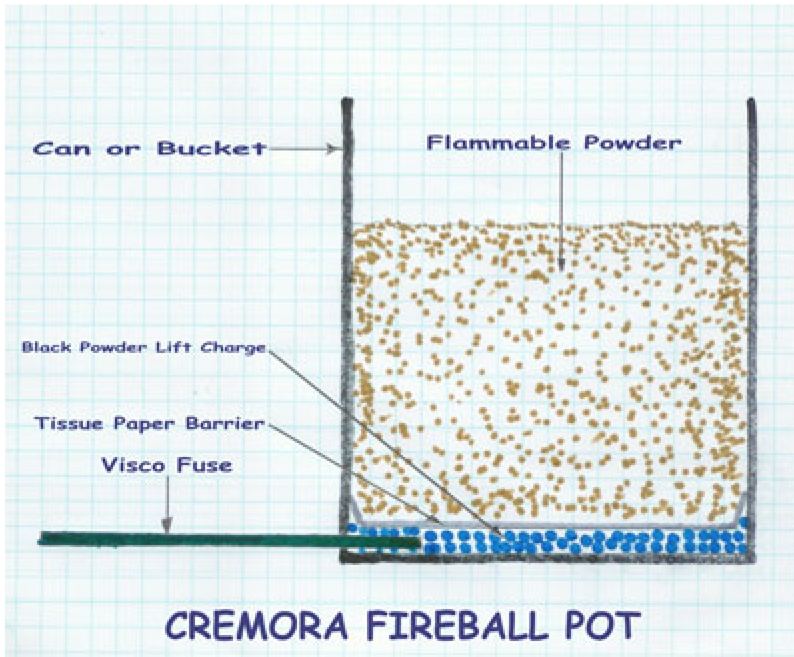
So, what is a “Cremora Fireball?”

In years past I've heard of accidents at grain silos or flour mills, where clouds of dust have been ignited by a spark resulting in a tragic explosion. A bag of flour is not a fire hazard, but mix it with air and it becomes a highly flammable mixture.

It takes fuel, oxygen and a heat-source to produce a fire. A Cremora fireball is simply a device which projects a powdered fuel up into the air where it gets mixed with the atmosphere, is ignited by the propellant, which results in a large fireball as the fuel and air burn together.

At some time in years past, an enterprising soul decided to project some Cremora brand coffee-creamer powder up into the air using a black powder propellant, and the Cremora fireball was born. Even though Cremora brand creamer is next to impossible to find nowadays, and other substitutes are used, these fireball pots will forever be referred to as Cremora pots, or just Cremoras.

The simplest of Cremoras can be made with just a metal can, some black powder, a 4" piece of visco safety fuse, a disc cut out of a paper napkin, and some flammable powder.



Construction of a Typical Cremora Pot

How to Make a Simple Cremora Fireball Pot

For a large fireworks display, Cremoras made in 5 gallon plastic buckets produce an impressive fireball for everyone to see. I'll provide some details on these in a moment, but these fireballs are so large that everyone really needs to be at least 200 feet from them because of safety concerns.

In smaller, backyard type displays, small Cremora pots, made in 12, 15, or 28 ounce metal cans, like what soups and vegetables come in, can produce impressive, safe fireballs. Some folks use cans as large as #10 cans, or even the size of a large coffee can. Small plastic pails and cans work well as containers, too.

Whatever container you use, you want a smooth interior wall, without any lip that protrudes toward the inside at the top of it. You want the contents of the pot to be able to be smoothly propelled skywards.

Warning: Safe is a relative term. As with any fireworks device that propels flame into the air and has the potential to malfunction and send pieces of the container flying, it is always best to maintain safe distances from the device when it fires. Barricade the device with concrete blocks, or bury the pot in a hole in the ground. Nothing would take all the fun out of this faster than having someone get hurt, especially some innocent spectator.

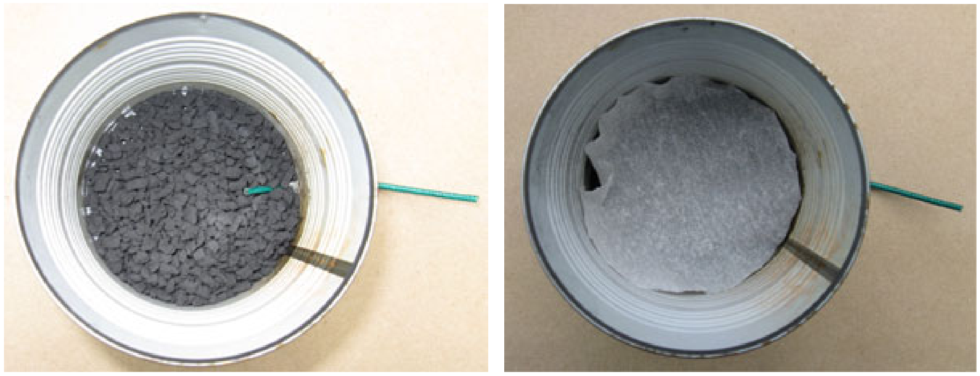
For these small fireballs, I start with a clean, empty can, and punch a visco-size hole in the side of the can, right near the bottom, with a sharp awl.

Preparing Empty Can Container for Cremora Fireball Pot

Note: It is best to perform all of the following procedures with the container in place in the location where the fireball will be shot. We want the flammable powder to stay fluffy, and this prevents the flammable powder from settling as it would if the pot was moved after assembly. If you build it in one place, then transport it to another (thereby settling and compacting the powder), instead of a fireball rolling up into the air, you are more likely to have an explosion of the can itself, possibly injuring yourself or bystanders with metal-can shrapnel. Building the device in its final location also prevents any possible static discharge between it and the ground which could occur if it was lifted up.

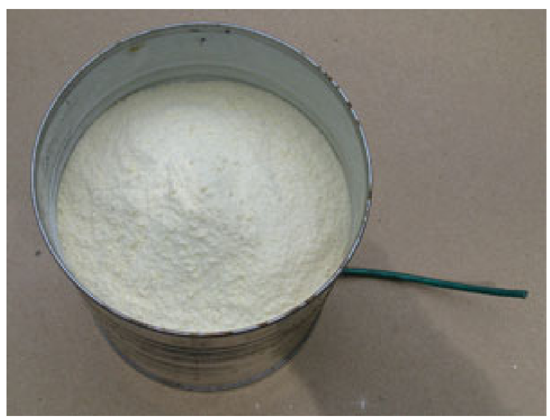
Now, I insert the visco safety fuse through the hole in the base of the can, put the can on the ground, and pour the black powder (BP) lifting charge into the can. I make sure the BP is spread evenly around on the bottom of the container. Then I cover the BP with a round piece of thin tissue, cut from a paper napkin or from facial tissue.

This tissue barrier prevents the flammable Cremora-type powder, which is about to be added to the can, from settling in between the BP granules, which would slow the BP's burn rate. We want the BP to burn rapidly and develop enough pressure to quickly propel the flammable powder into the air.



Cremora Fireball Pot with Visco Fuse, Black Powder, and Tissue Paper Barrier Installed

Now, it's just a matter of gently pouring the Cremora-type flammable powder into the can on top of the tissue-paper barrier, filling the can one-half to two-thirds full. If the powder you are using is clumped a bit and is not completely free flowing, it is a good idea to sift it through a wire-mesh kitchen colander before pouring it into the can.



Completed Cremora Fireball Pot

The Cremora is now ready to be fired. If it is not going to be fired immediately, cover the device with a piece of aluminum foil to prevent dew, rain, or humidity from affecting the contents.

You'll want to be a good 30-50 feet away from even one of these small fireballs when it ignites. You will feel the radiant heat from the fireball as it rises into the air. If you test-fire one of these during the daytime, you might see a giant smoke ring form as well.

Details, Details

As you are following along in this process, a few questions have probably now popped into your mind. How much and what type of black powder should I use? How does that vary from one size container to the next? What kind of Cremora-type flammable powder works best in these babies? How could I fire these electrically during a choreographed show? Could we add anything to the fireballs to make them more impressive? (We pyros are never happy to leave well-enough alone, are we?)

Black Powder Lift Charge

Commercial 2FA black powder is traditionally used as the lift powder in Cremora fireballs. A good place to start when determining how much of it to use is 0.1 ounce per square inch of container bottom. This results in the following amounts:

Container Diameter	Lift Charge
3-inch diameter container	0.7 ounce 2FA
4-inch diameter container	1.25 ounces 2FA
5-inch diameter container	2 ounces of 2FA
6-inch diameter container	2.8 ounces of 2FA
7-inch diameter container	3.8 ounces of 2FA
8-inch diameter container	5 ounces of 2FA
9-inch diameter container	6.4 ounces of 2FA
10-inch diameter container	8 ounces of 2FA

These amounts will result in a layer of 2FA on the bottom of the container that covers it completely and is about 1/4" thick. This is a good starting point, and can be adjusted to taste. The correct amount of lift powder will result in a great fireball, but the container will remain in place and intact.

The first time I ever made 5 gallon Cremora fireballs (10" diameter bucket bottom), I used a pound of commercial 2FA lift powder in each one. "Yeah, that looks about right," I said to myself and to those around me. We ended up with great fireballs, and pieces of bucket strewn far and wide. "Hmmm, maybe we can back off on that lift powder a bit."

In Skylighter Fireworks Tips, #96, we learned how to make very functional, red-gum/alcohol granulated black powder using Skylighter airfloat charcoal, and nothing more than a couple of screens.

This homemade black powder works wonderfully in these Cremora fireball pots. I actually like the slightly softer lift that this homemade BP provides. When using it, I like to use between 1.25 and 1.5 times as much as I would of the commercial 2FA amounts listed in the above table.

Different Kinds of Cremora-Type Flammable Powder

When this subject is brought up, quite a few variables are encountered. There are many different varieties of non-dairy coffee creamer available. As I said above, I was unable to locate the actual Cremora brand. I tested Coffee Mate, Kroger brand creamer, and the cheaper store brands from Wal-Mart and Biggs.

A friend of mine was able to purchase a couple of pallets of out-of-date Vitamite non-dairy, powdered milk replacer, and we've been making very nice fireballs with it for a couple of years. Vitamite is available from Diehl Food Ingredients, www.diehlinc.com, but it costs $180 for a 50 pound bag.

Powdered Milk Products to Use as Flammable Powder in Cremoras

One PGI member who has attended the conventions in years past has brought 50 lb. bags of floor-sweepings from a factory that makes powdered base for gravy mixes and soups, and has made this powder available to attendees. This powder quite often has a fat-content of 50-60%, and has produced some of the brightest and hottest fireballs I've personally ever seen. Very impressive!

I have often used Land-O-Lakes Lamb-Milk-Replacer and have been very pleased with the results. This product is now up to about $50 for a 25 lb. bag, and is often available at farm-feed supply stores.

Another pyro has used a product called Glufil which is powdered walnut shells. This dust is considerably less expensive, at $22 for a 50 lb bag, and is available at www.rogergeorge.com. I've seen photos of fireballs made with it and they looked very nice. The fellow who has used it reported that it did not perform quite as well as Cremora though.

I've heard of folks using fine sawdust, or even wheat flour. One well-respected pyro recently told me that he uses finely powdered Gilsonite, which is powdered natural asphalt, available from Skylighter. I had to mill the Gilsonite that I had on hand to a fine dust in my coffee grinder because it was originally in the form of larger crystals. Just remember that whatever you use, it must be a very fine, flammable powder.

Well, all of the above information and options certainly call for some experimenting, don't they? So, I got my lovely assistants, my wife and granddaughter, outside on a nice spring evening after dark, and I made up some small Cremora fireball pots in a 28 oz. can, using many of the flammable powders listed above.

At the last moment, I decided to include pots made with Skylighter airfloat charcoal, powdered confectioner's sugar, and my homemade spruce/pine airfloat charcoal. Then I fired them one at a time, and we graded each one based on how impressive the fireballs were.

The results were as follows, with the resulting fireballs rated on a scale of 1 to 5, with 1 being not-so-good, and 5 being "man-that-curled-the-hairs-on-my-arms":

Small 28-Ounce Fireball Scores

Ingredient	Rating	Effect
Wheat flour	2	
Kroger brand creamer	2.5	
Coffee Mate creamer	2.5	
Fine pine sawdust	3	
Powdered sugar	3.5	Interesting purplish flame
Wal-Mart brand creamer	3.5	
Lamb milk replacer	4	
Vitamite 4.5		Lower fireball than others
Spruce/pine airfloat	5	Lots of hanging sparks
Skylighter airfloat	5	Hot, high, bright fireball
Gilsonite 5		Hot, rolling orange and black fireball

Note: The one thing that kept the Vitamite from receiving a 5 was that it produced a lower fireball. It is a very fine, dense, powder, and tends to be more difficult to blow up into the air and disperse into a large cloud. I came to the conclusion that it needs to be fluffed up a bit, and decided to mix it half-and-half with sawdust in future testing. The performance of any relatively dense powder may be improved by mixing it with some sawdust in order to fluff it up a bit.

These were small, backyard-type fireballs, and I wanted to see how the top performing powders compared in large, display-size Cremoras. So I took some 5 gallon buckets to a recent club shoot, and tested large fireballs there. The results were as follows:

Large 5-Gallon Fireball Scores

Ingredient	Rating
Half-and-Half Coffee Mate/Wal-Mart brand creamer	3
Gilsonite 4	
Skylighter airfloat charcoal	4
Lamb milk replacer	5
Half-and-half Vitamite/sawdust	5

These large Cremora fireballs from a distance of 200 feet looked better when they were brighter, and the latter two produced those kinds of fireballs. But, none of the above was bad, and each one produced its own unique effect.

Firing Cremoras Electrically

Warning: This can be done easily, but must be done in a particular way in order to be done safely. I have heard of someone being gravely injured when they made a Cremora, with an electric match in the lift powder and the wire leads dangling out of the bucket, and then they lifted the assembly causing a static discharge through the ematch leads and firing the bucket.

First of all, the Cremora pot must be made in place and not moved. Barricade the pot by building it in a hole in the ground or by placing safe barricades around the bucket. If you are using a 5 gallon bucket, remove the metal handle to prevent it from becoming flying shrapnel in case the bucket is fragmented during firing of the Cremora.

Secondly, quick match, or plastic-tape-wrapped Fast-Fuse, must be run into the lift powder from outside the bucket, either through a hole near the bottom, or from the bucket top, down the inside of the bucket and into the black powder. The electric match is then installed into the end of the quick match/Fast-Fuse, which insulates the ematch from any static charge that might build up in the Cremora powder. Then, the Cremora pot is constructed as described above.

Constructing a 5-Gallon Cremora Pot to be Fired Electrically

Note: Some folks insert an inexpensive metal mixing bowl into the bottom of the bucket, and then install the Cremora fireball ingredients in and above that bowl. I have never done this, but, reportedly, it can increase and improve the upward thrust of the powder and the resulting fireball.

Interestingly, the Cremora fireball pot shown in the picture above, made at the last moment for illustration purposes, was made with the remaining 6 containers of the cheap Kroger coffee creamer that I had purchased for this project. In the small-can test shots, this powder was rated at only 2.5, a somewhat disappointing fireball.

But, the 5-gallon pot's fireball was very hot and impressive. This suggests there is plenty of room for experimentation and personal taste as these devices are developed and refined.

Parasitics

This is what we call additional effects that ride on top of a main device or effect. I, personally, like Cremoras made simply as described above but sometimes powdered metals like titanium or aluminum are sprinkled into or on top of the flammable powder as it is added to the container.

I've also seen small aerial fireworks shells, or just individual fireworks stars, placed gently on top of the fireball powder, to be ignited and propelled into the air when the Cremora is fired. This provides some room for creativity on the part of the fireworker, but as usual, safety precautions must be considered and safe setbacks must be observed. Additionally, after the firing of the Cremora, the site must be inspected for any un-ignited effects.

So, there you have them--some of the simplest, and most effective, fireworks crowd-pleasers you can come up with.

How to Make Strontium Nitrate Sparklers

By an Anonymous Skylighter customer

The very popular fireworks making book, *Introductory Practical Pyrotechnics* provides a neat project for making sparklers. Problem is Skylighter does not ship barium nitrate. What to do? Here's a project formula for making sparklers that use strontium nitrate instead of barium nitrate. Thanks to one of our readers, who wishes to remain anonymous?

A Sparkler Made with Strontium Nitrate

Strontium Nitrate Steel Sparklers

Component	**Parts**
Strontium nitrate (CH5543)	200 grams
Sparkler-grade steel powder (CH8300)	120 grams
Aluminum, bright flake, -325 mesh (CH0174)	32 grams
Airfloat charcoal (CH8068)	2 grams
Boric acid (CH8042)	6 grams
Dextrin (CH8107)	40 grams

+90 ml 25% aqueous ethanol (25% alcohol, 75% water) solution

Grind any coarse, un-ground components (if any) separately. For instance, strontium nitrate often gets clumpy or comes in crystalline form. Mix together all your sparkler components except dextrin. Add 25 ml of 25% aqueous ethanol to dextrin and stir until it becomes a paste.

Break up or discard any large clumps that form in your dextrin paste. Add paste to dry sparkler components and stir. Stir in 65 ml more ethanol solution. Dump your sparkler mixture into 41 mm OD x 12" long test tube (or pipe, whatever). The wet sparkler composition should be 7" to 8" deep.

Dip sparkler stick (or wire/whatever) into mix, remove it, and let dry 24 hours. Then apply 2 more coats in same manner. If needed, add about 5 ml ethanol solution to re-wet mix. Let your sparklers for dry for 24-48 hours.

The slag waste created when you dip the sparklers is fun to let dry in a pile and light on fire on the ground, too.

Notes:

You may have to adjust the volume of ethanol solution to make the sparkler paste consistency right; it varies slightly every time I do it.

Sparklers may be difficult to light. Propane torches or butane cigarette lighters are good sparkler lighters. Sparklers can also be lit off each other. I sometimes use a prime just for the tip of the sparklers that uses a black powder/dextrin slurry.

When the sparkler dip dries, you may notice rust from the steel. This may indicate that coating the steel powder first with linseed oil first may be the way to go, though I haven't ever had any problems with it. These sparklers were made in the Missouri summer, so they had plenty of humidity around.

The paste for the sparklers can come out a bit clumpy. Larger batches will even bubble out the sparkler coatings a bit. I haven't tried, but thorough mechanical mixing of the slurry would probably help. It doesn't affect the sparklers' burning at all.

The sparklers burn a little better than the commercial sparklers that one can buy, and they last longer, too. I recommend only burning these sparklers outdoors.

The sparkler formula isn't mine originally--I just modified it slightly. This is a great sparkler to make that doesn’t need perchlorate or barium nitrate. I've actually tried several formulations, including those with perchlorates, and the ones with perchlorates burn too fast, too erratically, and a little too energetically for using as a full coating on the sparklers.

How to Make Flying Fish Fuse Sparklers

By Kevin Shelley

Materials Needed

- Clear tape
- Flying fish fuse and/or falling leaf fuse
- Metal rod

We got this great little homemade sparkler project from Kevin Shelley. Thanks, Kevin. Here's how he makes this fast, neat sparkler using Skylighter flying fish fuse and falling leaves fuse.

"I'm writing to you to tell you how fantastic the flying fish fuse and falling leaves fuses are! There are any number of uses for these things, and I just thought I'd write about something we've been making with them: custom sparklers.

The way we make these sparklers is to obtain a bundle of wire marking flags from the local hardware store, after which we strip off the plastic flags. These will become the wires for our sparklers. Flying fish fuse is then clear-taped or tied in lengths to the thin metal sparkler rods.

Taping to the sparkler rod is a little faster, but tying can be pretty quick too, once you get in the groove on the assembly line. We are careful to space the tape/string so that the lengths of flying fish fuses or falling leaves fuses maintain a close relationship with the sparkler rods.

Using this sparkler making technique, interesting surefire homemade sparklers can be quickly assembled. Mixing the lengths of different flying fish and falling leaves fuses on the same rod can increase the variety of sparklers.

When mixing different fuses, we tape the ends of the different fuses in close proximity with one another on the sparkler so that the ignition train can jump the junctures. Using the red and strobing white falling leaves fuses, and the silver crackling flying fish fuses, your can assemble your own versions of the ever popular 'morning glory' sparkler-type novelty firework, with the exception that the end is way prettier than that of the morning glory sparkler.

More than one fuse can also be run 'full length' down the sparkler rod, which increases the singular effect of whichever fuse you use. The crackling flying fish fuses make an extra enjoyable experience when doing this (even to the point of being a little scary to firework tenderfoots). The green falling leaves fuse (GN1050), which is amazingly bright already, really responds well to doubling or tripling on the sparkler in this manner. It's like holding a miniature road flare in your hand. The red falling leaves fuse is also good. Although I'm unfamiliar with the other, new falling leaves fuses, I'm sure that they would also be excellent on these sparklers.

We also tape several foot-long lengths of crackling flying fish fuse together and then light the whole bundle without a sparkler rod. The racket is wonderful, and near the end of the burn the entire assembly sometimes takes to the sky."

How to Make Senko Hanabi Sparklers

By Ned Gorski

Materials Needed

- Charcoal
- Coffee grinder
- Potassium nitrate
- Screen, 100-mesh
- Sulfur
- Tissue paper

Introduction

In the past, I've kiddingly told fellow pyros that, at one time or another, I've made, or at least have tried to make, every kind of fireworks device except for snakes. That was before I heard about senko hanabi, though, and realized that I didn't even know what they are.

I've made some sparklers in years past, and senko hanabi are a kind of Japanese sparkler in the strict sense of the word. But, after a friend gave some of them to me last year, I realized I'd never tried to make anything like them.

According to Shimizu in Fireworks, the Art, Science and Technique ("FAST"), senko hanabi is a traditional Japanese firework, and essays about them date back to at least 1927. One Japanese-to-English, online dictionary spells it senkouhanabi, and defines the word as "toy fireworks." Hanabi means "flowers of fire," and these sparklers produce miniature versions of them.

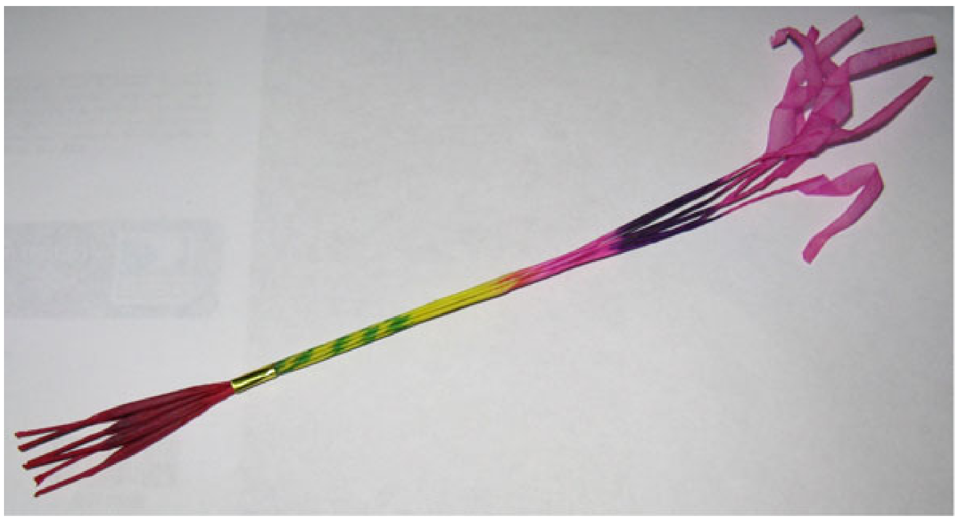
Senko is defined as "all ages," and perhaps refers to the fact that this firework can be enjoyed by people of all ages. Senkou is said to refer to "incense stick" and this type of sparkler has indeed been made on sticks, which resemble incense.

The word "sparkler" may be a bit misleading to us in the USA, though, because of what it brings to mind. Metal wires or wood sticks, dipped in pyrotechnic compositions, emitting bright sparks and lots of heat when they burn. "Be careful around your sister's eyes with that glowing metal wire," Mom would shout.

This Japanese version of the sparkler is much more delicate and subtle than what we are used to, though and a lot safer as well. I remember how startled I felt when I first got one of these to work, and it began emitting amazingly complex, delicate, branching sparks, shooting out four to eight inches. Like fire-snowflakes, I thought. I was amazed.

After I burned through a pack of them, I decided to send my Mom and Dad a bundle of these colorful little sticks. My folks are in their 80's and live in California, so I certainly wouldn't have been comfortable sending them any real "fireworks," but I just had to show them these mysterious little sparklers. I was excited as I imagined them going out onto their deck and burning a few of 'em.

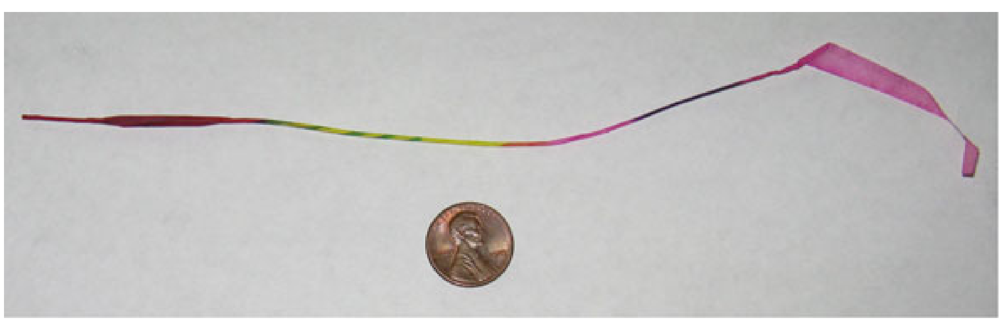
"You are going to be amazed by what you see when these little things really start doing their thing," I told them.



A Bundle of Chinese Senko Hanabi Sparklers

Dissection of a Senko Hanabi

Here's a photo of an individual senko hanabi.



One Senko Hanabi Sparkler

The bulging section toward the left end is what contains the sparkler composition. The comp is contained in twisted tissue paper, which can be fairly easily untwisted to empty the contents.

Senko Hanabi Composition Removed from Sparkler

The composition is a very dark black powder. And there is not much of it in there. I have an electronic scale, which is precise to one-tenth of a gram. It would not register the weight of the composition that I removed from this sparkler. It barely covered the tip of a one-eighth teaspoon measuring spoon. Its quantity equals about as much salt as you'd get if you shook your salt shaker a couple of times.

The rest of the sparkler, the handle, is also composed of tightly rolled up tissue paper. It feels as though it has been stiffened with a bit of a binder or glue of some sort.

Lighting a Senko Hanabi

To get a senko hanabi to work, you hang the composition end of it straight down from your hand. Make sure you are in an area with no wind, steady your hand, and then light that lower end. To really see the effect, it's best to do this in the dark, and in a ventilated area, but without wind, so you don't have to breathe the strong sulfur smoke.

The tip will burn up to the bundle of composition, which will begin to slowly burn, and if you are holding it still enough, a little blob of orange, glowing, molten slag will form. This is reportedly potassium sulfide, which contains carbon from the charcoal.

Then, all of a sudden, this molten ball will begin to emit the most amazing, delicate, branching sparks, often looking like fire-snowflakes. When you see this for the first time you'll be amazed.

I tried, over and over, to get a nice photograph of this phenomenon and failed miserably. This shot might give you the slightest impression of what the effect is like. You really have to see it in person to appreciate it.

Burning Senko Hanabi Sparkler

How to Make a Senko Hanabi Sparkler

There are several senko hanabi tutorials available on the Internet, and, as far as I can tell, all the information is based on the information contained in Shimizu's FAST.

The black composition is a simple one, consisting of three basic chemicals: potassium nitrate, sulfur, and charcoal. These are combined in a ratio of 60% potassium nitrate, 20-30% sulfur, and 10-20% charcoal. This is a typical black powder composition, but the quantity of the sulfur is doubled or even tripled.

Sometimes lampblack or soot is used instead of charcoal. If charcoal is used, the type of charcoal will influence the resulting sparks. Some folks use charcoal that is made of tissue paper or paper towel, soaked in a sugar solution, and cooked in a retort until it becomes a form of charcoal. See Skylighter Fireworks Tips, Issue #90, for details on cooking charcoal.

Shimizu also lists an alternate composition, consisting of 35% potassium nitrate, 45% realgar, and 20% charcoal or soot. Realgar is a chemical that is listed as a component of some old fireworks formulae, but it is seldom used nowadays because it has become difficult to obtain, and it contains arsenic, a bad thing in smoke if it is inhaled!

Note: I do have a small quantity of realgar, and I tried the above formula in senko hanabi. Shimizu states that realgar will produce "larger and more beautiful sparks than with sulfur." In the minimal experimenting I performed using it I did not find that it performed as well as the sulfur. And, when the composition burns, it emits a thick, yellow smoke, which I was not all that thrilled to be around.

My technique for making these experimental senko hanabi was as follows:

Weigh out chemicals in individual paper cups. Grind potassium nitrate and sulfur individually in a small coffee grinder until the chemicals are very fine. Combine and screen those chemicals with the airfloat charcoal through a 100-mesh screen several times.

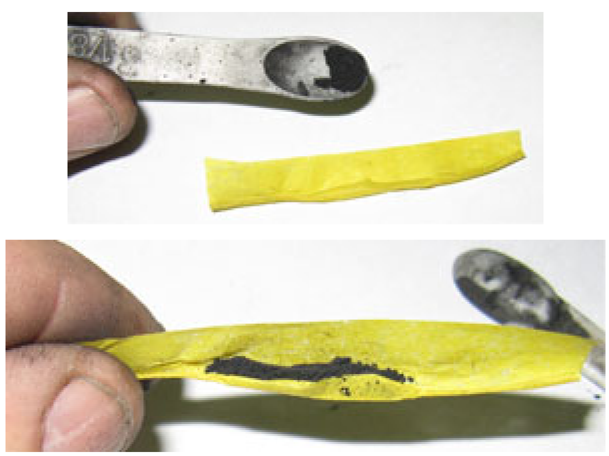
I began by using 16.5 grams of the potassium nitrate, 6.5 grams of sulfur, and 4.5 grams of airfloat charcoal. (This is approximately a 60/25/15 proportion of the components.)

Cut a piece of tissue paper, 1/2" x 2 1/2".

With slightly dampened thumbs and index fingers, begin to roll the tissue paper up at the ends, as if I'm rolling a cigarette. (Having come of age in the 60's and 70's, I, of course, would know nothing about this process.)

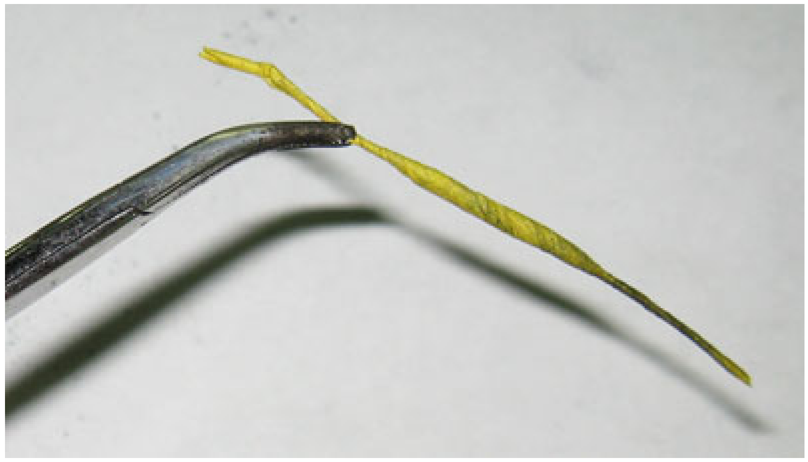
Rolling a Piece of Tissue Paper

I now dip the end of my 1/8-teaspoon measuring spoon in my composition and scoop out just that little bit of comp. I tap the powder out of the spoon into the little, rolled trough that was formed in my tissue paper.



Scooping Senko Hanabi Composition, and Loading it into Tissue Paper

Then it's just a matter of using my fingers to finish rolling the little sparkler and really twisting it into a tight little bundle. I like to hold my homemade sparkler with a pair of tweezers or a hemostat in preparation for burning it.



Homemade Senko Hanabi Ready to be Lit and Tested

Results of Experiments

When I made the first sparklers, using the composition listed above, they burned far too fast and did not form the little ball of slag which is necessary for the resulting final sparks to let fly.

So, I started to add more charcoal, one half gram at a time, as one would do to slow down a black powder rocket composition. This did end up retarding the burn speed, but the slag ball and the sparks never ended up forming.

Back to the drawing board. Since the original comp was burning too rapidly, I thought I'd start with the charcoal and sulfur components, and slowly add potassium nitrate until hopefully the desired results were achieved.

I ground the 6.5 grams of sulfur in my small coffee mill, and screened it in with my 4.5 grams of charcoal. I weighed out the 16.5 grams of potassium nitrate and milled it by itself in the coffee mill.

Then I started to add the potassium nitrate to the sulfur/charcoal mix a little at a time, starting with 4 grams and adding it in 1-gram increments. I tested the composition after each increase in the oxidizer, and after adding 11 grams of it, the ball of slag started to form and it began emitting the sparks I was after.

With a total of 12 grams of the potassium nitrate in the mix, the sparklers were working very well, and when I added another gram bringing the total to 13 grams, they started to burn too quickly as in my first experiments.

So the final working formula was:

Senko Hanabi Composition

Component	Parts	Percent
Potassium nitrate	12	52%
Charcoal 4.5		20%
Sulfur 6.5		28%
Totals 23		100%

This final formula is in the range of proportions that Shimizu demonstrated to work.

I tried both commercial airfloat and homemade spruce/pine airfloat charcoals, and they both worked well. The homemade charcoal produced sparks which were slightly larger.

I tried the lampblack that I had on hand in the formula, instead of charcoal, but I could not get it to work and produce sparks.

If I were going to make "production models" of these babies, I'd glue the tissue paper bundles to a bamboo skewer, or toothpick, handle.

Dr. Shimizu goes into much greater detail concerning the chemistry dynamics of the senko hanabi process, and other optional formulae, ingredients, and manufacturing processes.

When I first got into fireworking, one question was paramount in my mind: "How the heck do they do that?" I've continued to ask that about almost every pyrotechnic device I've seen, and I'm glad that Dr. Shimizu and others have left pointers along the way so that I could learn more about how these things are made.

How to Make a Model Ammonium Dichromate Volcano

By Ned Gorski

Introduction

A while back I received an email from Harry:

"Have you ever made an ammonium dichromate volcano? They are really popular with parents and teachers and look great daytime or night."

I responded: "Never learned how to make a volcano. I led a deprived childhood. No way they're doin' anything like that in science classes nowadays."

Making a volcano would, of course, be exactly the sort of school project which would capture the imagination of so many young students.

Harry shot back: "Neat little effect. The ammonium dichromate burns by itself, but you can add other fuels to make more life-like 'lava. For instance, charcoal 10 or 20-mesh. I imagine there's some flake titanium, ferro-titanium, etc. that would work as well. You could provide volcano formulas for high school projects."

Well, I was intrigued. I've made 16-inch ball shells and 36-inch girandolas, but never an ammonium-dichromate volcano. I couldn't let that stand for long. So I asked Harry to send me a few tubs of the ammonium dichromate, and I put it on my to-do list.

In the meantime, I did a little research on the Internet, and also found a couple of paragraphs about the volcano in the Skylighter Project Plans pages.

Warning: So, first off, a bit of a warning: Ammonium dichromate is rated as a hazardous toxic chemical on its MSDS. One should not inhale its dust, but that's not too tough to avoid since it comes as relatively large orange crystals, not a dust that gets easily airborne.

One should not ingest it. Well, Duh!

One should avoid skin contact. Wear rubber gloves if you're gonna touch the stuff (which is not necessary to create one of these volcanoes). Avoid eye contact. The stuff can cause cancer.

So, exercise appropriate caution with this chemical. If you're going to be making a volcano like this for a science fair, perform all actions and experiments with it outdoors, and when the volcano is "erupting" don't allow anyone to breathe the small amount of smoke and ash, which rises off of it.

Use common sense. I know, I know. Common sense is not in common use nowadays to protect folks from harm. Since everything even remotely dangerous is becoming illegal, folks are increasingly being born with no common sense chip. But, use common sense anyway. There, you see? You got me started.

The Scientific Stuff: Science for Kids - Old and Young

I'm not much of a chemist, but I did find this information interesting, and some other folks might as well.

Ammonium dichromate is sometimes referred to as Vesuvian Fire due to its use in the creation of these small volcano replicas.

Ammonium dichromate's formula is $(NH_4)2Cr_2O_7$.

Ammonium Dichromate (Skylighter #CH5500)

When it burns, it decomposes according to the following equation:

$(NH_4)2Cr_2O_7$ (solid) -> Cr_2O_3 (solid) + N_2 (gas) + $4H_2O$ (gas).

The gaseous byproducts are simple nitrogen gas and steam, so they are innocuous.

Chromium Oxide Ash Left after Ammonium Dichromate Volcano Burned

The solid product is chromium (III) oxide. What remains after the volcano burns is this solid, grayish-green ash. The chromium in it is toxic and possibly carcinogenic, so care should be exercised when handling it and disposing of it. Some of this ash flies up into the air when the volcano is burning, so you don't want anyone close enough to it to breathe the stuff.

The chromium oxide can reportedly be used in a thermite reaction to produce elemental chromium metal, so I'm going to save the chromium oxide ash to try to use it in such a reaction, since I am planning an article on thermite reactions.

Volcano Project

I decided to go simple and make a "volcano" out of a can and heavy-duty aluminum foil. I formed a lip at the bottom of the aluminum foil "cone" to catch the ash as it formed.

Making an Aluminum Foil/Pop-Can Volcano

I lit the top of the ammonium dichromate with a propane torch, and it burned and created a "volcano" effect, but at times the flame went deep into the orange crystals, down the sides of the can, and propelled some of the crystals up and out of the can, un-burnt. I was not completely pleased with the effect that was produced.

So I decided to try a shallow, tuna-fish can, sitting on top of the pop can.

Aluminum Foil Volcano Made with a Shallow Tuna Can

This volcano burned a little better than the first one, but still the flame worked its way down the sides of the can, and the ammonium dichromate did not burn evenly. I still was not satisfied.

I also noticed that igniting the ammonium dichromate with the propane torch was not all that easy. The pressure of the propane blew the crystals out of the way of the flame, and although some of them eventually lit and initiated the desired continuing reaction, the pile did not ignite right at the top of the heap.

So, I decided to try something really simple. I made a "tray" out of flat aluminum foil with the edges turned up to catch the ash. I poured a cone of about a half-pound of the ammonium dichromate in the middle of the foil tray, and inserted a 6-inch length of visco fuse into the middle of the pile of orange crystals.

Simple Pile of Ammonium Dichromate to Create a Model Volcano

Once the visco fuse burnt down into the cone of crystals, they ignited and a nice volcano-action formed and burned until only ash remained.

Well, then I thought that the way to get this baby really looking like a volcano, but still burn like it did in this last test, was to form the aluminum foil over the cans, but not cut the opening. I just piled the ammonium dichromate on top of this "mountain" on the flat section and inserted another piece of visco.

Daytime Ammonium Dichromate Volcano

(Click Image to Play Video )

I was really pleased with how this volcano looked and performed. It almost looks like the real thing--glowing, flaming lava flowing down the side of the Mt. St. Gorski. These volcanoes use about 1/4 pound of the crystals per volcano.

Nighttime Volcanoes

I thought I'd make a few other versions of the ammonium dichromate volcano at night. For the first one I repeated the procedure I followed in the last daytime test. This looked pretty cool as the "lava" burned and flowed down the sides of the "mountain."

Honestly, I like watching the volcano better in the daytime when I can see the greenish ash being formed and flowing down the sides of the hill. For the second nighttime volcano, I did the same as above except I stirred in a tablespoon of 36-mesh charcoal to see what sort of effect that would produce.

As this volcano burned, a lot of orange, charcoal sparks rose up into the air above it, creating an effect that was different than the standard, ammonium dichromate-only volcano.

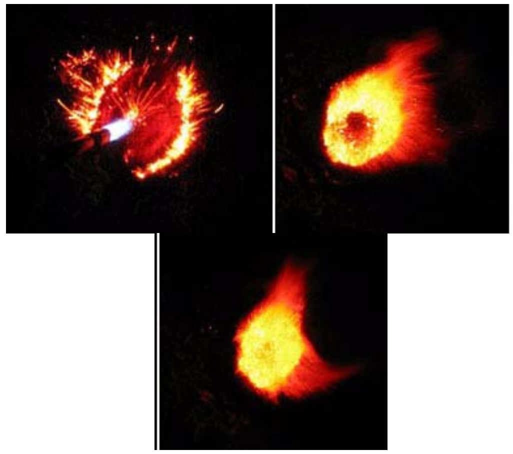
Ammonium Dichromate and Charcoal Volcano

(Click Image to Play Video)

For the third nighttime test, I mixed in about a tablespoonful of medium flake aluminum, and for the fourth and final test I added about a teaspoon of fine spherical titanium.

The addition of these metal fuels seemed to slow down the burning reaction, and did not produce the silver-white sparks, that I was half-expecting. There was an interesting, different sort-of molten flowing effect, as the reaction seemed to almost melt the ammonium dichromate and metal together, causing molten "lava" to flow down the mountain.

As a last offering to the pyro-gods, I simply poured about a half-pound of the ammonium dichromate onto a bare patch of ground and lit it with the propane torch.



Simple Ammonium Dichromate Volcano on the Ground
(Click Image to Play Video)

This caused the little volcano crystals to ignite from the sides and burn toward the center, and this was probably my favorite effect of the night. (After it, I had to get a shovel and completely clean up the green ash from the area.)

Conclusion

This was a fun little science project. I saved some of the ammonium dichromate for when my grandkids visit, and I'll introduce them to something they'll probably never have the chance to see in science class. And there's enough left to show them how to make a school project volcano just in case that time comes.

Making Gerbs (Fountains)

By Ned Gorski

Introduction

After talking for the past few weeks about all the interesting things we can do with commercially-made consumer fireworks, let's now make some simple, easy-to-make display items of our own.

In Fireworks Tips #89 I wrote about making nozzles and bulkheads. We'll be putting those lessons to work in this article. In Fireworks Tips #107 I explored cutting, treating, and rolling paper fireworks tubes. These tubes will also be used in this project.

Homemade fountains, called gerbs by pyro-folks-in-the-know, are very versatile devices. They can be used as stand-alone fountains shooting sprays of sparks skyward, as drivers on wheels, as downward spraying tubes in a homemade waterfall, or as line rockets.

I'll be demonstrating those line rockets, sometimes called rats or pigeons, in the newsletter following this one, so stay tuned. I'll also be using these fountains as drivers on a fireworks wheel. I described using commercial cone-fountains to drive one of these unique chromatrope double-wheels in Fireworks Tips #105.

Devices very similar to these fountains, employing a slightly faster-burning fuel and a somewhat different nozzle configuration, were what I described in the end-burning rocket motor essay in Fireworks Tips #95. In that article I showed how gerbs can be used to create a design, called a gerb set-piece.

Gerb Set-Piece (Photo by Nancy Stewart)

Gerbs (Fountains)

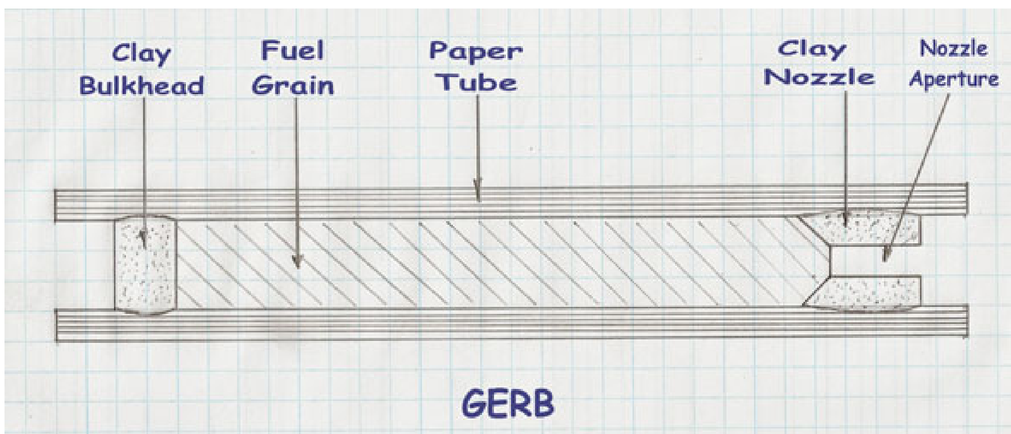
From Wikipedia: A gerb is a type of firework which produces a jet of sparks, usually from 15 to 60 seconds. It is a thick-walled tube filled with pyrotechnic composition and possessing a choke, which is a narrowing in the tube. Gerbs are often referred to as "fountains."

I don't know what the origin of the word "gerb" is, but I learned, while trying to find out, that there is a Star Wars race of the same name. Interesting.

The word is pronounced the same as "germ" but with a "b" instead of the "m." I wouldn't want to saunter up to a group of pyros, trying to appear experienced in the ways of fireworks, and say "gerb" as in "Gerber" baby food, now would I?

Gerbs are one of the most simple of fireworks devices, but they offer the opportunity to learn some basic fireworking skills, and also to get in the habit of practicing basic safety precautions.

Parts of a Gerb



Cross-Section of a Homemade Gerb/Fountain

Paper Fireworks Tube

I'll be using a 1/4-inch wall, 3/4-inch ID, 7-1/2-inch long, paper fireworks tube in this project: Skylighter tube #TU1068, or cut from #TU1065. This size tube, 3/4-inch ID, and the rockets and gerbs that are made with it, are traditionally referred to as "one-pound" tubes and devices. I have treated the tubes with Minwax Wood Hardener, and have allowed them to dry completely.

Clay Nozzle Mix

I have made some clay nozzle mix, and also some bulkhead mix, as described in Fireworks Tips #89.

Fuel

In the Skylighter Project Plans article, How to Make Saxon Fireworks Wheels by John Werner, two fuel formulae are included. I have used these compositions for saxons, stars, and gerbs, and they are among my favorites. I have slightly modified the two formulae so that they use only readily available chemicals.

Gold Glitter Gerb/Fountain Fuel

Component	Ratio	72-ounce Batch
Potassium nitrate	0.49	35.3 ounces
Airfloat charcoal	0.12	8.65 ounces
Sulfur 0.06		4.3 ounces
Sodium oxalate	0.08	5.75 ounces
Antimony trisulfide	0.15	10.8 ounces
200 mesh magnalium	0.10	7.2 ounces

(For the Antimony Trisulfide, either Chinese Needle or Dark Pyro may be used.)

Silver Titanium Gerb/Fountain Fuel

Component	Ratio	72-ounce Batch
Potassium nitrate	0.51	36.7 ounces
Sulfur 0.10		7.2 ounces
Airfloat charcoal	0.09	6.5 ounces
Spherical titanium	0.30	21.6 ounces

(For the titanium, either the fine (CH3010) or the coarse (CH3001) metal may be used. Each one will produce its own unique effect. The fine will produce a short, dense spray of small sparks. The coarse will produce a longer spray of fewer, large sparks. In this project I am using the coarse titanium.)

Each gerb will use about 3 ounces of fuel, and I plan on making about 24 of each type of gerb for use in these projects. So I am going to make 72 ounces of each formula.

To make smaller batches, simply multiply the ratio amount of each component by your final batch size to determine how much of each chemical to use. For example, if I want to make a 12-ounce batch of the gold glitter comp, I determine how much potassium nitrate to use by multiplying 0.49 x 12 and get 5.88 ounces (which I'll round off to 5.9 ounces).

Starting Fuel

The two fuels above will be all I need if I am using tooling which forms the nozzle aperture as I ram the gerb. But, if I am using tooling which forms a solid nozzle in which I then make a hole with a twist-drill for the aperture, I want to ram a first increment of fuel which has no metal included in it. This eliminates the possibility of creating sparks with the drill.

I only need a small batch of this starting fuel because I'll only be using one increment of it in each gerb.

Starting Gerb/Fountain Fuel

Component	Ratio	8-ounce Batch
Potassium nitrate	0.73	5.85 ounces
Sulfur 0.14		1.10 ounces
Airfloat charcoal	0.13	1.05 ounces

Mixing the Fuels

After weighing out the individual chemicals for one of the fuels, I screen the potassium nitrate, sulfur, and charcoal together through a 40-mesh screen, four times. I never put any chemicals like the antimony sulfide, magnalium, or titanium through my good screens because the metals will clog the holes in my screens, and future compositions that get screened could end up with some of the metals in them.

Then I put the screened composition into a bucket for which I have a lid. I screen the remaining chemicals through a fine-mesh-screen kitchen colander, allowing them to fall into the bucket, too. Then I put the lid on the bucket and shake it for awhile to thoroughly mix the ingredients.

I add enough denatured alcohol (available in the paint department of stores like Home Depot) to form a workable putty with the consistency of bread dough. The glitter batch required 20 ounces of the alcohol by weight. The titanium batch required 16 ounces, and the starting fuel batch took 2.4 ounces. No water is used when making these dampened compositions.

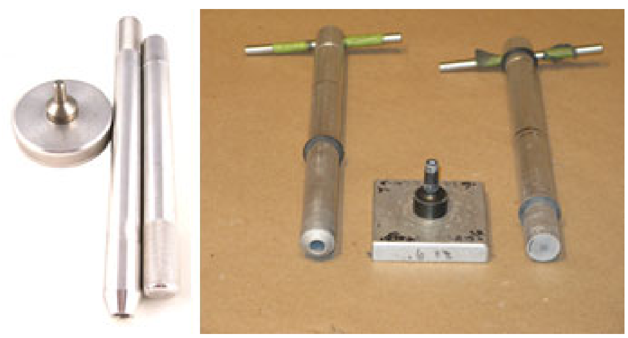
The putty is then screened through a 1/4-inch mesh screen onto a kraft paper lined tray. I've made a framed screen which fits nicely into some kraft-paper-lined metal cookie sheets. After granulating the putty through the screen, I spread the granules out evenly with a coarse-toothed comb and allow them to dry thoroughly.

Granulating Fuel through a 4-Mesh Screen onto Kraft Paper

Note: This alcohol-granulation step greatly reduces the dust that gets produced during the following ramming operation. It produces soft, relatively dust-free granules which will crush easily during the ramming to form a densely consolidated fuel grain.

Tooling

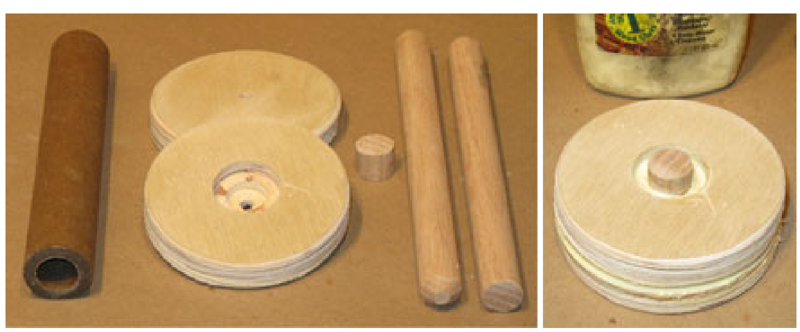
Skylighter sells one-pound gerb tooling, #TL1110. I have a set of gerb tools that is very similar to that one.



Two Gerb Tooling Sets

Note: You can see the rubber o-rings that I keep on my rammers. These keep dust from easily fluffing out of the tube as the rammer is inserted.

It is possible to make your own gerb tooling. I start out with two, 4-inch diameter discs cut out of 3/4-inch plywood (or these can be square). I also cut some lengths out of a piece of 3/4-inch diameter oak wooden dowel.



Paper Fireworks Tube and Homemade Gerb Tooling

I started by drilling a 3/4-inch hole, 1/2-inch deep into one of the plywood discs. Then, using the same centering hole, I drilled a 1-1/4-inch wide, 1/4-inch deep, recess in the disc.

The two plywood discs are glued together, and a 3/4-inch piece of the dowel is glued into the hole of that same size. This assembly is allowed to thoroughly dry.

I've cut two 9-inch lengths of the dowel to make the rammers. I leave the one rammer flat-ended, with the ends sanded smooth. I bevel the end of the other rammer at a 45-degree angle except for the center 1/4 inch, using my belt sander.

The convergent angle that is formed on the top of the nozzle by this beveled former helps direct the hot gasses out of the aperture and reduces burn-through of the tube side-wall.

I use aluminum foil duct-tape to cover the flat top of the base nipple and the end of the flat bottomed rammer so that they don't stick to the clay or fuel as they are being rammed.

It is also possible to make longer-lasting rammers out of aluminum rod.

Finished Homemade Gerb Tooling, With Aluminum and Wood Rammers

The only additional tools I'll need for this project are a solid post on which to pound the gerbs, a rawhide mallet, a funnel, and some measuring spoons. I'll also use a drill bit to hand-twist-drill the nozzle aperture.

I ram devices on a 6x6x36-inch piece of treated pine, which absorbs the shock nicely without bouncing. A rawhide mallet transfers all of its force to the rammers, whereas a rubber hammer would bounce off and would not be nearly as effective.

Tools for Ramming Gerbs

Let's Make Some Gerbs

The first step in the actual process of making gerbs is to place the paper tube onto the tooling base, and ram the nozzle clay. I place a mark on the nozzle end of the tube because once the completed gerb is rammed it will be difficult to tell the nozzle end from the bulkhead end.

As you can see in the sketch of the gerb, I want the actual throat of the nozzle to be about as high as the tube ID, or 3/4 inch in this case. I mark my nozzle-forming rammer with a Sharpie at the point where the top of the tube will be when the rammer is inserted far enough to be sitting at the top of such a nozzle.

Marking the Nozzle Rammer, and Ramming Clay to Form Nozzle

Then I experiment with introducing and pounding enough clay to form that 3/4-inch tall nozzle. In this case, 0.5 ounce (a flat tablespoonful) of the bulkhead clay created just the right nozzle thickness once it was rammed.

I used 16 moderate blows with the mallet to ram/consolidate the clay. A very slight bulge in the tube where the nozzle is pressed is good; you can see in the sketch that perfection is when you ram the nozzle and bulkhead so that they slightly bulge the tube wall. This locks them into place and helps them withstand the extreme gas pressures of the burning gerb. But obviously I don't want to apply so much force that the tube is damaged or splits.

I've been pounding nails with a hammer just about all my life, so it comes naturally to me. It pays to take some time to practice swinging the mallet smoothly and with consistent blows, and it is an acquired skill which will pay off handsomely once it is mastered.

If I am forming a solid nozzle that I'll have to drill into to form an aperture, I use the bulkhead clay mix which has no grog in it. Any grog in the mix would prevent me from being able to do such drilling.

If I am using tooling which forms the aperture (no drilling required), then I use nozzle mix which has the grog in it. This mix is less susceptible to erosion during the burning of the gerb.

Now I want to press my fuel grain in the paper tube on top of the formed nozzle. I place a mark on my flat-ended rammer where the top of the tube is when that rammer is inserted all the way to the top of the nozzle's beveled edge. Then I put more marks on the rammer every 1/2 inch below that first mark.

The last mark is 1 inch from the lower end of the rammer. That marks the top of the last fuel increment.

Marking the Flat-Ended Rammer for Increments of Fuel

I want to ram the fuel in half-inch increments so that they are very solidly consolidated. Very slightly rounded half-tablespoons-full of the fuel produces increments of that size in these tubes.

If this is a gerb in which I'm going to have to drill the nozzle aperture, then the first increment of rammed fuel is made with the starter mix which has no metal in it.

Note: I measure out about 3 ounces of the fuel into a paper cup, and this is the only exposed composition in my work area as I work. I keep the rest of my compositions in tightly capped containers. Minimizing this kind of exposure can save my life in case of an accident. I wear safety glasses while I work. I consider it to be safe to hand-ram the fuel with the spherical titanium in it, but I would not do so with rougher, sponge-type titanium.

After that starter increment, I ram increments of the standard fuel until I reach the last mark, which leaves a 1-inch empty void in the tube. I use 8 moderate blows of the mallet to consolidate each increment of the fuel. Again, I try and repeat these blows with the same force each time in order to produce consistently burning gerbs. If I don't, my gerbs will burn with differing degrees of power-sometimes producing a high spray, then dropping down lower. I want all my gerbs to burn the same.

I now ram one increment of the bulkhead clay, which fills 1/2 inch of that void, and leaves the last 1/2 inch of the tube empty.

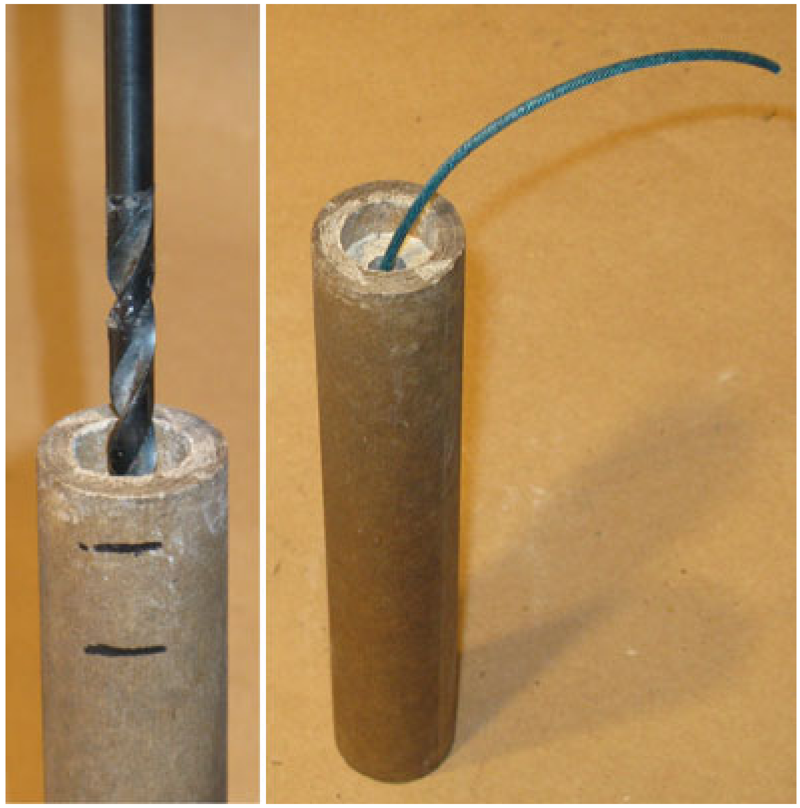
Note: One secret to really effective gerbs is to ram about 1/8 inch of black powder, similar to FFg sporting grade powder, in between the final fuel increment and the clay bulkhead. When the gerb burns to that point, the black powder burns almost instantaneously, producing a "bounce" which finishes the gerb off dramatically, leaving no doubt that it's done.

The commercially made gerb tooling that I have automatically forms a 5/16-inch nozzle aperture. If I have pressed a solid nozzle with homemade tooling, I use a 5/16-inch drill bit, gently twisted into the nozzle by hand, to form the hole in the rammed nozzle clay. I let the drilled-out clay fall back into my tub of clay mix because it's just fine to re-use it. I drill until the bit is just through the clay and into the starter fuel.

As you'll see a bit later in this essay, it is also possible to use different size drill bits to vary the size of the nozzle hole. This also changes the thrust of the gerb, the height of the spray of sparks, and other aspects of the effect.

I then take some Chinese visco fuse, double over about 1/2 inch of it, making a little "V" on one end of it, and insert that doubled end into the nozzle hole. I like the Chinese visco, as opposed to the American, for lighting rockets and devices like these gerbs because it throws out a tremendous amount of sparks as it burns. As a result, it lights things very reliably.

The gerb is now ready to be stuck in the ground, taped to a stake, or inserted into a wood base with a drilled recess, ready for ignition.



Drilling the Nozzle Aperture and Fusing

Final Results

These gerbs, made with either fuel, burn for 20-25 seconds. The glitter fuel produces a graceful, soft, golden spray of popping glitter globules. The titanium fuel produces a forceful, bright spray of silver sparks.

I have to say that even after almost 20 years making fireworks I still get excited when I make one of these devices, take it out into the field, and light the visco, waiting to see how it performs. I suppose it's the one activity I've never lost interest in.

I won a PGI gerb competition a few years back with a pair of 1-1/2-inch ID gerbs. I carefully weighed out alternating increments of the glitter and titanium fuels, so that the pair burned with simultaneous pulses of the bright titanium sprays alternating with periods of the soft glitter plumes. Then I ended both gerbs with dramatic "bounces." I was very pleased with the fountains and apparently so were the judges.

Experiments

The final pressure at which a gerb burns is determined by the power of the fuel and the size of the nozzle aperture. With a given fuel, the pressure and height of the spray can be adjusted by changing the size of the hole in the nozzle.

A large hole, or no nozzle at all, results in a low pressure, short spray. The fuel will burn relatively slowly. When these fountains are hung in a line, upside-down, to create a waterfall, this sort of slow, graceful, low pressure burning is desirable.

A smaller aperture will result in high pressure, tall spray, and faster burning fuel. Too small a hole will result in the strength of the nozzle or tube being exceeded, and the tube will violently rupture or the nozzle will be blown out of the tube.

So within certain limits the size of the drill used to make the nozzle aperture can be adjusted and the burn of the resulting gerb can be observed and noted.

This is all just part of the fun of fireworking. In my playing around, I found that the glitter gerbs work very well with 1/4-inch to 5/16-inch nozzle apertures, burning for 25 seconds. With a 3/16-inch hole, the gerb burned 3-5 seconds faster with more thrust, and the glitter effect was almost completely lost.

The titanium gerb results were: 5/16-inch aperture - 20 second burn with about an 8-foot tall spray; 1/4-inch aperture - 20 second burn with a 10-12-foot tall spray; 3/16-inch aperture - 16 second burn with an impressive 16-foot tall spray.

1 Gold Glitter and 2 Silver Titanium Gerbs

(Click Image to Play Video)

A 1/4-teaspoon "bounce" increment of FFg sporting black powder produced a very impressive final "thwump" at the end of the gerb's burn.

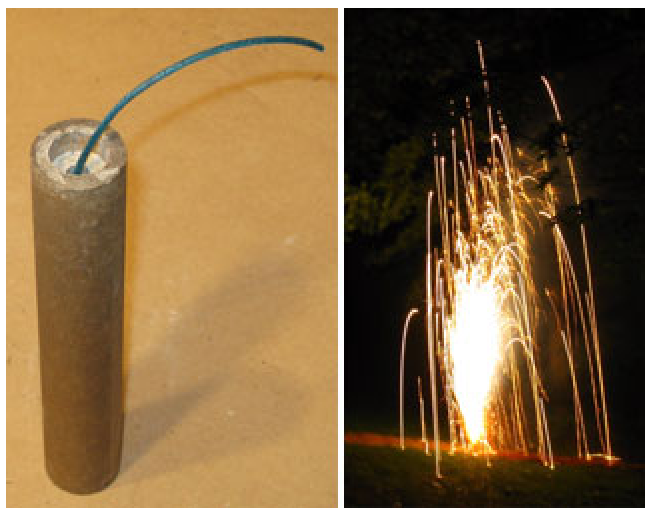
Next time I'll use these gerbs to drive wheels and line rockets. They can also be used, hanging upside-down, to create a waterfall/rain-shower effect.

Using Homemade Gerbs Creatively, as: Waterfalls, Wheel Drivers, Set Pieces, and Line Rockets

By Ned Gorski

Introduction

Last week, in Fireworks Tips #108, I made some homemade gerbs, also called fountains, using either a gold glitter composition or a silver titanium one. These fountains create nice effects, either fired one at a time, or in a "front" with the gerbs in a line, spaced 8-10 feet apart.



Homemade Silver Titanium Gerb

One of the things I really love about handmade gerbs is their versatility. In this article I will show you how to incorporate these fountains in some other devices:

- I'll mount some gerbs on a frame to create a waterfall.
- I'm going to show how to make a very simple, beautiful, color-changing wheel.
- I'll recreate the Chromatrope wheel that was described in Fireworks Tips #105, using homemade fountains to drive it.
- I'll show how to make a simple set-piece in the shape of a star, using two different types of titanium in the silver formula.
- And a simple line rocket will be assembled.

Making the Gerbs

I totaled up the number of the glitter gerbs and the titanium fountains I need for all the projects I have planned, and I rammed them as described in Fireworks Tips #108, Making Fountains Quick and Easy.

I drilled 1/4-inch nozzle holes in all of them except the four titanium gerbs that I have planned for the sample waterfall. I made 3/8-inch apertures in those nozzles so that they spray the silver sparks out more gently.

Also, the glitter gerbs are going to be used in pairs with the titanium ones. The glitter gerbs will burn, and then they will passfire from their bulkhead ends to the nozzle end of the Ti ones. So, I've drilled 1/4-inch passfire holes through the bulkheads of the glitter fountains.

When they are going to be used individually, I fuse the gerbs with Visco as shown in the photo above. But when they will be used in devices such as the ones I have planned for this project, I fuse them differently.

I cut some 4-inch lengths of thin blackmatch from Quick Match or Super-Fast Paper Fuse. This match is doubled and inserted into the nozzle holes of the gerbs.

Lengths of Thin Black Match, Cut, Doubled, and Inserted into Gerb Nozzles

I screen together, through a 40 mesh screen, a black powder prime composition, consisting of:

Component	Ounces
Potassium nitrate	1.5
Air float charcoal	0.3
Sulfur 0.2	
Dextrin 0.1	

In a paper cup, I add enough water to the prime powder to create a slurry with the consistency of jam. This slurry is put in a plastic baggie, the top of the baggie is twist-tied closed, and the excess plastic is cut off. I clip a very small corner off of the baggie, and pump the prime into the nozzle holes until they are full.

I finish this priming/fusing off with a dusting of fine black powder granules, and the prime is allowed to dry for a couple of days.

Priming the Gerbs with Black Powder Slurry

This combination of blackmatch and black powder prime ensures a very positive ignition when the flame from quickmatch fusing reaches the ends of the gerbs.

Now I install paper buckets on the fused ends of all the gerbs, and on the passfire ends of the glitter gerbs. These buckets consist of 4-inch by 9-inch pieces of 40-pound kraft paper glued and rolled onto the ends of the paper tubes, resulting in a double walled bucket.

Installing Paper Buckets on Gerbs

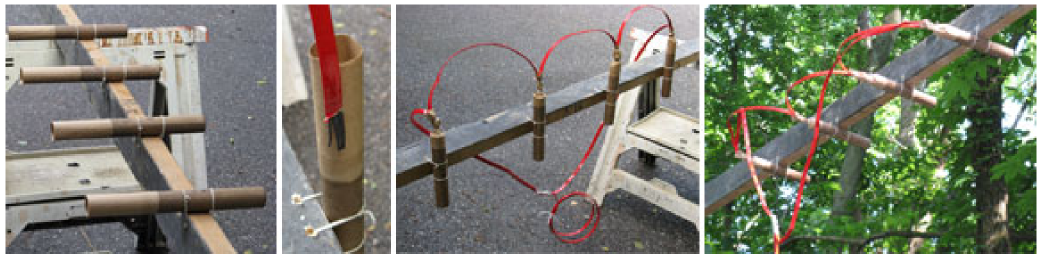
Making a Waterfall

Traditional waterfalls use thin-walled paper tubes filled with a potassium perchlorate and aluminum composition, and hung pointing downward. The waterfall I'll be making with these silver titanium gerbs will be a little different than that.

I was watching a special on Niagara Falls the other day, and I noticed that the water projects horizontally off of the rock river-bed and then gradually arcs over and starts to fall vertically. I started to wonder if something like that could be done with these Ti gerbs.

So, as an experiment, I'm going to mount four Ti gerbs, with the 3/8-inch nozzle apertures, horizontally on a board, 12 inches apart. I'm interested in seeing what sort of effect that produces.

Note: In past articles I've shown how super-fast paper fuse or fast yellow visco can be wrapped with aluminum foil duct tape to produce quick match if one does not have access to that fuse.



Constructing a Waterfall with Homemade Silver-Ti Gerbs

Four-Tube Waterfall

(Click Image to Play Video)

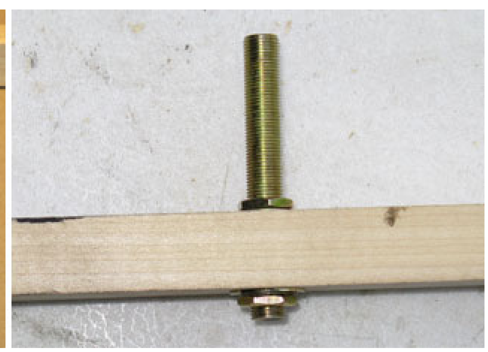
I was not completely thrilled with the effect this falls produced. Many of the silver sparks burned out flying horizontally before they started to fall vertically. Even with the 3/8-inch nozzle aperture the gerbs still had too much thrust.

The next day I decided to make one gerb without any nozzle at all. I just pressed silver-titanium comp into the tube, and burned it. I was happier with the un-choked tube and would use gerbs in that configuration in the future. The waterfall effect would have been better with 16-foot vertical supports instead of the 12-footers that I used this time.

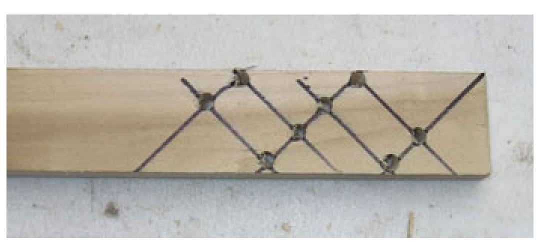
Single-Tube Waterfall (No Nozzle)
(Click Image to Play Video)

Making a Simple Color-Changing Wheel

For the wheel frame, I took a 4-foot piece of 1x2, and mounted a threaded tube through a hole in the center of it. I will later use a 1/4-inch lag bolt to mount the wheel to a vertical support post.



Then I drilled a pattern of holes in the ends of the 1x2, through which I'll tie on the gerb drivers.



Holes Drilled in Wheel Arms

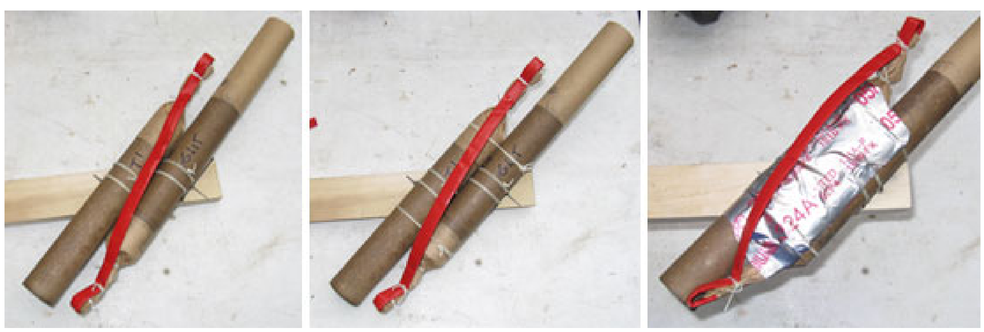
I use waxed string to tie the glitter gerbs to the outer end of the 1x2, nozzle end pointing out. Then the Ti gerb is tied on next to it facing in the same direction. These drivers end up staggered so that the glitter gerb's sparks do not ignite the fusing of the Ti gerb.

Drivers Tied onto Wheel Arms

A quick match passfire is tied into the passfire end of the glitter driver and over into the thrust end of the Ti one.

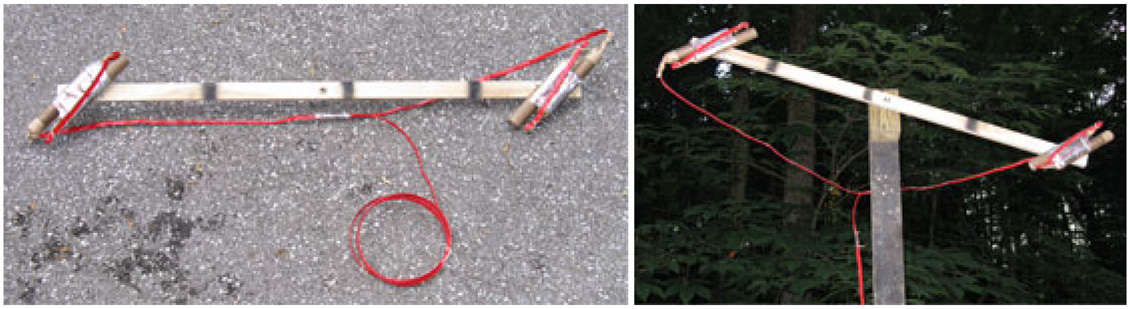
I tie the pair of gerbs together to further improve their stability. Additionally, I covered the string ties with aluminum foil duct-tape so that there would be no chance of the ties burning through when the passfire ignites.

Note: In the past, to attach drivers, I've used plastic zip-ties or iron wire which are both less susceptible to flame damage, but this time I wanted to use the string, which is simpler, less expensive, and lighter.



Drivers Nosed and Fused

The completed wheel is now ready to mount to a support post. There is a wood block at the top of the post to space the wheel out and away from the support to keep the wheel from hitting it.



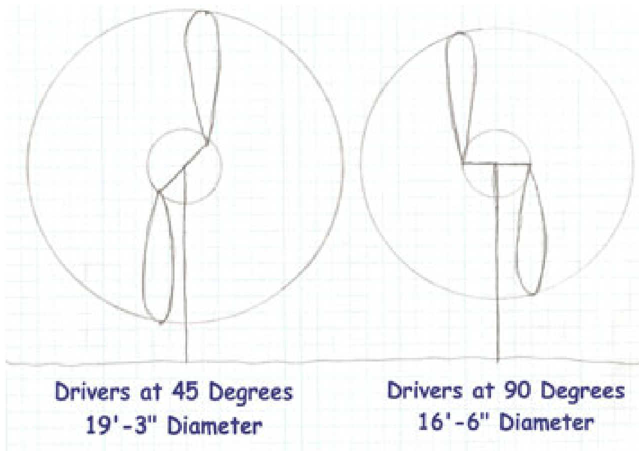
Completed Wheel with 2 Pairs of Glitter and Titanium Gerb Drivers

When I am attaching the quick match drop-leader to a device which is designed to move, such as a rocket, girandola, or wheel, I always install a "positive disconnect" section. A "positive disconnect" is simply a section in the quick match which is designed to burn through and fall away. This is done by exposing, and overlapping bare black match from the ends of two pieces of quick match and wrapping with clear packing tape. I then tie the packing tape bucket to secure it in place.

This disconnect ensures that the plastic-and-paper match pipe and the black match string actually detach from the device. I have had moving devices fail to move due to the incomplete detachment of the quick match leader. This is a bad thing.

Positive Disconnect Section Constructed in Quickmatch Leader

Note: Mounting the drivers at a 45-degree angle to the 1x2, instead of at a 90-degree angle increases the final wheel display's diameter. It also decreases the thrust that the drivers impart to the wheel, thereby slowing its rotation and making it appear more graceful.



Drawing of Drivers Mounted at 45-Degree and 90-Degree Angles

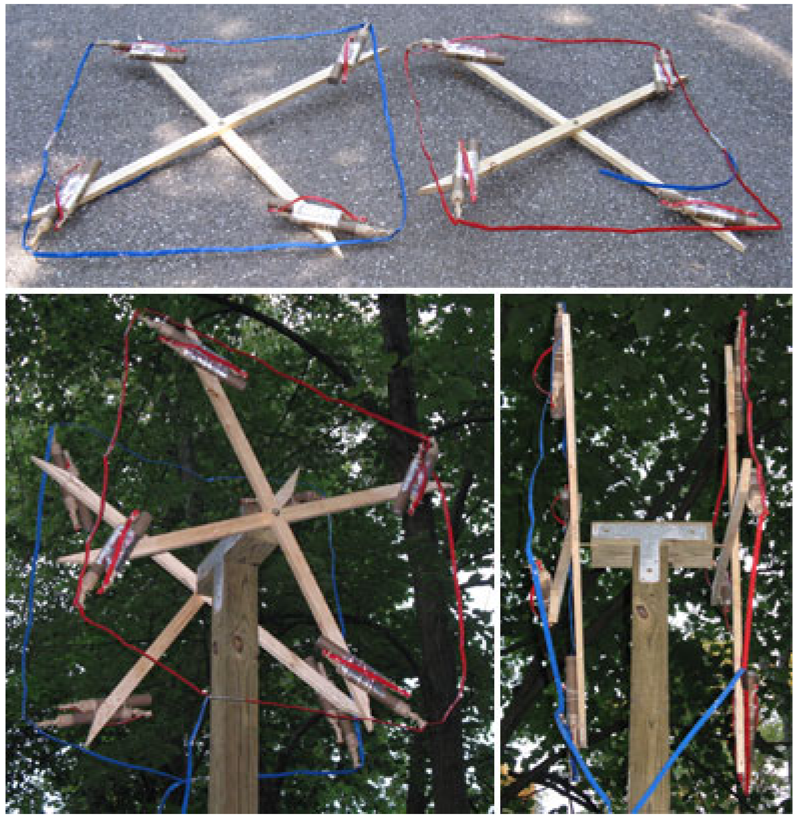
Note: As I was constructing the wheel, I was constantly thinking through the ignition and burn sequences, and imagining all the possible things that could go wrong and could be avoided. The aluminum foil over the string ties was such a counter-measure. In even this small wheel there is a lot of time and effort and I'd really like it to work well. There's a huge difference in the feeling I have when something works as designed, as opposed to disappointment I feel when it crashes and burns.

Simple, One-Armed Color-Changing Wheel

(Click Image to Play Video)

Making a Homemade Chromatrope

I also remade the chromatrope wheel, this time with homemade gerb-drivers. The ends of the arms on the two wheels will have pairs of gerbs mounted on them in exactly the same manner as the simple wheel above. One wheel will rotate clockwise, and the other will move counterclockwise.



Assembly of Chromatrope Wheel

Chromatrope Wheel with Homemade Drivers

(Click Image to Play Video)

Making a Star Set-Piece

Homemade fountains can be arranged in a multitude of ways to create a set-piece, forming letters, a word, or any other design. I decided to create a simple, 5-fountain, star set-piece to illustrate what can be done with these gerbs.


Star Set-Piece and Driver Shim

I used 12-foot 1x4's to make the framework, and mounted the gerbs with zip-ties and a shim under the nozzle end to slightly point the exhaust out away from the frame. The shim is simply a section of a 1.25-inch ID paper tube.

For this little project I made 5 gerbs with the coarse spherical titanium (CH3001) and 5 with the fine spherical Ti (CH3010). The two effects were dramatically different.


Star Set-Pieces Using Coarse and Fine Spherical Titanium

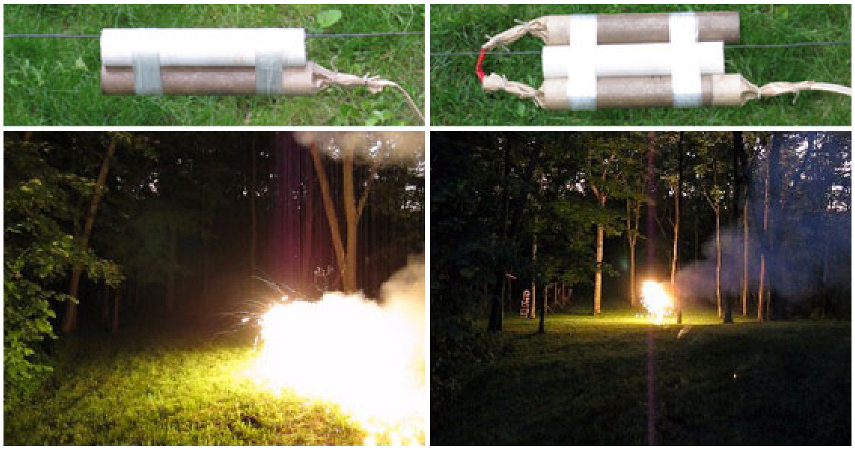
(Click Image to Play Video)

The star on the left, using the coarse Ti, could have easily been made twice as large, and the one on the right with the fine Ti could have been made slightly smaller.

Line Rocket

With one last little bit of creativity, I assembled a couple of line rockets. The first one had one driver (this type of rocket makes a nice effect flying into a bonfire as the fire is lit). The second one had two drivers in opposite directions, one burned then passed fire to the other, produced a back-and-forth flight.

In both cases, the gerbs were taped to a piece of PVC plumbing pipe which has the same OD as the fountain tubes. The pipe is installed on a length of iron wire as the wire is strung tightly between two solid supports, like trees. In this case, in order to develop enough thrust with the Ti gerbs, I drilled the nozzles with a 3/16-inch drill.



Line Rockets

(Click Image to Play Video )

In his book, Introductory Practical Pyrotechnics, Tom Perigrin has some fun ideas for other creative variations on the line-rocket theme. Rat Packs, Jeweled Rats, Pigeons: So many experiments, so little time.

Conclusion

So there you have it. Plenty of ideas on ways to put simple homemade gerbs to use. They don't make much noise, they are relatively safe, their effects last a long time, they make for instant gratification, and they offer endless opportunities for creativity.

Colored Gerbs

By Ned Gorski

Introduction

In Fireworks Tips #108 I described a method for making homemade fountains, called gerbs, including how to make the tools for ramming them. In Fireworks Tips #109 I explored a few creative devices using fountains.

Homemade Silver-Titanium Fountain

I was ready to move on from gerbs, but then I received a note from Paul N, a loyal Skylighter customer. In his letter, he began by referring to his homemade waterfall, in which he used consumer fountains, a trick I described in Fireworks Tips #106.

In part, Paul said:

"I used a tube fountain from a local C shop and using rebar tie wire to hang them between two trees in my front yard, and the superfast paper firecracker fuse I got [from] Skylighter… the thing TOOK OFF and was brilliant. 20 feet of BRILLIANT! As they burned out, a secondary fuse lit some suspended large "colored flowers" firecrackers which just ROARED. It was a serious crowd pleaser. Even now I am still jazzed, and you can tell Mr. Gilliam I said so. Now that I have that concept down, I want to make a curtain of color, and I need to get or make RED and BLUE fountains (er, gerbs.) I have, as they say, an idea. Can you tell me of formulae for making red and blue gerb comp?"

I of course did not relay this message to Harry, lest he get an even bigger head about the service he provides to us pyro fanatics. I could sure relate to Paul's enthusiasm and inspiration. How often I have felt that same way.

I have never seen colored consumer fountains at local shops that might be used in the way that Paul envisions.

I like to use colored fountains as one of the stages in devices like wheels and girandolas (horizontal flying wheels). Just recently I was giving some more thought to homemade colored gerbs, and had dug out a past PGI Bulletin article by John Glasswick, entitled Gerb Colours.

John is a friend of mine and a master pyro craftsman, his gerbs and wheels are something to see. We see one another just once a year at the PGI convention and we have often competed against each other with our wheels or ground displays. It has been no disgrace to have him beat me in a competition, and it's been a real honor the few times I've edged him out in points.

Ned and John Glasswick (on right) Prepare to Fly a 24-Inch Girandola at the 2007 PGI Convention in Fargo, North Dakota

John hails from Canada, and spells words funny, like colour and splendour, but we won't hold that against him. He graciously allowed me to use the information in his article as the foundation for this one. In that essay, John relates that he got many favourable comments about the colors of his gerbs one year at the convention, along with quite a few requests for his formulae.

John started with a favorite red formula that had been shared by Tom DeWille on the Pyrotechnic Mailing List several years back. This red formula was slightly modified to create the other colors, with one exception; blue.

The blue composition came from Joel Baechle's Pyrocolor Harmony, to which John added 15 parts titanium for sparks. About that book, John states, "I found Joel's book well worth purchasing, and the book has also been invaluable for me for star colour formulas."

Note: There is another nifty blue gerb formula and method described by Mr. Gilliam in the Fireworks Tips #52 article, Blue Steel Gerbs.

So, rather than quickly moving on from the subject of gerbs, why don't we spend one more week on them, and explore color gerbs.

Colored Gerb Composition Formulae

The following are the formulae from John's article, as well as Joel Baechle's blue composition, to these formulae John added 13% titanium. I use either fine spherical titanium such as CH3010, which produces a short, dense spray of fine sparks, or the coarse spherical Ti such as CH3001, which produces a long spray of larger silver sparks.

If you want a simple colored flame with no silver sparks, the titanium may be omitted completely. It could also be replaced with ferro-titanium if less brilliant, yellow-silver sparks are desired or even coarse charcoal for a softer, orange spark spray.

Blue Gerb Composition

Component	Ratio	16-ounce Batch
Ammonium perchlorate, 200 micron	0.38	6.10 ounces
Black copper oxide, or red	0.16	2.50 ounces
Titanium 0.13		2.10 ounces
Parlon 0.12		1.90 ounces
Aluminum, 325 mesh fine flake	0.10	1.60 ounces
Hexamine 0.08		1.30 ounces
Airfloat charcoal	0.03	0.50 ounces
Total 1.00		16 ounces

Red Gerb Composition

Component	Ratio	16-ounce Batch
Strontium nitrate	0.44	7.05 ounces
Parlon 0.17		2.70 ounces
Magnalium, 200 mesh	0.17	2.70 ounces
Titanium 0.13		2.10 ounces
Red gum	0.09	1.45 ounces
Total 1.00		16 ounces

Green Gerb Composition

Same as above except substitute barium nitrate for the strontium nitrate.

I ended up making only red, blue, and green color compositions. Other colors were made by combining these comps in various ratios as described later on.

I will include John's other formulae, though, as listed below:

Lime Gerb Composition

Same as green except use 0.43 barium nitrate, and 0.01 sodium nitrate.

Yellow Gerb Composition

Component	Ratio
Barium nitrate	0.26
Sodium nitrate	0.18
Parlon 0.17	
Magnalium, 200 mesh	0.17
Titanium 0.13	
Red gum	0.09

Orange Gerb Composition

Component	Ratio
Strontium nitrate	0.29
Parlon 0.17	
Magnalium, 200 mesh	0.17
Sodium nitrate	0.15
Titanium 0.13	
Red gum	0.09

Purple Gerb Composition

Component	Ratio
Potassium perchlorate	0.20
Strontium nitrate	0.20
Parlon 0.16	
Magnalium, 200 mesh	0.16
Titanium 0.12	
Black copper oxide, or red	0.08
Red gum	0.08

Turquoise Gerb Composition

Component	Ratio
Barium nitrate	0.36
Black copper oxide, or red	0.18
Parlon 0.14	
Magnalium, 200 mesh	0.14
Titanium 0.11	
Red gum	0.07

Some Notes Concerning These Formulae

Strontium nitrate and sodium nitrate are hygroscopic, which means they will readily absorb moisture from the air. They should be stored in tightly sealed containers, and desiccant packs stored with them will help keep the chemicals dry. It can be helpful to dry the chemicals prior to using them, by spreading some of the chemical out on a kraft-paper-lined cooking sheet and heating it in a 200-degree oven for 2 hours.

Warning: I repeat, this oven-drying is only done with these individual chemicals, never mixtures.

Once gerbs are made using either of these chemicals, they should be burned in short order or they should be stored in tightly sealed containers (Ziploc baggies work well) with some desiccant packs.

Barium compounds are toxic, and simple precautions such as wearing gloves and a respirator will prevent them from being absorbed through the skin or lungs. Some folks are very sensitive to barium, and I've heard tales of those who have suffered its poisoning. It does not sound like fun.

Some folks substitute saran for parlon with good results.

There is an article, Lancework - Pictures in Fire, by the Kosankes, in Pyrotechnica XV, which contains formulae for lance. The authors begin with red, green, and blue compositions and then combine those three powders in the following ratios to create other colors:

- Yellow - 0.25 red, 0.75 green
- Orange - 0.60 red, 0.40 green
- Chartreuse - 0.14 red, 0.86 green
- White - 0.14 red, 0.28 blue, 0.58 green
- Purple - 0.60 red, 0.40 blue
- Aqua - 0.25 blue, 0.75 green

Similarly, the Veline color star formulation system, found in Tom Peregrin's Introductory Practical Pyrotechnics, starts with four basic color compositions, red, green, blue and orange, and mixes them to obtain other colors:

- Yellow - 0.45 orange, 0.55 green
- Chartreuse - 0.20 orange, 0.80 green
- Aqua - 0.20 blue, 0.80 green
- Maroon - 0.85 red, 0.15 blue
- Salmon - 0.25 red, 0.60 orange, 0.15 blue
- Purple - 0.15 red, 0.05 orange, 0.80 blue

I've always found it interesting that these basic color comps are not combined in the same combinations that paints would be. They are rather mixed so that the light they emit combines to give the appearance of a completely different color. I used these color-combining methods to achieve the other various colors of gerbs using the basic color compositions: red, green, and blue.

Priming/Starting Compositions

In his article, John states, "I have found the compositions difficult to ignite, but I have had no problems as long as they are primed with a 50:50 mix of black powder/gerb composition."

In the Making Gerbs article in Fireworks Tips #108, I described a starting fuel composition. I rammed one increment of this fuel before introducing any standard fuel, especially in gerbs where I was going to be drilling the nozzle aperture with a twist-drill. This prevents sparks during that drilling.

This starting fuel is perfect for priming the gerbs as John describes. The first rammed increment above the nozzle will be starting fuel. The second increment will be 50:50 starting-fuel/gerb-composition. Then increments of the colored gerb composition will be rammed.

This is called "step priming", and is a common practice, especially when rolling round stars, when a low-temperature composition is going to ignite a high-temperature one.

This will work well to ignite our color gerbs, with one big exception. No composition containing ammonium perchlorate may be in contact for any length of time with a composition containing potassium nitrate, such as the starting fuel or any other standard black powder composition.

This is because the combination of potassium nitrate and ammonium perchlorate forms extremely hygroscopic ammonium nitrate within a short amount of time. If you try that combination, you'll soon end up with a soggy mess which will not burn.

You might try standard priming if you're going to ram your blue fountain and take it right out and burn it.

But, with the blue gerb comp which contains ammonium perchlorate, or any color mixture which contains that composition, we have to have a different first-fire/priming mixture if the gerbs will be stored for any length of time.

Potassium Perchlorate First Fire Composition

Component	Ratio	8-ounce Batch
Potassium perchlorate	0.60	4.8 ounces
Airfloat charcoal	0.25	2.0 ounces
Sulfur 0.15		1.2 ounces

This composition will be used to ignite the ammonium perchlorate containing gerbs in the same step-priming fashion described above. For simplicity, it actually can be used to prime any of these color gerbs.

Mixing Gerb Compositions

For this project, I want to make several of each type of gerb in the basic colors, and I want to try mixing the basic compositions to form the other colors. So, I want to mix up 16 ounces of each of the red, blue, and green formulae for starters.

I think I'll make up those basic mixes without the titanium in them. I can then see what they look like with just the colors, and then I can add the Ti to the mix for individual gerbs to see how they look with that metal in them.

Many of you may know this, but there is a nifty way to remember the basic colors of the rainbow: Roy G. Biv: Famous pioneer in paint coloration. Well, maybe not.

Red, Orange, Yellow, Green, Blue, Indigo, Violet (Indigo is the bluish purple, and Violet is the reddish purple, and I usually just lump them together as purple when I think of the rainbow): ROYGBIV.

So, I want to make a rainbow of colored gerbs. To make a 16 ounce batch of one of the formulae, I take the decimal ratio of each individual chemical, and multiply that decimal by the final batch size to arrive at the amount of that chemical to use. For example:

16 ounces of red gerb composition

- 0.44 x 16 = 7.04 ounces of strontium nitrate
- 0.17 x 16 = 2.72 ounces of Parlon
- 0.17 x 16 = 2.72 ounces of magnalium
- 0.13 x 16 = 2.08 ounces of titanium
- 0.09 x 16 = 1.44 ounces of red gum

Total = 16 ounces

(My little digital scale weighs to the nearest 0.05 ounce, so I round the above amounts to the nearest 0.05 ounce, to get 7.05, 2.7, 2.7, 2.1, and 1.45 ounces, respectively.)

I then add all the individual chemical amounts together to make sure that the total is about 16 ounces (may vary a bit due to number rounding). In this case the total comes to exactly 16 ounces.

After weighing the chemicals out individually, I screen them one at a time through a fine-mesh kitchen colander, into a bucket. I check the weight of the complete composition and make sure it is very close to the original total batch weight I wanted. This ensures that I didn't miss a chemical, and that I weighed each one accurately.

Note: If, during the screening, I discover that any of the individual chemicals won't pass the screen, I mill that single component in a small coffee grinder until it is very fine. I have a mill that is dedicated to fuels, and one that is used only on oxidizers. I never put metals into any of the grinders.

Screen Colander, Bucket, Coffee Grinder for Milling and Mixing Gerb Fuels

I put the lid on the bucket and shake it a bit, to thoroughly mix the contents. Then I gently screen the mix one more time through the colander to break up any remaining clumps of chemical.

I did not granulate these compositions. I did use rubber o-rings on my tooling drifts to keep the loose comp from fluffing out when the tooling was inserted into the tubes.

Ramming Gerbs

A few more tips from John Glasswick's article will come in handy now. He does not press his gerbs, but simply compacts the compositions with his body weight on the tooling. Since the nozzle clay really holds up best when it is solidly compacted, I decided to ram the nozzle as I usually do, with 12-16 rawhide mallet blows. I used bulkhead mix without any grog in it since I plan on hand-drilling the hole in the nozzles.

After the nozzle was rammed, I started with a flat half-tablespoonful of the starting fuel, and consolidated that increment with 8 light hits with the mallet. I followed the starter fuel with an increment that consisted of 1/2-teaspoonful of starter fuel mixed with 1/2-teaspoonful of gerb composition. I simply mixed these fuels in a paper cup with a gentle swirling motion before introducing the mix into the gerb tube.

Note: Since I'm ramming the blue composition which contains ammonium perchlorate, and I'm planning on mixing that comp with other colors to produce color-mixes, I actually just used the potassium perchlorate first-fire composition for the priming of all the gerbs I made for this project.

Then I rammed increments of gerb fuel and finished off with a clay bulkhead, just like any standard gerb. I rammed all of these increments with the same 8 gentle drops of the rawhide mallet.

Note: One of the reasons John does not pound on his compositions is that they contain sponge titanium which he uses. Rough metals like that can cause sparks when they are hand rammed with a mallet. I'm using smooth spherical titanium, and I consider this to be safer to hand ram, although I am using gentle hits when I do this with these formulae. It is best to do this outdoors with no large quantities of exposed compositions just in case any accident occurs.

John notes that he uses thicker walled tubes for these gerbs because they burn hot and can burn through the walls of thinner tubes. I used 1/4-inch wall tubes throughout these gerb projects.

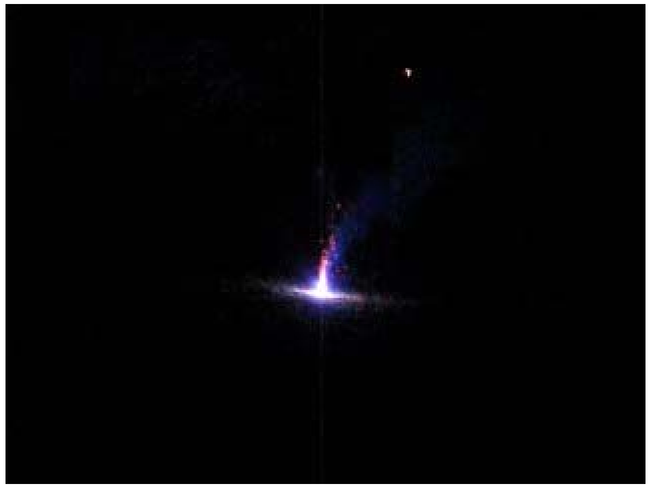
And, finally, because these compositions have magnalium in them, among other ingredients, they produce dross or slag when they burn. This dross can tend to clog a narrow nozzle aperture, so the holes that we'll drill in these nozzles will be on the large side. For these 3/4-inch ID tubes I'm going to drill 3/8-inch nozzle holes. 5/16-inch ones might work, too, and would produce a bit more thrust and a higher spray of sparks.

Results

Blue

I rammed a gerb in a 7.5-inch tube using the blue composition, without any titanium in it. It ate up 1.9 ounces of the blue composition, and once the starting fuel increments burned, it produced a really nice blue flame about 10-inches long. The fountain burned for one minute.

The same gerb, using 1.75 ounces of blue comp and 0.25 ounces of titanium, mixed in a paper cup prior to ramming, burned exactly the same except it also produced a nice 6-foot tall spray of bright silver sparks.



Blue Gerb Without Titanium

Note: I am not cropping these gerb photos so that you can see their relative brilliance by comparing how much of the surroundings light with each one.

Red

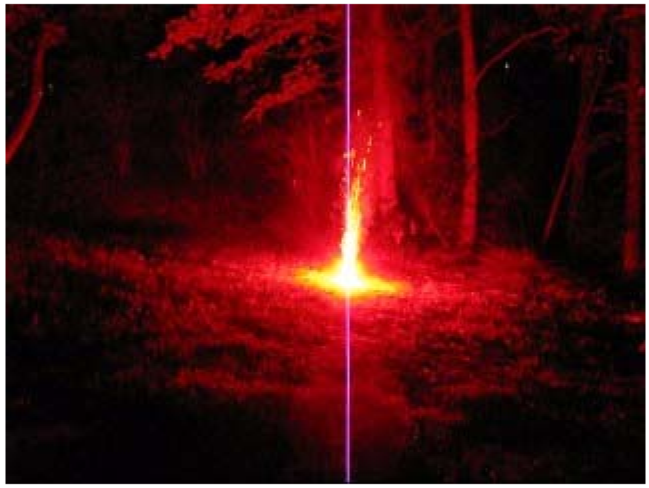
I rammed a red gerb in a 7.5-inch tube, without any titanium in it. It took 2 ounces of the composition to do this. After the first-fire increments burned, a brilliant 8-inch red flame spouted forth for 60 seconds. But, the tube sidewall did burn through for the last 10 seconds and a lot of the flame started spewing sideways out of that enlarging hole.

The gold-glitter and silver-titanium gerbs I made a couple of weeks ago only burned for about 30 seconds, so I could settle for a 30 second burn with these color gerbs as well. To accomplish that, looking at the sketch of a gerb and noting that the actual fuel grain in the 7.5-inch tubes is a little over 5 inches long, I could start with half that fuel grain. This would result from ramming the gerbs the same way, but starting with a 5-inch tube.

A red gerb in a 5-inch long tube, rammed with 1 ounce of composition, burned for exactly 30 seconds, with no tube sidewall burn-through. It's hard to overstate the brilliance of these red gerbs. Man, they are fierce!

My assistant in these comparisons was my granddaughter, Michelle, and the red gerb was her favorite by far.

I added 0.15 ounce of titanium to 1 ounce of the red comp and rammed that in a 5-inch tube. That gerb burned identically to the one above, but with a 6-foot spray of silver sparks. Very nice.



Red Gerb Without Titanium

Green

Since the green gerb composition simply replaces the red's strontium nitrate with barium nitrate, I expect it to perform similarly to the red. (Famous last words.)

So I'm going to try 1 ounce of the green comp in a 5-inch tube. (It actually only took 0.75 ounce of the comp.) This gerb burned with a brilliant green for exactly 30 seconds, with no tube burn-through.

0.10 ounce of titanium added to the 0.75 ounces of green fuel produced the same effect, with the addition of the silver sparks.

Green Gerb without Titanium

Yellow

For starters, I thought I'd try something simple to produce a yellow gerb: a combination of the red and green comps I already had mixed up, in a 0.25/0.75 ratio, as the Kosankes recommend with their lance method.

So I took 0.25 ounce of the red comp and 0.75 ounce of the green and mixed them together. That mixture got rammed into a 5-inch tube, and I had 0.10 ounce of the mixture left afterwards.

That gerb burned with a brilliant yellow flame, similar in brilliance to the red and green gerbs. I did notice a bit of a green tint around the edges of the flame, so I tried one with 0.30 red and 0.70 green to see if I could balance it on the yellow a bit better.

I did like the more pure yellow color of that mixture better.

Yellow Gerb

Orange

Yellow worked, why not try the Kosanke proportion for orange: 0.60 red/0.40 green.

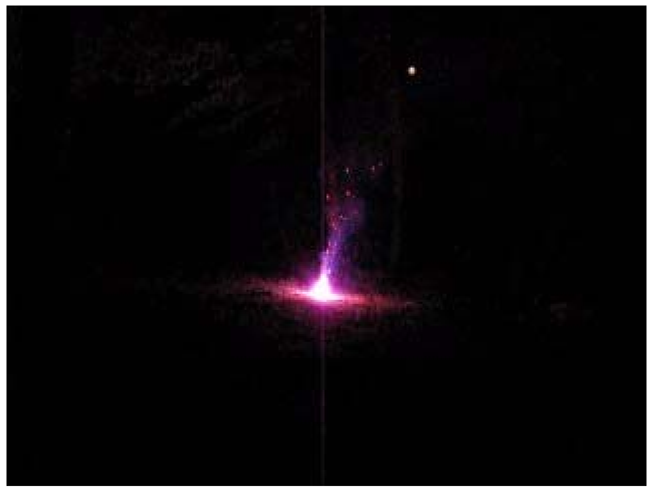
A 5-inch tube, burned with a brilliant orange flame for 30 seconds. The color looks more like red in the photo and video, but the gerb definitely had a brilliant orange color to it.

Orange Gerb

Purple

One more color to try out. I prefer a purple that leans toward the blue end of the spectrum: an indigo. So rather than try the Kosanke 60/40 red/blue, I thought I'd try something more along the Veline proportion: 0.20 red/0.80 blue.

Oh, man, really nice 30 second purple fountain tending toward the blue end of the spectrum, just like I like it.



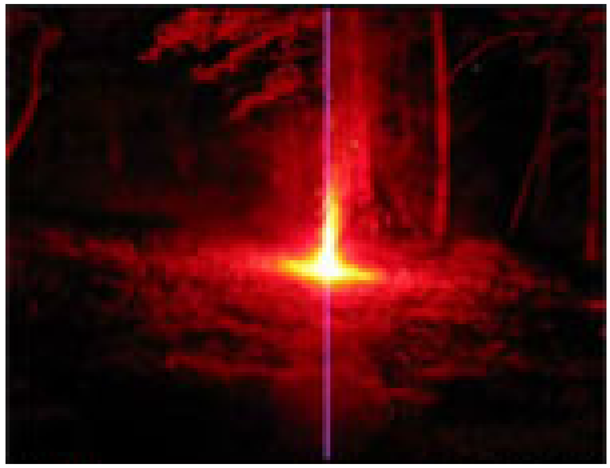
Purple Gerb

5/16-Inch Nozzle Aperture

I decided to try out my standard gerb tooling which automatically forms a 5/16-inch hole in the nozzle, rather than hand-drilling a 3/8-inch hole in a solid nozzle. This should increase the pressure inside the tube during the burn, and also increase the possibility that the dross formed by the burning fuel will clog the nozzle as it burns.

I used a 5-inch tube, 0.75 ounce of the red fuel to which I added 0.10 ounce of 36 mesh charcoal. This gerb burned for 30 seconds with a flame that was similar to the gerbs with 3/8-inch nozzle holes. It did produce a nice, soft, 5-foot tall spray of orange sparks which did not detract from the brilliance of the red flame.

Note: One more time, remember to begin each gerb with an increment of the starter fuel, and then one of 50/50 starter fuel/gerb composition.



A Rainbow of Gerbs

(Click Image to Play Video)

The video shows a complete rainbow of the gerbs with 36-mesh charcoal sparks as they burn consecutively.

Conclusions

Well, I have ways to make each of the 6 colors of the rainbow in brilliantly burning 30-second gerbs: Red, Orange, Yellow, Green, Blue, and Purple.

These colors, and other possible combinations, all start with only 3 basic color compositions: Red, Blue, and Green. I really have to try Aqua, one of my favorite colors, and then there's chartreuse. What color is chartreuse, anyway?

And, if I want to I can make a blue fountain that burns for 60 seconds. (I suspect it is the magnalium in the other mixes which burns so hot that tube burn-through begins at 45-50 seconds with them.)

I can add the titanium to the compositions for a tall spray of silver sparks, or the gerbs can be burned with only the brilliant colors illuminating everything around them.

These fountains will make great additions to wheels and girandolas, and in the back of my mind I can imagine them lined up on a frame, shooting their flames on an angle, and creating designs and letters with them.

How to Make Blue Steel Gerbs

By Harry Gilliam (source: AFN)

Materials Needed

- Ammonium perchlorate (CH5005)
- Bentonite clay (CH8078)
- Copper carbonate (CH8087)
- Fountain tooling
- Hexamine (CH8142)
- Stearic acid (CH8298)
- Steel, fine powder
- Tubes, 1/2" ID, 1/4" thick (TU1065)
- Visco fuse (GN1000, GN1001, GN1004)

This little gerb project is from *The Best of AFN III* (BK0011). It is part of a larger article entitled "Micro star Bursts-Without Micro stars." Thanks to Jack Drewes at AFN for letting us reprint it here.

An anonymous booklet of formulas from E. D. Chemco under "BLUE STEEL FOUNTAIN" refers to a "crackling titanium effect;" "crackling," eh? But the same titanium flakes mixed with Meal-D powder or whistle pyrotechnic compositions gave just "plain" sparks. Nor were micro star bursts seen with steel or aluminum. I don't know what variations in the red flame powder will do to the effect, or what I'd get with a choked case, or with solvent-dampened pyrotechnic composition.

Presumably the incandescent titanium flake, without benefit of a cast micro star around it, rises through the flame and develops a crust derived at least in part from the powders or pyrotechnic composition products. Gas within this crust then explodes through. It's a pretty effect, simply produced. Following is from the booklet, "Formulas" by Ed Moore.

Blue Steel Fountain (Gerb)

Parts/Percent by Weight

Component	Part/Percent by Weight
Ammonium perchlorate	65
Hexamine 10	
Stearic acid	7
Copper carbonate	6
Steel, fine powder	12

The pyrotechnic composition is tamped lightly into a choked case, 1/2" ID with a 1/4" wall. If a small amount of Titanium is added to a portion of the pyrotechnic composition and that pyrotechnic composition is charged into the tube first, then the regular pyrotechnic composition next, the effect is to change from a delicate steel to a crackling Titanium gerb.

Gilliam's comments on this gerb:

When I made these gerbs, I played with substituting all kinds of metals and percentages thereof. I eventually settled on coarse titanium flake as my spark of choice. But I also like the iron-to-titanium effect change, and also experimented with color changes. If you use iron or steel, try our CH8300 sparkler grade steel.

Substituting barium carbonate to make green, or strontium carbonate to make red can change gerb flame color. I first made these gerbs using the same tubes hand cut from TU1065. I didn't have proper fountain tooling so I was using a dowel to ram a 3/4-inch-thick dry bentonite clay (CH8078) plug.

Then I rammed the composition in, topped it off with another clay plug, and then lightly drilled (hand drilling, not electric) a 1/4" wide hole thru the clay into the pyrotechnic composition. I then just stuck a couple of inches of visco fuse into the hole, lit it and got back. Blew up every time.

What eventually worked was using a real, fountain tool. I surmise that the solution lay in the fountain tool's shaping of the venturi-like nozzle on the inside of the gerb. The clay plug is slant-shaped so as to direct the gasses and sparks toward the outlet. This is a pretty violent gerb, as gerbs go.

After I switched to using real fountain tools for this particular gerb, my explosions went away. Well, almost went away. I was also successful at making them explode by increasing the titanium percentage to higher than 15%. So I reduced the titanium percentage back down to 12 and everything was cool again.

I also later re-read the article above, particularly the words "lightly tamped" regarding packing the pyrotechnic composition into the gerb tube. It would be safest if these gerbs were made with a press, using an arbor or hydraulic press. These gerbs are fun and make a spectacular quick and uncomplicated project.

How to Make Saxons

By John Werner

Materials Needed

- (2) 3/4" I.D. x 7-1/2" long convolute tube, 1/4 " wall thickness (Skylighter #TU1068)
- (3) 3/4" diameter x 10" wooden dowels
- Small funnel
- Powder scoops
- 1/4", 3/16", & 1/8" Drill bits and drill motor
- Hot melt glue gun
- Black match
- Quick match (GN3001)
- Visco fuse (GN1000)
- Masking tape
- Ramming mallet
- A short length of cardboard, plastic, or other tube about 1 inch long x 1/4-1/2" diameter
- 1-1/2" x 1-1/2" x 4" wood block
- Antimony sulfide
- Bentonite clay (CH8078)
- Black powder, Meal D
- Charcoal, airfloat (CH8068)
- Magnalium, -200 mesh (CH2072, CH2073)
- Potassium nitrate (CH5300)
- Sodium oxalate (CH8280)
- Sulfur (CH8315)
- Titanium powder

Introduction

Saxons are a very simple ground based revolving device similar in effect to a wheel but much more basic in construction. Imagine a long, tubular propeller shape spinning about a central pivot, being driven by the exhaust from nozzles located on the sides of the item. In ground displays, saxon spark wheels are used as a stand-alone item mounted on a pole like a wheel, either singly or in multiples.

However, they are very often used in combination with lance work, gerbs, fountains, and candles. Saxon spark wheels spin rapidly. Their purpose is to lend animation and movement to set piece work. Depending on the pyrotechnic compositions used, their effect can range from tight, compact circles of delicate, lacey orange sparks to huge, brilliant silver and white displays twenty feet or more in diameter (often complimented in the center with color changing rings).

Due to their very compact design, saxon spark wheels are easy to transport and set up on the display site, requiring nothing more than a few nails and a 2x4 support post.

Smaller saxon spark wheels are made up of a single, heavy wall convolute wound tube, solidly plugged at each end and filled with an appropriate driver composition. Larger saxon spark wheels are more conveniently made using two tubes connected in the middle with a dowel or stick.

Nozzles are merely holes drilled or punched through the wall of the tube close to the plugged ends, at right angles to the tube axis. A pivot point is provided at the midpoint of the device to allow the saxon spark wheel to rotate on a support member.

As such they offer the pyrotechnic craftsman a relatively safe and very easy weekend project that can be developed into many spectacular variations all made with a minimum of experience, tooling and materials. Saxon spark wheels can be made in a wide range of sizes and effects.

For the purpose of this article, a medium size, two-tube, gold glitter to silver transformation saxon spark wheel will be described. Gold glitter is often difficult to make work in a fountain or driver. However in this application the supplied glitter formula works beautifully and makes for a very elegant effect.

Although this is an excellent project for the beginner, it is recommended that they have some previous experience with mixing pyrotechnic formulas and are familiar with standard safety procedures.

Assembly

Label tubes as "A" and "B." Using one of the wood dowels, ram a 3/4" thick clay plug in tube "A" and tube "B." In each tube, drill a 1/4" diameter hole as close to the clay plug as possible; these holes are the spark wheels nozzle orifices. Leave one of the wooden dowels in the tube while drilling to facilitate making a clean hole.

In tube "A," drill a 3/16" relay hole, 5-1/2" up from the plugged end, and on the opposite side from the previously drilled nozzle orifice. Place a small piece of masking tape over the spark wheels relay hole.

In both spark wheel tubes "A" and "B," insert a piece of black match, 1-1/2 long, into the nozzle so that approximately 3/4" of black match remains outside of the hole. If the match is thin, two pieces should be inserted to more completely fill the spark wheel holes. Bend the match down so that it lies parallel with the axis of the spark wheel tube and tape it in place. The tape should cover the hole and the match.

Ram spark wheel tube "A" (the one with two holes) with the gold glitter pyrotechnic formula and the single hole spark wheel tube "B" with the silver titanium pyrotechnic formula, leaving 1-3/4" of each tube empty at the top. On spark wheel tube "A" with the additional 3/16" hole, the powder should be just filled past this hole, and there should be powder in the hole itself (peel back tape to check).

An additional small charge of clay can be rammed in each spark wheel tube if desired to prevent powder from accidentally leaking out until the separating dowel is glued in place. One and a half inches of empty tube should still remain at the top. This extra step is useful when large numbers of spark wheel tubes are being made up, and the spark wheel tubes are being moved around a bit before final assembly.

White glue or hot-melt glue the 10" wood dowel into spark wheel tube "A". Before gluing spark wheel tube "B" on to the opposite end of the dowel, carefully line up the nozzle holes of each spark wheel tube so that they are pointing in opposite directions.

Make a reference mark on the dowel and the unglued spark wheel tube "B" once you are satisfied with the alignment. Remove spark wheel tube "B" from the dowel, apply glue, and slide the spark wheel tube back in place, realigning the reference marks.

Measure to find the midpoint of the spark wheel. Mark this point and drill a 3/16" diameter hole into the dowel at a right angle to the plane of the 1/4" nozzle holes in the spark wheel tubes. This is the pivot point and should accommodate a 16-penny nail.

Cut a length of quick match to go from the relay hole in spark wheel tube "A" to the nozzle hole in the spark wheel tube "B" (both of these holes should be on the same side of the saxon spark wheel, and in a straight line parallel to the axis of the device).

Starting at the nozzle on spark wheel tube "B," remove the bit of tape from the black match. Slip the black match up into the sleeve of the quick match and tape the match down to spark wheel tube "B". Run the match down the length of this tube, down the wooden dowel, and up to the relay hole on spark wheel tube "A."

Tape can be used at intervals to secure the match to the spark wheel tubes and dowel. Finally, remove the tape from the relay hole (make sure you can see powder in the hole) and tape down the end of the match over the hole.

At the nozzle hole on spark wheel tube "A," secure either a longer piece of bare black match or a piece of visco fuse next to the black match protruding from the hole; tape in place. The tape should completely cover all connections at each hole to prevent accidental or early ignition. This is the fuse you will use to light the saxon spark wheel.

A nail is inserted into the pivot hole in the dowel. It should be a loose fit and the dowel should spin freely around it. Nail the saxon spark wheel onto the flat side of the wooden block. A 1-inch length of small diameter tube can be slid on the nail between the saxon spark wheel and the wooden block to act as a spacer.

A 1/8" hole drilled in the block first will facilitate nailing and prevent the block from splitting. Two additional holes should be drilled on either side of the first hole to allow the block to be screwed or nailed to a support post used to display the saxon spark wheel. Use caution when nailing that no loose powder is in the nailing vicinity, due to the possibility of striking a spark.

Arrange the saxon spark wheel at least 6' above the ground; 8' to 10' is much better. Light fuse, stand back and enjoy.

Formulas

Gold Glitter

Component	Parts by Weight
Meal D	65
Sodium oxalate	8
Antimony sulfide	15
Magnalium, -200 mesh	10
Charcoal, airfloat	2

Silver Titanium

Component	Parts by Weight
Meal D	9
Potassium nitrate	44
Sulfur 9	
Charcoal 8	
Titanium 30	

Everything above is parts by weight. If commercial Meal D black powder is not available, home ball milled black powder can be substituted. In lieu of this a simple mix of potassium nitrate 75, charcoal 15 and sulfur 10 can be made up and used in the pyrotechnic formula, however, nozzle hole diameters may need to be reduced.

Additional Notes

Although masking tape for attaching the quick match in step 10 above can be used for quick prototyping, for the most part it does not look neat and professional on the finished product. A better method to hold the match in place as described in this article is to use a strip of 30# Kraft paper, pasted with wheat paste or white glue. When dry, the paper shrinks down tight, for a clean appearance and a tight cover.

Frequently Asked Questions

Q: Why not drill the nozzle holes after the spark wheel tubes are completely rammed?

A: Pre-drilling the holes beforehand is safer and allows you to precisely place the holes near the clay plug. It allows the black match to be held in place by the rammed spark wheel composition. It is also much faster to do when making up large numbers of saxon spark wheels.

Q: What needs to be done to keep the spark wheel nozzle hole from enlarging as burning progresses?

A: Enlargement of the spark wheel hole is normal; usually this will not cause a problem. Saxon spark wheels turn so easily that the hole can get very large and the saxon spark wheel will still function. There are several ways to make a better nozzle orifice, but all involve more work and are generally not necessary for this device.

Q: How big can I make saxons?

A: I have made saxon spark wheels 6' in length with 1" I.D. tubes. As the pole or dowel connecting the tubes increases in length, spin rate is decreased. The limiting factor to size and burn time is how long the spark wheel tube will hold up before burning completely through.

Q: What other pyrotechnic formulas can be used?

A: Try anything and find out. Saxon spark wheels are so quick and easy to make that the only limits are what chemicals you have to play with. Any pyrotechnic formulas for gerbs or fountains will work. Try colored driver mixes.

Q: What is the best way to display saxons?

A: Saxon spark wheels are most effective when fired in multiples. I make 16' support poles, with one saxon spark wheel mounted at the top and a second saxon spark wheel mounted half way down at 8'. I then space 10 poles about 20' apart. When burning, this gives a wall of fire 200' by 30' high. With a slow spin rate, the effect of many saxon spark wheels is almost hypnotic.

Q: What is the best way to ignite multiple saxon poles?

A: With multiple poles, each pole should be electrically fired. Quick match is too slow. However, you must be careful that the wire leads from the electric match do not get wrapped around the saxon spark wheel, preventing it from spinning.

Variations

The saxon described is a two-tube version connected with a wooden dowel. This is the best method for making large saxon spark wheels. Smaller, shorter versions can also be made using a single tube without a dowel.

The ramming sequence would be: clay plug, composition, clay plug separator at the middle of the tube, composition, and clay plug, using the entire length of the tube. The clay plug separator in the middle allows you to drill a hole for the pivot point. The disadvantage of this style is that the holes need to be drilled after the ramming has been completed.

Have both nozzle holes point in the same direction. This causes the saxon spark wheel to revolve first in one direction and then in the reverse direction as it transfers to the other spark wheel tube.

Have both spark wheel tubes light at the same time; nozzle holes must be pointed in opposite direction. The saxon spark wheel will spin much faster, but the burn time is reduced by half.

Use multiple pyrotechnic formulas in each spark wheel tube for more color changes. Attach color pots (like short, stubby lance) to the side of the saxon spark wheel; this produces bright rings of color inside a halo of sparks.

Use longer spark wheel tubes with multiple pyrotechnic formulas in each tube and multiple nozzle holes all matched to burn at the same time. This results in a halo of sparks with several color rings inside. The Chinese make a great version of this.

Use four (or more) spark wheel tubes. Instead of a single wooden dowel, make up a cross-shaped piece that allows four tubes to be mounted for extended effect capability and burn time.

Try combinations of above suggestions.

How to Make Tourbillions (Spinning Fireworks)

By John Werner.

Materials Needed

- Aluminum rammer, 3/4" x 10" (TL1008)
- Bentonite clay (CH8078)
- Black match
- Black powder, Meal D
- Charcoal (CH8062)
- Drill bits, 1/4" and 1/8" and drill motor
- Funnel, small
- Hot melt glue gun and glue
- Kraft or typing paper 7.50" x 3.92"
- Masking tape
- Masonite board, 2' to 3' square sheet
- Potassium nitrate (CH5300)
- Powder scoops, small
- Quick match (GN3001)
- Ramming block
- Ramming mallet
- Sulfur (CH8315)
- Tube, 3/4" I.D., 7-1/2" long, 1/4 wall thickness (TU1068)
- Tube, 3/4" I.D., 2-1/2" long, 1/4" wall thickness (TU1065)
- Visco fuse, green (GN1000)
- Wooden stick, 7-1/2" x ½" x 3/16"

Tourbillions are an old form of spinning fireworks that used to be much more popular in public displays but today are never seen except as very small and simplified consumer fireworks. Also known as whirlwinds, geysers and table rockets, they are a large heavy wall tube arranged to briefly spin horizontally on the ground and then to lift off into the air by means of two side spin holes and two or more lift holes bored into the underside of the tube.

A stick is attached at right angles to the tube to form a cross, the purpose of which is to insure that the tourbillion maintains a flat level spin as it rises into the air. The effect is a huge umbrella shaped display of sparks rising into the sky that terminates in a final burst of sparks which looks almost like a normal aerial shell at the apex of its flight.

This final burst is a unique property of tourbillions and caused by the fact that the two spin nozzle holes and the two lift nozzle holes all share the same tube and use the same body of rammed powder. When the device first starts to burn there are several inches of powder between holes but as burning progresses this powder "wall" gets thinner and thinner. Just before burnout it becomes so thin that it suddenly breaks down and the powder is rapidly ejected out all four holes in a final blast of sparks.

Although this is an excellent project for the beginner, it is recommended that you have some previous experience with mixing pyrotechnic formulations and are familiar with standard safety procedures.

Assembly

Make a tube extender using a 2-1/2 " long section of the exact same tube which will be used for the tourbillion. First, cover the outside of the tube with a single layer of heavy paper (40 to 70#) and glue in place. This makes the outer diameter slightly larger.

Masking tape can be substituted for the paper in a pinch. Next glue or tape a strip of heavy paper 1-1/2" wide x 8" long onto the tube such that roughly 1/2" extends past the end of the tube forming a "skirt" as the strip is rolled on the tube (should go around twice). Set aside to dry.

Using a ramming block with a 3/16" high step or nipple, ram a clay plug 9/16" thick in the 3/4" I.D. x 7 1/2" tourbillion tube. The top level of the clay inside the tourbillion tube should be at least 3/4" from the end of the tube. This plug must be heavily rammed to prevent it from being blown out.

In roughly 8 increments ram the tourbillion formula to a height of 6-3/4" in the tube, leaving 3/4" of empty space at the top of the tourbillion tube.

Use the tube extender made in step one to facilitate ramming the final clay plug. Place it over the end of the tourbillion tube. The paper skirt of the extender should telescope over the tourbillion tube, centering the extender and holding it in place on top of the tourbillion.

Measure into the extender tube the same amount of clay as used in the initial clay plug (from step 2). In the un-rammed state, the clay fills a greater volume of space than is available (3/4") at the end of the tourbillion tube. By using the extender tube the clay is kept from overflowing and, when rammed, should pack down to form a nice neat plug that is recessed 3/16" from the lip of the tourbillion tube.

Take the 7.5" x 3.92" wide strip of paper and fold it in half lengthwise, then fold in half lengthwise a second time; unfold. When open, the paper should have three parallel crease lines running along the length. Please note that the dimensions of the paper should be the same length as the tourbillion tube and the width should allow the paper to make exactly one turn around the tourbillion tube.

Align the paper so that these lines run horizontally as the paper sits in front of you. Starting with the top crease, measure in from the left-hand edge of the paper 7/8" and make a small mark on the crease line; this is point "A".

On the middle crease, measure and mark two points 2-3/4" from the left (point "B") and the right (point "C") edges. A third point "D" is added exactly halfway (3-3/4") from the left and right edges. Finally, on the bottom crease measure in 7/8" from the right (point "E"). Poke a small hole in the paper at each of these 5 points.

Wrap the paper strip around the filled tourbillion tube and secure in place. The hole positions should be transferred to the tube with a pencil or awl. Points A & E are the spin holes, points B & C are the lifter holes, Point D is the "wing" or balance stick attachment location.

At points A, B, C & E (NOT D), carefully drill a 1/4" diameter hole about 1/2" deep. Use a slow drill speed, and always do this in a remote, outdoor location. A full-face shield is recommended when attempting any type of drilling in tubes containing pyrotechnic compositions.

Find the center of the 7-1/2" x 1/2" x 3/16" stick. An excellent source for tourbillion sticks is wooden stir sticks obtained from paint stores. For this project one stir stick will make two balance sticks.

Rest stick on flat surface and apply hot melt at mid point (point D) of tourbillion tube. The tourbillion tube should rest on top of the stick and cross at right angles with the 2 lift holes (B and C) pointing straight down and the 2 spin holes (A & E) alternately aimed left and right. Alignment is critical to proper functioning of the tourbillion.

Hot melt glue is not sufficient to keep the stick secured to the tourbillion tube when the spinning firework is in operation. Drill a 1/8" hole in the stick close to and on either side of the tourbillion tube. Take a 6" piece of soft iron or copper wire, form into an inverted "U" shape, place over top of tube with the legs of the "U" passing down through the holes in the stick.

Twist ends of the wire tightly together on the underside of the stick. Trim back twisted portion to form a knob of wire not more than 3/16" high. This knob will act as a point for the tourbillion to spin on when placed on a smooth piece of Masonite. Try giving the tourbillion a spin to insure that it can do so easily.

Run a piece of quick match from spin hole "A" diagonally over the top of the tourbillion tube body and into spin hole "E" on the opposite side. The paper piping will need to be cut back 1/2" at either end of the quick match to expose a portion of the black match inside. This exposed portion is threaded into the spin holes.

A piece of bare black match is run from inside lift hole "B" up to spin hole "A", cut and taped down next to the match going in hole "A". Repeat on the opposite end with a piece going from lift hole "C" to spin hole "E". Neatly tape everything in place. Tape should cover all bare match completely.

In the section of quick match running over the top of the tourbillion (from A to E), find the exact center and insert a 2-1/2" piece of green visco fuse through the piping of the quick match. Secure in place.

Select a test-firing site. Set down the Masonite sheet on a section of level ground and place tourbillion at the center of the sheet. Give a final hand test spin. The tourbillion should spin freely by itself for 2 or 3 revolutions before stopping. Light fuse, and stand back.

Tourbillion Fuel Formula

Component	Parts by Weight
Meal D	35
Potassium nitrate	45
Charcoal 15	
Sulfur 5	
Total 100	

This tourbillion formula is one recommended by Lancaster ("Fireworks Principles & Practice") from his section on tourbillions. Results will vary depending on the quality of your meal powder. Try using with 80-mesh charcoal, or additional 5-10% titanium to increase the spark trail.

Frequently Asked Questions

Q. I've read several books containing descriptions of tourbillions and they all use a curved hoop for a balance stick or a twisted stick like a propeller. How come you use a straight stick?

A. The only purpose of the curved stick was to allow the tourbillion to more easily spin on the ground without the ends digging into the ground. A straight stick with a center pivot point (like a top) is much easier to make and actually gives a more stable spin. Propeller shaped sticks provide little or no additional lift. Efficient propeller design is no trivial matter, on top of which the spin rate of a tourbillion is way too low to make a propeller effective.

Q. Most descriptions of tourbillions have the spin holes located more in toward the center. How come you place them right near the clay end plugs?

A. With the holes located closer to the center the spin rate will be increased due to the increased burning surface available (there is powder inside the tube, left and right of the spin hole). However, the total burn time is reduced due to closer hole spacing, limiting the height that the tourbillion will attain. Since the device spins in a stable fashion using my hole layout, the added burn time is a desirable feature.

Variations

Increasing tourbillion tube length provides for additional burn time and improves flying height. The balance stick should be lengthened also to maintain stability (normally the stick length is the same the tourbillion tube length). New hole spacing must be used to reflect the increased length of powder in the tourbillion tube. Follow this rule:

Divide the total length of powder in the tourbillion tube into thirds. Locate the lift holes at the 1/3 mark and at the 2/3 mark, with the spin holes located near the clay end plugs as usual.

Use a gold glitter saxon mix or a color driver mix to power the spin holes. If you are using the 6" of rammed powder as in this article, the first 1" would be gold glitter then 4" of tourbillion mix, then 1" of gold glitter mix. If you are using a longer tourbillion tube, each spin hole (for the glitter formula) uses 1/6 of the total powder column.

Increase tourbillion tube I.D. and length for more impressive takeoffs, ascent, and final burst. Preventing the lift holes from enlarging will greatly increase flight altitude.

On large tourbillions a 6-hole arrangement can be utilized to improve launch stability and reliability. Placement of the first 4 holes (A, B, C and E) is identical. Two additional holes (F and G; they can be smaller - 1/8") are added on the underside of the tourbillion tube in line with the lift holes, and are located 1/8" further in from each end of the tourbillion tube than the spin holes.

Matching is slightly different. Instead of running match from the lift holes to the spin holes, the match now goes from the 1/4" lift holes (B and E) to these smaller lift holes and is not connected at all to the spin holes. What this does is allow the tourbillion to build up its stabilizing spin velocity first.

Since the additional 1/8" holes are located very near the spin holes, approximately 1or 2 seconds later flame will issue from these holes, ignite the match which travels over and ignites the main lift holes. Erratic flights are greatly reduced by having a delayed lift hole ignition.

Bright White Strobe Pots

By Gary Berg, Ken Miller, and others (source PML)

Materials Needed

- Ammonium perchlorate (CH5005)
- Barium sulfate (CH8030)
- Magnalium, -60 mesh (CH2063, CH2064)
- Magnesium, atomized, -100 +200 mesh
- Nitrocellulose (CH8198)
- Potassium dichromate (CH5525)
- Potassium sulfate (CH8222)
- Rammer, wood or aluminum
- Strontium sulfate (CH8313)
- Tube, thin walled

These strobe pot formulas were lifted from the Pyrotechnic Mailing List and used with the authors' permissions. Some of the ingredients may not be available to everyone, but it's a worthwhile project anyway.

All parts listed are by weight and do not necessarily add up to 100.

Component	**Part by Weight**
Ammonium perchlorate	60
Magnesium, atomized, -100 + 200 mesh, coated with potassium dichromate	30
Potassium sulfate	10
Potassium dichromate, milled dust	additional 2-3%

OR

Component	Part by Weight
Ammonium perchlorate	60
Magnalium (magnesium-aluminum alloy) -60 mesh, coated with potassium dichromate	25
Barium sulfate	7.5
Strontium sulfate	7.5
Potassium dichromate, milled dust	additional 3-4%

The blend of sulfates gives a nice clean white with no greenish cast. (For a nice star substitute 10% of the 60 mesh Mg/Al with -200 mesh. Adding a tiny bit of medium mesh titanium makes a fun star.)

For strobe pots, dampen lightly with nitrocellulose solution and tap or press into a thin wall tube with a wood or aluminum rod. Prime as is normal for ammonium perchlorate mixes.

How to Make Flashing Strobe Pots

By Ned Gorski

Introduction

Close your eyes and listen to this music. What do you see when you do so?

Click here to listen to *The Who*.

If you don't see a large fireworks mine-shot, followed by a line of 30-second strobe pots, ending with another large mine-shot, then you really need to be subscribed to the Quilting-101 newsletter instead of this one on making homemade fireworks.

Man, that music gets me in the mood for strobes. The first mine-shot would grab the attention of any fireworks-display audience. Then the soft and subtle section of strobes would calm them down and get them ready for their emotions to build during the show.

Strobe pots are among the simplest of fireworks devices and are easy to make. They can really add some of that low-level variety to a pyro-display that so helps to keep an audience's attention.

"Hey, here's something different," they'll say to themselves as they stop, settle in, and start to pay attention.

How Do These Pyrotechnic "Twinklers" Work?

It is not necessary, of course, to have a scientific understanding of strobes in order to make them. Like baking a loaf of bread, chemistry is not necessary. All you need is a recipe, the right ingredients, and a feel for the proper ways to manipulate those ingredients.

But for the scientifically minded, there are a few informative resources, which explore the strobe phenomenon in depth. In the 1979 edition of Pyrotechnica, Number 5, Robert Cardwell, the editor and publisher of the Pyrotechnica series, wrote an article, Strobe Light Pyrotechnic Compositions: A Review of Their Development and Use.

In this essay, Cardwell explores the historical development of strobing compositions and presents quite a few different formulas.

Dr. Takeo Shimizu, in Fireworks, the Art, Science and Technique (FAST), originally published in 1981, writes about "Twinklers," which is how he refers to strobing stars. He presents an outline of the development of these strobing compositions, progressing during the second half of the 1900's.

Specifically Shimizu writes, "In Germany, U. Krone and F. W. Wasmann suggested that a twinkle composition consists of two kinds of compositions mixed with each other, for example, a smolder composition and a flash composition. Ammonium perchlorate smolders when it is mixed with a small quantity of magnesium. This can be used for the smolder composition. A mixture of magnesium and sulfate flashes when it is heated to a high temperature. This can be used as the flash composition."

So, interestingly, a strobe composition is actually a mixture of these two types of comps, a smoldering one and a flashing one. When the mixture is lit, the first one begins to smolder. When the heat rises high enough, the flash comp ignites and emits a flash of light and heat. Then the mass returns to the smoldering state until the heat rises high enough to repeat the flash.

In some compositions, magnesium-aluminum (magnalium) is used instead of the magnesium. Magnesium requires a coating to prevent it from prematurely reacting with the oxidizer in the comp.

Additionally, sometimes barium nitrate or other oxidizers are used instead of ammonium perchlorate.

In 1987, John "Skip" Meinhart offered some details about his noteworthy strobing star formulas in Pyrotechnica XI. Except for Shimizu's White formula, and Skip's Pink formula, all the rest of the formulas use magnesium as the metallic fuel ingredient.

In the 1992 Pyrotechnica XIV edition Jennings-White explores Blue Strobe Light Pyrotechnic Compositions. Up until that point in time, blue strobes had not been explored in depth because of some unique problems associated with the chemical mixtures required to produce that color in a strobe.

All of this information ought to be able to keep you reading until late into the night if you are so inclined.

Making Strobe Pots

I won't be focusing on making strobing stars in this project, but only simple, ground-effect strobe pots.

I'm also not going to be making any of the formulations, which contain magnesium. As I said, using that metal requires a special coating process because it does not form an oxidized protective layer on its own, as do aluminum or magnalium.

There seems to be some debate as to whether or not magnalium needs to be treated and coated when it is used in compositions containing ammonium perchlorate. Meinhart states, "I have had success using magnalium powders that have not been treated with potassium dichromate. In practice I have often used treated metal powders, but this does not always seem to be necessary."

Whereas in Hardt's Pyrotechnics, Barry Bush notes that the formulas he cites which contain magnalium or magnesium in combination with ammonium perchlorate do "require the metal powders used to be treated with potassium dichromate." Shimizu also specifies treated magnalium, and details the methods of treatment in FAST.

Shimizu does state that if there is any reaction between magnalium and ammonium perchlorate, which would be encouraged by the presence of water, it would only be a slow reaction in which the metal is affected gradually.

I have used untreated magnalium in these formulas, with no problems. One sign of an unwanted reaction would be the heating-up of the composition as I'm working with it, so I always pay attention to see if that is occurring. I avoid adding any water to such a composition. I also don't store these devices for long periods of time, which could produce a slow reaction of the ingredients, especially in the presence of moisture.

So, I think I'll make simple white and pink strobe pots. The white formula is the most commonly cited one:

White Strobe Composition

Chemical	%	64 Ounce Batch	1800 Grams
Ammonium perchlorate	57	9.15 ounces	257.1 grams
Magnalium	24	3.8 ounces	107.1 grams
Barium sulfate	14	2.3 ounces	64.3 grams
Potassium dichromate	5	0.75 ounces	21.5 grams

Shimizu specifies 80-mesh, whereas other sources specify 100-200-mesh. The mesh of the metal is known to vary the flash rate of the strobe, so some experimentation is in order. Initially, I'll be using 200-mesh magnalium, Skylighter #CH2072.

Barry Bush has an interesting note in Pyrotechnics concerning this formula. This formula "may be given a faster frequency by replacing the barium sulfate with anhydrous magnesium sulfate. The resultant fast strobe is sometimes called a "shimmer effect." I'll have to try this sometime in aerial-shell strobe-stars, since it is an effect I have admired in commercial shells.

Additionally, the flame created by this "white" composition is brilliant, but it does have a very slight green tint caused by the barium. Barium normally produces very green flames with the addition of a chlorine donor such as Parlon or Saran. Another experiment would be to include small amounts of these chlorine donors to shift the color of the white strobe pots to green.

The pink strobe pot composition is as follows:

Meinhart Pink Strobe Composition

Chemical	%	64 Ounce Batch	1800 Grams
Ammonium perchlorate	57	9.15 ounces	257.2 grams
Magnalium, 200 mesh	15	2.45 ounces	68.6 grams`
Strontium sulfate	11	1.85 ounces	51.4 grams
Strontium carbonate	8	1.2 ounces	34.3 grams
Parlon	4	0.6 ounces	17.1 grams
Potassium dichromate	5	0.75 ounces	21.4 grams

All the chemicals (except the magnalium, which I don't put through fine screens) are fine enough to pass through a 100-mesh screen. If they are not, they are milled individually in a blade-type coffee mill. See Fireworks Tips #112 for details and safety precautions concerning this procedure.

Note: Ammonium perchlorate does not play well with potassium nitrate. The combination forms ammonium nitrate, which is very hygroscopic, attracting moisture out of the air like crazy, rendering any mixture or composition containing it wet and useless. Don't grind either of these chemicals in a coffee mill which has been used on the other chemical, unless the mill has been thoroughly cleaned with soap and water.

Warning: Potassium dichromate is toxic and a known carcinogen. A good respirator and rubber gloves are required when working with this chemical, and when using it in pyrotechnic compositions. Don't breathe this stuff or get it on your skin.

All the chemicals for a given formula are weighed out individually and are passed through a 20-mesh screen 3 times to thoroughly mix them.

Then the composition is mixed with enough nitrocellulose (N/C) lacquer (Skylighter #CH8198P) to create thick putty, similar to Play-Doh. I did not dilute the lacquer, but used it right out of the can, as-is. The one-pound batches required 3 ounces, by weight, of the lacquer.

I started mixing the composition in a plastic tub with a paint stir-stick, and finished by kneading it with gloved hands.

Mixing Nitrocellulose Lacquer into Strobe-Pot Composition

The dough is then pushed with gloved fingers into paper tubes to create strobe pots. I start this process by pushing the tube into the composition-putty to get the filling started.

Large pots can be made with 1.5-inch ID tubes, cut into 1.5-inch long sections. Or, smaller pots can be made with 3/4-inch ID tubes, cut into one-inch long sections, or even longer. While thicker-walled parallel tubes, like rocket tubes can be used, strobe-pot tubes do not need to be super-strong, so spiral-wound tubes like Skylighter #TU2142 or TU2053 can be used.

Large diameter strobe pots would be appropriate for large displays and venues. Smaller ones are nice in backyard size shows. Varying the length of the paper tube will adjust the total burn-time of the strobe pots, so their duration can be dialed in for specific uses.

For this project, I think I'll make mostly 3/4-inch ID by 1-inch long strobes to determine how well they are working and how long they burn, plus a few other sizes to see how they perform, too.

Batch of "Flashing Fireworks" Made with One-Pound of Composition

Once the composition has been stuffed into the paper tubes, they are placed on their sides and set aside on a tray to dry out in the open air. N/C lacquer releases acetone and other highly flammable solvents as it dries, and I don't want these vapors collecting in my shop as this occurs.

Toward the end of the tube filling, the remaining strobe-putty started to dry out and became difficult to consolidate into the tube. I added just a touch of acetone to the composition to re-dampen it.

It took 3 or 4 days for these pots to dry completely. When I tried to burn them before they were completely dry, they did not burn with a regular strobing-action, but burnt with a more continuous flame.

Priming the Strobes

The dry pots will light well if they are ignited with a piece of visco fuse or with a propane torch. But if I want them to ignite reliably with a fast-fuse or quick match line of fuse, then I need to prime them.

A black powder prime containing potassium nitrate cannot be used on these because of the incompatibilities between the nitrate and the ammonium perchlorate. In short, Dr. Shimizu lists a different prime specifically for this use.

Ignition Composition for Twinklers/Strobes

Chemical	%	16 Ounce Batch	450 Grams
Potassium perchlorate	74	11.85 ounces	333 grams
Red gum	12	1.9 ounces	54 grams
Charcoal, airfloat	6	0.95 ounce	27 grams
Potassium dichromate	5	0.8 ounce	22.5 grams
Aluminum, flake 100-325	3	0.5 ounce	13.5 grams

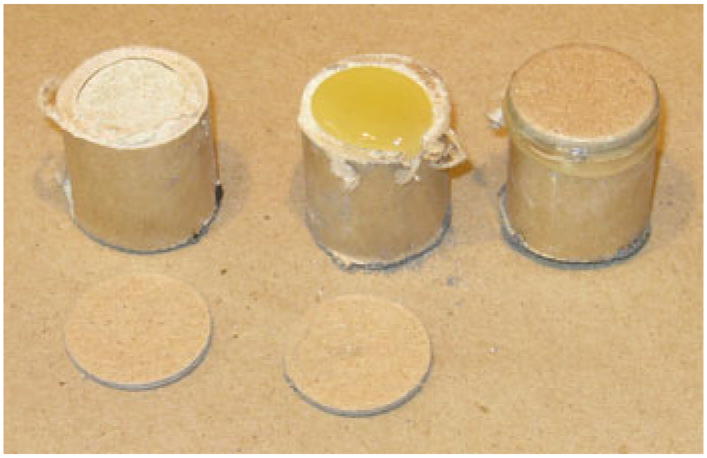
After making sure all the individual chemicals (except the aluminum) will pass through a 100-mesh screen, I weighed them out individually and mixed them together by passing them through the 20-mesh screen three times.

I weighed out 1 ounce of the dry strobe prime composition, and added 1 ounce (by weight) of the nitrocellulose lacquer. This created a wet prime comp that had a consistency between that of honey and peanut butter.

I used a wood stick to apply this wet prime to one end of each strobe pot, and quickly pushed that wet end into some dry strobe composition for the final prime layer.

Priming Strobe Pots for Easy Ignition

I perform one final operation to finish the individual strobe pots; I hot-glue a paper disc onto the bottom of each pot. This prevents sparks and/or slag from dropping and igniting the bottom of a twinkler prematurely as the pot burns. It also facilitates mounting the pots to a board when a show is being set up.

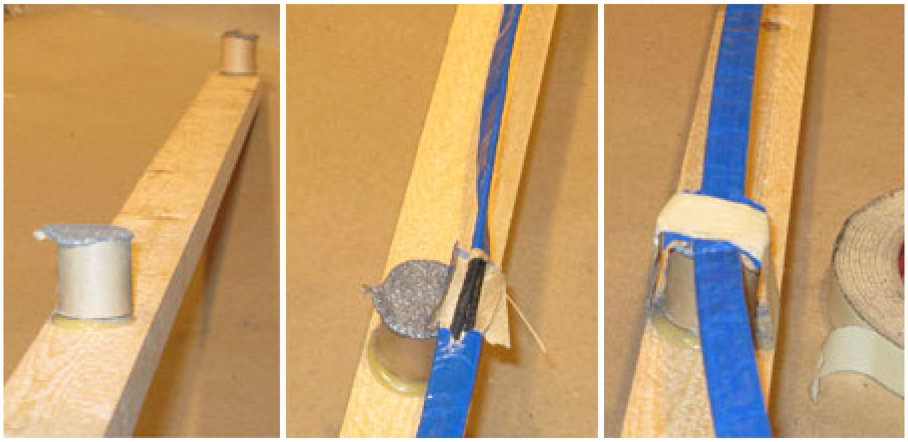


Paper Discs Hot-Glued to the Bottom of Strobe Pots

Mounting and Fusing Strobe Pots for Use in a Fireworks Display

Once the individual strobe pots have been completed, they can be mounted to a board and fused for easy installation out in the field prior to a fireworks show.

To do this I simply hot-glue the pots to a board at the desired spacing. I find a spacing of 4 feet on-center to work well. Then a run of quick match or tape-covered fast-fuse is used to fuse all the pots together. A "window" is opened up in the quick match-pipe, and the bared black match is taped on top of the strobe pot with 3 wraps of masking tape.



Strobe Pots Hot-Glued to a 1x2 Board, and Fused with Quick Match

The quick match can be ignited by a piece of visco fuse, or an electric igniter can be employed, per the information in Skylighter Fireworks Tips #'s 102 and 104.

Three Strobe Pots Ready to Be Electrically Fired

Results

I burned white and pink strobes made with the 200-mesh magnalium. The white one burned for 15 seconds with a very fast strobe rate of about 10 flashes per second. The pink one actually looked red, burned for 23 seconds, and flashed about 4 times per second.

Warning: These strobe pots burn with an extremely brilliant flame and light. It is best to avoid looking directly at them to prevent eye damage. Placing the pots where their light can reflect off of a structure or trees makes their effect visible without having to look directly at them.

Strobe Smolder Phase, White Strobe Flash, and Red Strobe Flash

200 Mesh Red and White Strobes

(Click Image to Play Video)

I liked the performance of the pink/red strobe, but the white one flashed too rapidly for my taste. So, I made a new batch of each color using 60-mesh magnalium. I know that using a larger granulation of the metal will slow down the burn time and also its strobe frequency. Burning these new strobes produced the following results:

White strobe with 60-mesh magnalium, burned for 25 seconds, and flashed 1.5 times per second. I found this to be a very pleasing strobe frequency. Red strobe with 60-mesh magnalium burned for 27 seconds, flashed at a rate that varied from slow to fast. This pot just couldn't seem to find a groove and settle into it.

60 Mesh Red and White Strobes

(Click Image to Play Video)

Of the four variations I prefer the white strobe pots made with the 60-mesh magnalium, and the pink/red twinklers made with the 200-mesh magnalium.

Although I made mostly 1-inch long twinklers, I also made some larger ones. Two-inch long ones, made in the 3/4-inch ID tubes, burned as follows:

- 2-inch white strobe with 60-mesh magnalium burned for 40 seconds with about 2.5 flashes per second,
- 2-inch long red strobe with 200-mesh magnalium burned for 40 seconds with flashes varying from slow to fast again.

And, last but not least, I rigged up some white strobe pots using 60-mesh magnalium on a board and accompanied them with the music. You can get the idea of what I had in mind in the first place as a nifty addition to a fireworks display. Click the video below of the three white strobe pots accompanying Who's Won't Get Fooled Again.

White Strobes Set to Music
(Click Image to Play Video)

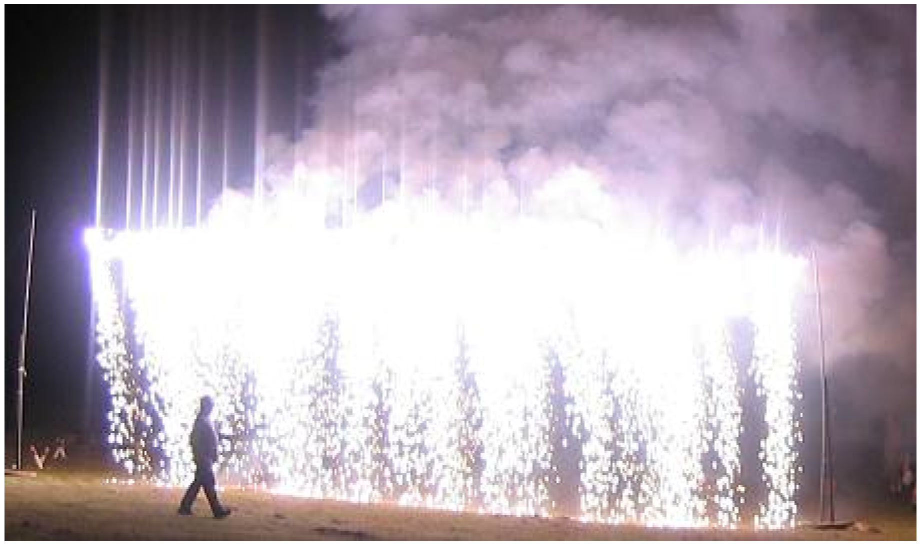
I do like what these simple, low-level ground devices can contribute to a fireworks show.

Making a Waterfall

By Gary Christ

Materials Needed

- Acetone
- Alcohol
- Aluminum flake, firefly mixed (CH0155)
- Aluminum flake, flitters, fine (CH0140)
- Aluminum flake, flitters medium (CH0141)
- CPVC tubing, 3/4" wide, 8-1/2" long
- Charcoal, airfloat (CH8068)
- Dextrin (CH8107)
- Drill & 5/8" drill bit
- Funnel
- Magnalium, 200 mesh (CH2072, CH2073)
- Masking tape
- Parlon (CH8210)
- Potassium perchlorate (CH5402)
- Quick match (GN3001)
- Red gum (CH8230, CH8231)
- Strontium nitrate (CH5543)
- Sulfur (CH8315)
- Visco fuse (GN1000, GN1001, GN1004)
- Water
- Waterfall tubes (TU2040)
- Wire
- Wood, 2x4
- Wooden dowel, 5/8"



Gary Christ's Waterfall

Gary writes: "I guess I'll fess-up! When it comes to the firework tubes, I took a hint from Dan Williams' page. As my wife is a schoolteacher, we have an over abundance of used 8 1/2 by 11 computer paper. We take a sheet of paper and loosely roll it around a 5/8-inch diameter form. Or, if you don't want to roll your own, you can use Skylighter's TU2040 spiral wound waterfall tubes. This project takes 50 firework tubes."

"The tedious part is in the loading! Once more we took a hint from Dan's page. A length of 3/4 inch CPVC tubing (the tan stuff) about 8 1/2 inches long will serve as a holder or reinforcing sleeve. Add a coupler to the top of the tube to serve as a crude funnel.

A stand for this whole contraption was fashioned from a 2 X 4 and a one-inch long 5/8-inch diameter wooden dowel. Sand down half of the dowel to loosely fit into the paper tube. Drill a 5/8-inch diameter hole, 1/2 inch deep into the 2 X 4. Smack home the dowel and viola, a stand is born."

"Next, mix up a batch of waterfall composition. Here's the recipe. All ingredients are measured in percentages by weight.

Waterfall Composition

Component	Percentage
Potassium perchlorate	49
Aluminum flake, flitters, fine	34
Aluminum flake, firefly mixed	8
Aluminum flake, flitters medium	8
Dextrin 2	

"The waterfall composition is moistened with a mix of 25% alcohol and 75% water until it is slightly damp (we mix about 500 grams at a time). This will activate the dextrin to make the waterfall composition pretty hard when dry.

Ram about a teaspoon of waterfall composition at a time with your dowel until the firework tube is almost full, say about 3/4 inch to 1/2 inch from the top. Leave this much head space for the starter portion."

"After the tubes have dried (a few days), a starter waterfall mixture is needed. Once more the formula was taken from Dan Williams and is as follows. By the way, when the starter fireworks waterfall composition lights, it will burn RED." All ingredients are measured in percentages by weight.

Starter Composition

Component	Percentage
Strontium nitrate	50
Parlon 18	
Potassium perchlorate	8
Magnalium, 200 mesh	12
Charcoal, airfloat	5
Sulfur 5	
Red gum	2

"Mix with acetone into a gooey, stringy mess. Dab a good bit in and insert a length of visco fuse, let dry, and this baby is ready."

"As for stringing the firework tubes together, cut a length of wire and pass it through the bottom of the tube and twist into a loop for suspending it above the ground (visco fuse will be pointing down). Quick match the tubes together about a foot apart (takes about 75 feet). Tape the tubes together top and bottom a foot apart with masking tape.

This will stabilize this monster when you loft it up into the air about 15 to 20 feet. String about 60 feet of wire through the loops of the tubes. Tie the ends of the wires to the poles and loft it all into the air."

“Light and enjoy. This waterfall lasts about 70 to 90 seconds.”

Notes on fireworks waterfalls: Lancaster’s text (from Fireworks Principles and Practice) on waterfalls points out some important considerations in making waterfalls. First, he included waterfalls in his chapter on "Colored Fires, Bengals, Lances, Portfires, and Torches" because waterfalls are closely related to these devices.

He states that waterfall formulations contain "an excess of aluminum in order that the burning materials will fall to the ground with the appropriate sparks." When you look at the formulas he provides, and at other waterfall formulas, you will often see a mix of aluminum particle sizes.

This ensures that the waterfall has a rich spray of sparks, which are burning all the way from the nose of each firework tube down to the ground. The smaller particles will burn up early; the medium sized ones part way down; and the largest all the way to the ground. If you are improvising your own waterfall formula, try to find a mix of aluminum particle sizes for your composition.

Another consideration is the use of thin-walled tubes, so they can be consumed by the burning waterfall composition. Using thicker walled tubes, such as sky rocket tubes, can leave you with remnants of the waterfall burning a distracting orange long after the waterfall effect has finished.

Other waterfall effects can be made using titanium or iron/steel fountains, and attaching them to a long rope or mounted horizontally on a board.

Dense, Bright Blue Smoke Device

By Chris Starrett

Making smoke devices isn't as simple as it sounds. The burning mixture can't get too hot or too cold. It must have just the right ratio of burning material to dye to create a vivid color rather that looked like something washed out with tinges of the promised color. It must be relatively easy to light and burn all the way through for a maximum length of smoking time.

Blue Smoke Formula

Composition	Percentage
Blue smoke dye	50%
Potassium chlorate	25%
Asphaltum 14%	
Powdered (confectioner's) sugar	6%
Baking soda	3%
Dextrin +3	

Make sure all is very fine powder and well mixed.

Put 3/4 of the mixed composition in a plastic bag and add water mixed with 10% denatured alcohol. Add a little at a time and knead to the point you can form a ball that won't crumble. Add the remaining 1/4 of composition and knead more. If it won't hold together and crumbles, add a couple of drops more water and knead the hell out of it.

It's very important that it's not too wet. You can tell if it's too wet by squeezing a ball of it in your hand. If water comes out between your fingers, it's too wet. In that case, add more dry comp. Once you have a firm ball, granulate it through a ten mesh screen and let dry. If your comp. is too wet, you will only get a smear on the screen.

I used tubes that had a 2-inch inside dimension (ID), and that were 3" long. I epoxied plywood to one end. Then filled the tubes 3/4 full of the smoke comp. and lightly pressed it down.

Then I epoxied plywood to the top, and made a 3/4-inch hole in the plywood, stuck a fuse in and put a slurry of meal powder around the hole to keep the comp. from falling out and to hold the fuse in. A wad of tissue paper would work just as well. The composition does not require any prime to ignite, just a fuse. For best results, ignite these in sunlight.

This formulation burns so cold that you can burn it in a paper cup and only after the smoke stops, does the cup start burning. The dye stains everything it touches, so be careful. You might want to use latex gloves and wear clothes you don’t care about. Orange GoJo hand cleaner gets the dye off your hands nicely.

Blue Smoke Formula

From Kenneth Miller

Brother Katz has been after a formula that uses our phthalocyanine blue smoke dye. I scratched high and low to find one, and finally got Kenneth Miller to provide me with one. I have not tested it personally. But Kenneth, never one to blow smoke up..., knows his smokes and although I would not trust him around any of my wimmen, he can certainly be relied on for a good smoke. All parts are by weight. --HG

Kenneth Miller's Phthalo Blue Smoke

Composition	Percentage
Phthalocyanine Blue (#CH8265)	50
Potassium chlorate	30
Confectioner's sugar, sifted fine	20

Making Roman Candles Gary Smith's Secret Way

By Ned Gorski

Materials List

- Aluminum, atomized, 325 mesh (CH0105)
- Blackpowder, FFg
- Candle Holding Jig
- Charcoal, Airfloat (CH8068)
- Coffee Grinder, blade-type
- Dextrin (CH8107)
- Drying Box
- Elmer's Glue
- Ferro-Titanium, 30-60 mesh (CH8110)
- Ferro-Titanium, 40-325 mesh (CH8112)
- Funnel
- Hand Saw
- Kraft Paper, Fiber-reinforced
- Mallet (TL4100 or TL4040)
- Nozzle Mix
- Potassium Nitrate (CH5302)
- Rammer, 3/4-inch (TL1008)
- Ramming Base
- Sandpaper
- Scoop
- Screen, 20-mesh (TL2002)
- Sodium Bicarbonate (CH8275)
- Sulfur (CH8315)

- Titanium, medium spherical (CH3010)
- Tubes, 3/4 Inch ID (TU1066 or TU1065)
- Water
- Visco Fuse (GN1000, GN100)

What's All the Mystery about Making Roman Candles?

I really like Roman candles. But even though Roman candles appear to be the simplest of fireworks devices, they are a real challenge to make so that they perform consistently. Especially if you use the traditional methods you'll find in all the books.

I'm going to show you a secret method for making Roman candles that you haven't seen before. I promise you absolutely will not find Roman candles made like these in any of the books (at least, not yet!). Best of all, you can use this new method to overcome all the Roman candle problems that traditional candle-making methods create.

Look. Where rubber hits the road is how well your fire works in a fireworks display, right? Well, read on and learn how Roman candles work, what goes wrong, and how to make Roman candles like nobody you know has ever seen.

Here's a video of one of the first successful Roman candles I made using the method I'm about to teach you.

8-Shot Streamer Star Roman Candle

(Click Image to Play Video)

Notice now consistent the timing is between the shots. One star is coming down and going out, quickly followed by the next shot. That kind of consistency and effect is what I was going for. And that's what is hardest to achieve using traditional Roman candle fireworks-making techniques.

With all the candles I've made using this new method, the timing between shots has been within one second of each other. If you talk with pyrotechnics folks who have made their own Roman candles, they'll tell you how remarkable that is.

You see, anyone can learn how to make a Roman candle, but making them so that the timing and height of the shots is consistent, well that's what you don't see very often. Of course, Roman candle fireworks are a great way to test the color, burn time, effect and ignitability of your new star compositions. And a single candle is just fun to light, sit back, and enjoy. You can gang multiple candles together, say 7 of them in a bundle, or set them up in a fanned rack to fill the sky from left to right with Roman candles' shots.

So Why Is a Roman Candle Firework Called Roman?

Despite the fact that we Gorskis prefer to call these devices "Polish candles," for some reason that name has not caught on yet. So, why were these devices called "Roman candles" to begin with?

It seems that as far back as the early 1800's, both French and Italian authors were using the term "Roman candles" to describe such devices. Since Italy was one of the countries which greatly influenced the development of fireworks, it is not very surprising that one of its most prominent fireworks devices would have its name associated with its greatest city, and the name of its once-sprawling empire.

Exactly What Is a Roman Candle?

Traditionally, a Roman candle has been thought of as a single-tube fireworks device which fires multiple, consecutive shots of projectiles skyward, and which emits a fountain-like spray of sparks between shots.

Those projectiles can be individual firework stars, comets with various colors and effects, single crossette comets, mine-shots of multiple stars, combination star-and-report devices, or small aerial star shells.

Roman Candle Consumer-Fireworks

But one comet fired skyward from a mortar is sometimes considered to be a single-shot Roman candle. And indeed, single-shot candles, arranged in fan-shaped mortar racks, have become common in many modern displays.

Consumer-firework Roman candles can be as small as 1/2-inch inside-diameter tubes, and large professional-display candles can be found with a tube ID as large as 3 inches.

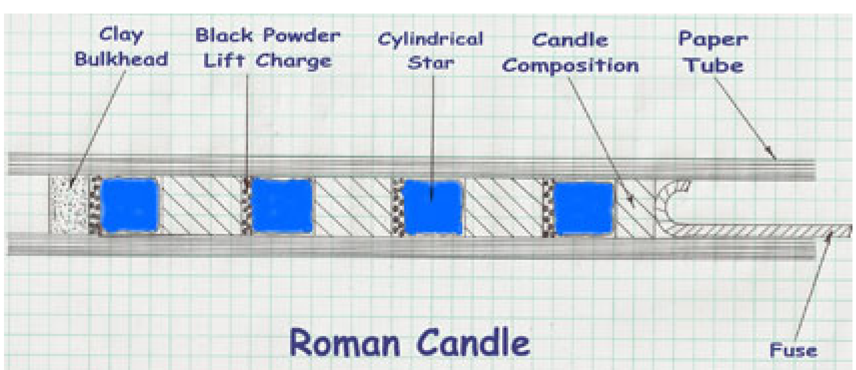
I'd suppose if you asked someone, "What are the most common types of fireworks you can think of," the response would be something like, "Firecrackers, sparklers, bottle-rockets, and Roman candles."

Certainly Roman candles play a part in many of our childhood fireworks memories. Often they were held in our hands as they fired, but there have been so many mishaps resulting from malfunctioning candles that hand-held Roman candles are now discouraged.

I once made the mistake of thinking I could hold a one-inch display candle in my hand as it fired. The first shot propelled a star skyward, and the rest of the candle backward out of my hand to who-knew-where. I had to quickly find it and stabilize it with my foot as it finished firing. I still haven't lived that down in my local fireworks guild. I don't recommend you try any similar stunts. With these larger Roman candles, it's best to tape them to a stake and firmly secure them to the ground before ignition.

How is a Roman Candle Constructed?

The most common, and traditional method of Roman-candle construction involves alternating layers of black-powder lift charge, cylindrical stars, and a slow-burning candle/delay composition, with the bottom of the tube plugged with a clay bulkhead.



Roman Candle Cross-Section

If you imagine lighting the candle's fuse, it will burn down until it ignites the first increment of the delay composition. That rammed increment burns slowly like a gerb (fountain), spraying sparks out of the end of the tube, which would normally be pointing skyward. Of course, when I say "normally be pointing skyward," this "dog and Roman candle" video from YouTube pops into my mind: http://www.youtube.com/watch?v=i8mDAae7LEY. That one shot just about takes out the kid and the old man at the same time!

When the last part of that first increment of delay composition burns through to the first star, the prime on the star burns quickly and ignites its whole surface. That, in turn, lights the first layer of black-powder lift charge, which propels the star out of the tube. At the same time, the top of the second increment of candle composition is ignited, which begins a repeat of the whole process.

The Roman candle in the sketch is called a "four-ball" Roman candle, since it will sequentially shoot four stars out of the tube. "Ball" refers to the ascending ball of flame each star will produce.

Typically candles are made with pumped, cylindrical stars, which have flat bottoms and tops. The flat bottom holds the black-powder lift charge in place, and the flat top supports the delay composition nicely.

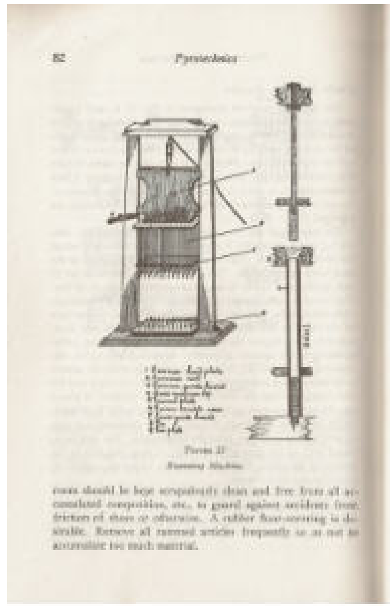
Why Do I Make Roman Candles?

In the past 20 years or so in this hobby, I've only tried to make Roman candles a few times, although they are among the most elementary of devices. Quite honestly, in those attempts I was never completely satisfied with the results.

And you know what's funny? Even though I'd made 16-inch aerial fireworks shells and 36-inch diameter girandolas, I felt like I couldn't make a consistently performing Roman candle that would live up to my expectations.

One reason I wanted to get good at producing nice little Roman candles is that they can be fired in any location suitable for the discharge of consumer fireworks. Big fireworks devices like big shells and girandolas require a big display site and a display permit. But it's nice now and then to make a little rocket or Roman candle and be able to take it outside to shoot and see how it performs.

In his 1947 book "Pyrotechnics," George Weingart has a section on rolling cases (tubes), for Roman candles. He also has instructions for making an individual, 3/8-inch ID, eight-ball Roman candle.



Weingart's Sketch of a Roman Candle Making Machine

Weingart describes a simple machine for mass-producing consumer-fireworks candles. I have seen the remains of a similar machine at the Rozzi's Famous Fireworks plant near Cincinnati, Ohio. My understanding is that the machine I saw was the very one Weingart based his sketches and descriptions on.

How to Make a Roman Candle

I've seen traditional Roman-candle-making instructions elsewhere, and they seldom differ significantly from the ones in Weingart.

A parallel tube is plugged at the bottom with a rammed increment of clay or with a glued-in section of wooden dowel. A scoop of black-powder lift charge is loosely put into the tube, followed by a star, which fits nicely into the tube. This is capped off with an increment of the candle-composition delay powder, which is rammed "with about six light blows of a small mallet" according to Weingart.

And this is where Roman-candle construction gets tricky. That increment of delay composition must be rammed solidly enough to get it really consolidated and locked into the tube. That is necessary in order to prevent fire from being prematurely blown down the tube past it when the star above that increment is shot out of the tube.

The delay charge must also be in the tube tightly enough that fire cannot creep between it and the inner tube wall as it burns, which would also prematurely ignite the star below it.

If you've ever rammed fountain composition in a paper tube, you know it takes a fair amount of force to solidly compact the powder, in order to produce the right effect when the fountain is lit.

But, when one is ramming Roman-candle delay composition, that increment sits on top of a loose star sitting on loosely granulated black-powder lift charge. This is an inherent conflict: not an ideal situation for getting a solidly compacted increment of delay composition.

And here's what you see as a result--the most commonly seen Roman-candle failures--stars which fire from the tube in a rapid-fire, unevenly-paced manner; sometimes more than one star fires at once; or the paper tube ruptures because of the amount of pyrotechnic material, which ignites everything at once prematurely.

All of this results from not having a solid base on which to ram each increment of candle composition. That makes the construction of these simple devices a real challenge, especially in candles larger than about a half-inch ID. Larger diameter delay increments are harder to solidly compact sufficiently than smaller diameter ones.

There must be a better way. Enter my pyro buddy, Gary Smith. Recently on Passfire.com Gary posted a video of a fairly complex Roman candle he'd made. The individual shots were color-to-report inserts, which are harder to make than simple stars.

But, what I noticed immediately was that his shots were very evenly spaced apart, and that there was a nice fountain of fire-dust spewing from the mouth of the tube between shots.

This was a very nicely constructed, consistently-performing Roman candle that I knew from personal experience was hard to achieve. I simply had to know more. Gary was kind enough to share with you and me the unique method he developed of achieving nicely compacted, traditional delay increments between the shots. And that is what produced the consistent effects, which so impressed me when I first saw his video.

Using Multiple Tubes to Make One Roman Candle

Huh? Say what? I thought we'd already defined a Roman candle as a "single-tube fireworks device which fires multiple, consecutive shots of projectiles skyward."

How can we use more than one tube to make a Roman candle?

Well, therein lies Gary's trick, which hopefully will forever be known as the "Smith Method" of constructing candles.

Looking at the sketch of the Roman candle above once again, you'll notice there is a recessed, empty space below the clay bulkhead in the paper tube. Putting the tube on a base, which has a ramming nipple, and then dropping loose clay into the tube and ramming it with a drift and mallet creates that void.

Materials and Tools Ready to Ram Clay Plug in Paper Tube

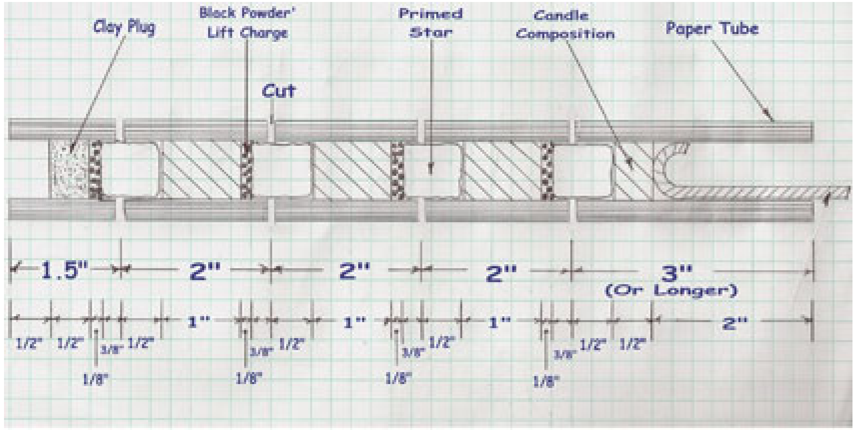
Way back in Skylighter Newsletter #89, I gave directions for mixing clay nozzle and bulkhead mixes. I also showed how to ram nozzles and bulkheads, and a photograph of a cutaway tube with a nozzle rammed in it.

Either of those clay mixes is usable for the clay plug at the bottom of a Roman candle. And the photo shows how a clay nozzle or bulkhead locks into a paper tube by slightly expanding the tube in that area.

Cutaway Paper Tube Showing Locked-In Clay Bulkhead

I can just imagine Gary thinking, "How can I get each delay increment solidly locked into the paper tube the same way the clay plug is?"

And then the light went on in his head: "Cut the tube into sections, ram each delay increment solidly into its section, and then reassemble the tube sections into one solid case." I imagine a picture popping into his mind something like the sketch below.



The Tube Sections of a Smith-Method Roman Candle

Although the sketch shows a 4-ball candle, additional 2-inch middle sections can be added or removed to increase or decrease the number of shots.

Note: The top, 3-inch or longer tube section creates the first "mortar" out of which the first star is shot. Within certain limits, the length of a mortar determines how high the projectile goes. Technically, 3 inches is the shortest practical tube from which to shoot the first star. But with a tube that short, the first shot will not go as high as the shots that follow it. So, I actually prefer to use a top tube section that's 5-inches long.

I have arrived at the specific dimensions for this particular Roman candle based on my particular stars and delay composition. To the left of each increment of the delay (candle) comp there is a 1/2-inch void just like the one to the left of the clay plug.

The nipple on the ramming base creates this 1/2-inch recess in each section. A tube section is slipped onto the ramming base. The proper amount of delay composition is loaded into the tube and then rammed with a drift and mallet.

This creates a very solid, securely positioned increment of delay composition, which prevents most types of Roman candle failures. There it is, simple as that: the Smith secret to Roman candle construction.

Now, here's how to make a Roman candle using this method to show all the steps involved.

Now, How to Make a Roman Candle

For this Roman candle, I'm going to alternate shots of D1 glitter stars with shots of willow diadem silver-streamer stars. First a glitter shot, then a silver streamer, then glitter, silver streamer, and so on. The candle in the video at the beginning had only silver-streamer stars.

For the willow diadem stars, I'm still using the total amount of metal that is specified in the formula. But rather than using three different types of metal, I'm only using fine, spherical titanium, Skylighter #CH3010. This long-burning star leaves a nice, long silver tail behind it that "pops" as the bits of titanium catch fire and burn.

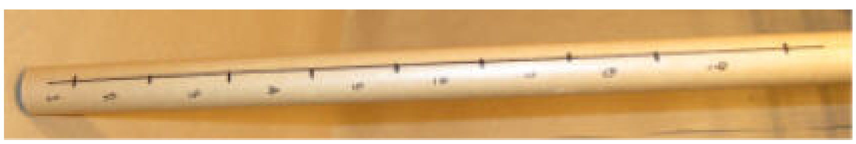
The dimensions in the sketch above are based on my primed 5/8-inch diameter, 5/8-inch long pumped stars, which I made the same way I made the gold-glitter comets in Fireworks Tips #111.

I prime the ends and sides of the stars so that fire is transferred as quickly as possible from the top to the bottom of the star. The final primed stars end up being a little under 3/4-inch diameter and about 3/4-inch long.

The star dimensions dictate that I use 3/4-inch ID parallel tubes for this project. Either the extra-strong, 1/8-inch wall Skylighter TU1066 tubes, or the standard, 1/4-inch wall Skylighter TU1065 tubes will work well in this project.

These long tubes work well because they can be marked, and all the Roman candle sections can be cut out of one length of tube. This makes it easy to reassemble the sections later on.

I want to make an 8-shot candle, so I mark and cut a tube as shown below. I write a number on each section, starting with #1 at the bottom of the tube.

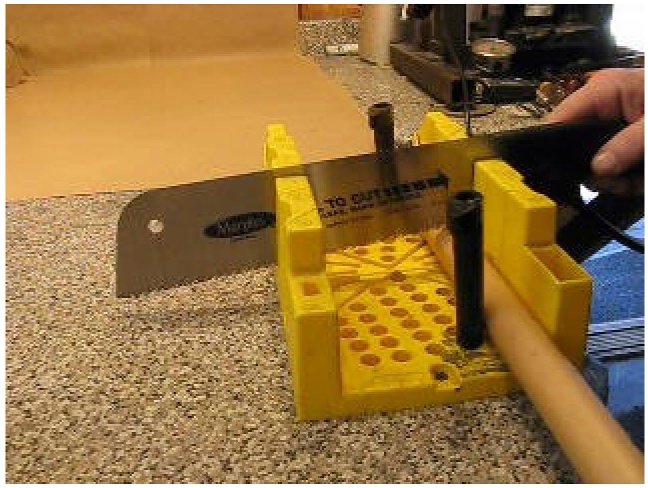


Roman Candle Tube Marked into Numbered Sections before Cutting

The markings will enable me to reassemble the tube sections exactly as they came apart, which will increase the potential for me to arrive at a nice straight finished candle. I allow about 1/16-inch for each of the saw cuts.

In the drawing above, notice that there will be a star at each of the cuts. So I mark 8 cuts, plus the cut at the top of the candle. The bottom section will be 1.5-inches long and the top one will be 3-inches long.

Then I cut the tube into sections.



Cutting Paper Tube into Sections

(Click Image to Play Video)

Roman Candle Tube Cut into Sections

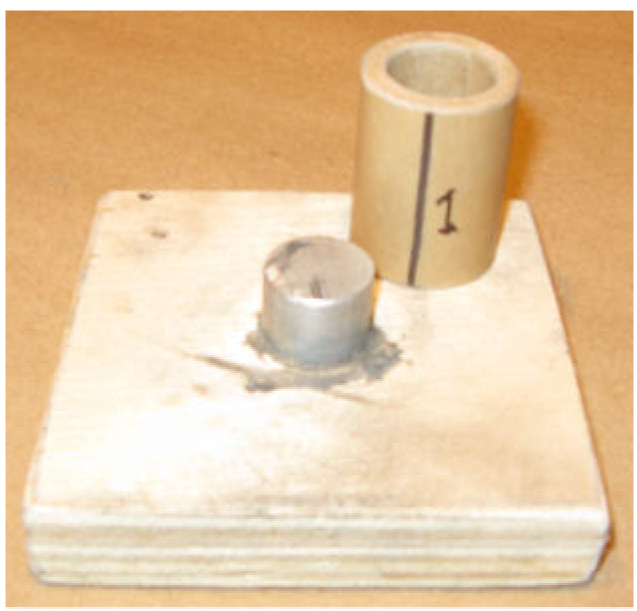
I use a little sandpaper to smooth the inside and outside edges of each end of the tube sections. Smooth ends make for smooth reassembly later on.

Sanding Ends of Roman Candle Tube Sections

(Click Image to Play Video)

Now I put section #1 on the nipple of the ramming block with the bottom of the tube down.

I made the ramming base and nipple by drilling halfway through a piece of 3/4-inch thick plywood, and epoxying a length of 3/4-inch diameter aluminum rod into the hole. I got the rod from Home Depot (in the nuts-and-bolts aisle where they have a rack of metal rods and angles), and cut it with a hack saw just long enough that 1/2-inch of it projects from the plywood. I used a file to smooth the top end and edges.



Ramming Base with Aluminum Nipple and Section #1

I load 10 grams (one flat 1/2-tablespoon) of bulkhead-clay mix through a funnel into the tube. When loading the clay into the short tube through the funnel, I use a 1/2-inch wooden dowel to push the clay through the funnel and slightly compact it into the tube. This helps get all the clay through the funnel and down into the short tube, so it doesn't spill out over the top.

I ram the clay plug with a 3/4-inch rammer from one of my sets of rocket tooling, and 8 moderate blows with the rawhide mallet. This results in a 1/2-inch thick plug in the tube section. A section of 3/4-inch wooden dowel could certainly be used as a rammer in this project, as shown in the article on making gerbs.

Ramming Clay Plug into Roman Candle Bottom Section

(Click Image to Play Video)

Note: I want to fully consolidate the clay and lock it into the tube without damaging or splitting the tube. This takes a bit of practice. With the softer, standard tubes, a slight bulge will form in the tube, which can be felt if one runs their fingers up and down the tube.

Now it's time to ram the delay-composition increments into the other sections of the tube. I have played with a variety of delay compositions, from relatively fast-burning ones to those that are slower burning. I like to keep the delay increments about 1-inch long between the stars. This provides a nice, solid plug, which does not allow fire to pass prematurely around it.

So, the burning speed of those 1-inch increments determines how much time there is between shots of the Roman candle. With the stars I am using, I prefer the timing I get using the following candle delay composition (This is a classic star formula which can be found in various books).

Chrysanthemum 8 (from Shimizu) Delay Composition

Chemical	%	79 Gram Batch
Potassium nitrate	0.49	35 grams
Charcoal (airfloat)	0.40	29 grams
Sulfur 0.06		4 grams
Dextrin 0.05		4 grams
Water +0.10		7 grams
Total 1.10		79 grams

Note: The weights have been rounded off, and this size batch will make enough composition for the 8-shot Roman candle I'm making.

I grind the potassium nitrate in a blade-type coffee mill fine enough to pass a 100-mesh screen. I do the same with the sulfur. The charcoal and dextrin are already that fine.

Grinding Potassium Nitrate in a Coffee Mill

(Click Image to Play Video)

25-50% of the airfloat charcoal can be replaced with 80-mesh or even coarser charcoal for longer hanging sparks in the fountain plume between candle shots.

The chemicals are put in a sealed plastic tub and shaken to mix them. Then they are worked through a 20-mesh screen or kitchen colander 3 times to thoroughly mix them and break up any remaining clumps of chemical.

Sifting Powder through Screen

(Click Image to Play Video)

Using a spray bottle, I spritz the composition with water as it sits in a plastic tub on a scale, until 7 grams of water has been added. Between every couple of spritzes I swirl the comp in the tub to spread the water around.

I work the water into the powder with gloved hands and then push the damp composition through the 20-mesh colander twice to really integrate the water.

Working Water into Delay Composition

(Click Image to Play Video )

Then, just as I did with the increment of the clay in tube section #1, I ram increments of the still-damp delay composition into the remaining tube sections. I always place each section with its bottom down on the ramming nipple. This creates that 1/2-inch void in the bottom of each section as shown in the sketch.

Sections #2 through #8 now get 10 grams of the composition rammed into them. Ramming that amount of comp yields delay increments that are 1-inch long in each section. Finally, I ram 5 grams of the composition in tube section #9, which produces a 1/2-inch long delay increment.

Then I allow the delay increments to dry overnight, using my drying box. They would dry in a few days if they were put in a warm location of the storage area.

Note: Often, directions for making candles specify ramming dry, granulated delay composition. At first I wondered if I should granulate and dry the comp, and I discussed this with Gary. His theory is that damp composition slightly wets the adhesive layer inside a paper tube, and when it dries it really glues the delay increment in place. Makes sense to me, and ramming it damp really creates a dense, hard plug of composition.

Once the tube sections and delay increments are dry, it's time to assemble the sections of the Roman candle, with lift charges and stars installed as I go along.

One homemade jig really helps at this stage, and ensures the assembled Roman candle ends up perfectly straight. I took this tip from one of the photos of Gary's process, and expanded upon it for my own purposes.

Homemade Jig for Assembling Roman Candle Sections

The jig is made up of two, 36-inch long pieces of 1-inch by 1-inch aluminum angle channel from the same section of Home Depot mentioned above. One of the pieces has two 1/4-inch diameter, 2-inch long carriage bolts and nuts installed in each end to act as feet to stabilize the channel during use.

I lay out the now-dry candle tube sections in numerical order on the jig. I also lay out my stars in the order in which I want them fired, along with a cup of FFg sporting-grade black powder from a gun shop.

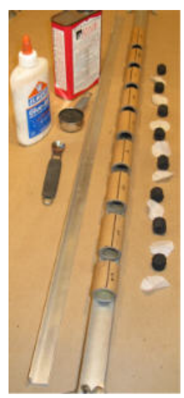
Of course, with a bit of dialing in, I could also use my homemade black powder for the lift.

I'll be using Elmer's glue to assemble the candle and a 1/4-teaspoon kitchen scoop to measure the black powder lift charges.

Assembling Roman Candle Tube Sections

(Click Image to Play Video)

I have cut out little disks of tissue paper the same diameter as the tube OD to go between the stars and the lift powder. The tissue prevents the black powder from migrating up past the star between the star and the inner wall of the tube. I want to keep all the lift powder down below the star to maximize the star's propulsion out of the tube.

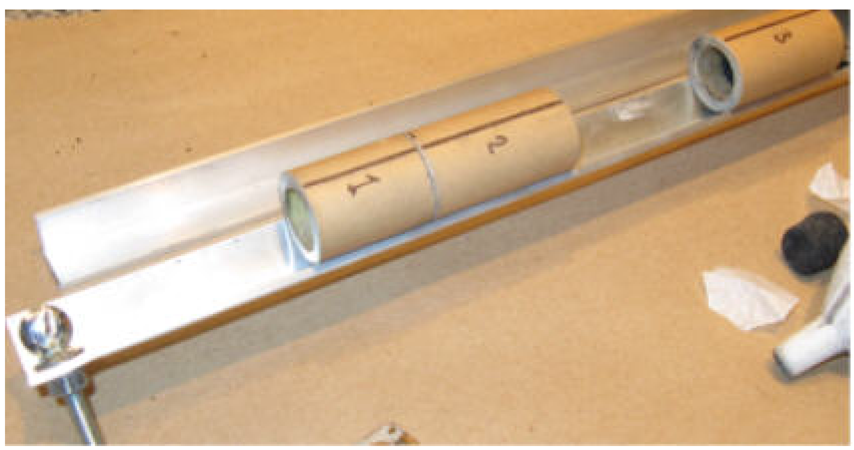


Roman Candle Parts--Ready to Assemble

To assemble section #1, I stand it, bottom down, on my workbench, and drop 1/4-teaspoonful of the black powder into the top of that section through a little funnel. I place a tissue paper disk over the top of the tube and push a star and the tissue down into the tube, seating it firmly against the black powder. Then I apply a thin ring of Elmer's glue around the top edge of that section.

First Roman Candle Section--Loaded with Lift Powder, Tissue Paper Disk and Star, Elmer's Glue Applied

I then push section #2, bottom down, onto the glued section #1, and wipe any excess glue off with a paper towel. Then, while I'm pressing those sections together, I pick them up and lay them into the trough of the alignment jig. Pushing them down on the jig ensures that they are perfectly aligned, and I push them together end-to-end to make sure the glue joint holds tight.



Tube Sections 1 and 2 Glued Together and Aligned on the Jig

Then I carefully pick them up, continuing to press the sections together, and stand the assembly upright.

Again I load lift powder, tissue, and star, and run a ring of glue around the top of the tube. Then, I assemble section #3 in the same manner as #2.

I repeat this process until all nine sections have been assembled and I have the whole shebang resting in the jig.

All Sections of Roman Candle Glued Together and Aligned

I could just press the sections together end-to-end, make sure they're sitting nice and straight on the jig, and let the glue dry. But, nooo, not me. I'm a bit more of a perfectionist than that.

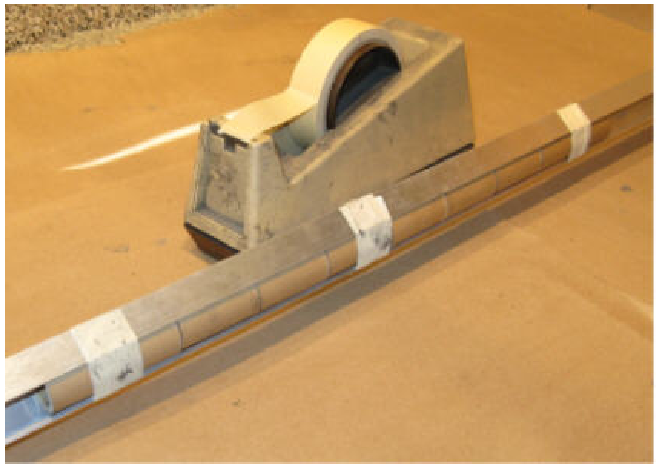
Note: That's kind of a funny revelation. When I was a kid, my Dad was always hollerin' at me for not cleaning up his shop after using his tools, or for not finishing up a project I'd started. Now, with my pyro avocation, I've gotten very particular about cleanliness in my shop in order to prevent serious accidents. And I've also come to know that meticulous work habits are a sure way to achieve consistency with my artistic fireworks devices. We live and learn. Sorry, Dad, and thanks; I finally got it!

So, I go one more step to really clamp the candle sections tightly, end-to-end as the glue dries, and to ensure my candle ends up perfectly straight when it's dry.

I lay another piece of the aluminum angle channel on top of the glued-up candle. (You were wondering what that extra piece was for in the pictures above, right?)

Roman Candle Sandwiched Between Two Aluminum-Angle Sections

Then I take 12-inch pieces of masking tape and put bands of the tape, stretched tightly with the sticky-side-out, around the aluminum and candle sandwich. This really holds the glued tube sections nice and straight.



Masking Tape, Sticky-Side-Out, Holding Tube Sections Straight

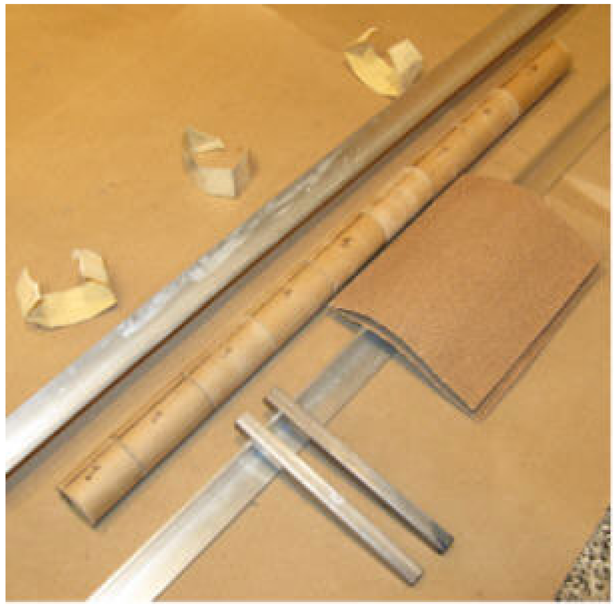
To really pull the tube sections tightly together as the glue dries, I install two 1/2-inch square, 4-inch long, pieces of steel bar, and two tightened strap clamps. Gently tightening the clamps snugs the tube sections together, but I don't tighten them so much that the ends of the tubes are damaged.

Of course, long rubber bands or elastic bungee cords could be used in place of the strap clamps. Pieces of wood could also be used instead of the steel crossbars.

Pulling the Tube Sections Together with Steel Bars and Strap Clamps

It takes 2-3 hours for the glue to dry sufficiently to allow the assembled candle to be removed from the jig. I remove the strap clamps and steel bars, tear the bands of masking tape, which remove easily because they were applied, sticky-side-out. Et voilà! A sturdy, straight Roman candle emerges.

A little 100-grit sandpaper quickly knocks any rough spots off the outside of the tube joints.



Dry and Sanded Roman Candle Removed from Jig

Well, let's stick a piece of visco fuse into this puppy, take 'er outside, and fire it up. Right?

Hold on there, podnah. Not so quick. The candle tube, as it currently is, really is not that strong yet. End-to-end glue joints don't have much structural integrity. If this particular Roman candle is going to survive the pressures when it fires, those joints will have to be reinforced a teensy bit.

Reinforcing and Finishing the Roman Candle

(Click Image to Play Video )

Enter fiber-reinforced, gummed, kraft-paper tape. One of my favorite supplies is a tape that I get from Staples: 2.8-inch wide, fiberglass reinforced, paper packaging tape, Staples #468231. This stuff is light, thin, and really molds well to the tube once it's wet.

Although I usually cut the tape to length with scissors because of the fiber-reinforcement, I use my manual tape dispenser as a wetting station to wet the tape. A sponge could also serve this purpose.

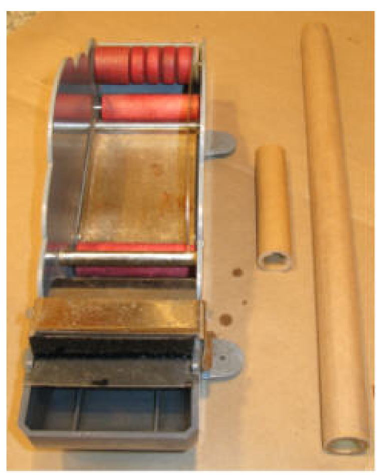
Fiber-Reinforced, Gummed Kraft Tape, and Manual Tape Dispenser

The glued-together candle is 18.5-inches long. I cut four 18-inch strips of the kraft tape to use to reinforce the tube. Each strip will run lengthwise on the tube, and will wrap around to cover about 3/4 of the tube circumference. Therefore, the four strips, staggered as they are applied, will create 3 complete layers of tape on the candle.

Four 18-Inch Strips of Tape for Reinforcing Candle Tube

I run a strip of tape through the dispenser's wetting station, and carefully apply it lengthwise on the Roman candle tube. Each strip has to be kept straight; the long edge of the tape needs to be parallel to the length of the tube. I get the first strip pasted down tight. Then, I butt the long edge of a new strip right up against the edge of the first piece of tape. Since each strip only wraps around 3/4 of the tube's circumference, once it is pasted down, the second piece of tape will overlap the first one some. I repeat this process for all 4 pieces of tape. That way the gaps in the tape get staggered around the circumference of the tube.

In between each strip application, I burnish the previous strip down nice and smooth with a scrap of paper tube. When all the strips are on, I give the whole tube a nice hard burnishing to produce a flat, smooth application of all the tape.



Kraft Tape Applied to Tube and Burnished Smooth with Paper Tube Section

Oh, yeah, that baby's looking nice, and feeling strong now. After inserting a hooked piece of visco fuse as shown in the candle cross-section sketch, I put on a wrapping of colorful paper, and tie the paper snug around the fuse. Now she's ready to take out, tape to a stake in the ground, and light.

Completed Roman Candle Ready to Fire

3 Finished Roman Candles

(Click Image to Play Video)

Conclusion

You might be thinking, "That was a lot of work to produce one, simple fireworks device, wasn't it?" Naah. Not really. There was probably about an hour's worth of work in the construction of that one candle, all told. It may sound like a lot of time and effort, but once you get going on the project, it's really not that complicated.

This new Smith method of making Roman candles is such an improvement and can produce such nice consistent results for the hobbyist, that I just can't help but be excited about it, especially after my past, less satisfying results.

When I carefully look at the videos of all the Roman candles I made using this new method, every initial delay after ignition was just about exactly 4 seconds, and every intermediate delay was within one second of 8-seconds long. It don't get no better than that.

On top of that, I'm already imagining creative variations on the above theme: mine-shot candles, crossette-comet candles, color-to-report-insert candles, married-comet ones, matrix-comet projectiles, and crackling-microstar-comet varieties.

Crack Balls

By Dan X.

I like to try to figure out how commercial fireworks products are made. Here's a case in point. I found these two little colored balls, which, when hit together, make a bang. You would think that if you coat a stone with something that will detonate or burn it would cause a chain reaction and burn all the way around, but it doesn't if you do it using the formula below.

Crack Ball Formula

Composition	Parts by Weight
Potassium chlorate	60%
Sulfur 35%	
Dextrin 2%	
Powdered glass	3%

The formula will work without the glass, but not as well. The glass helps it to detonate. I had some glass beads from a bead blaster. I used my mortar and pestle to ground it into a fine powder. You could do the same with broken Christmas tree ornaments or any other thin glass using a cheap coffee and spice grinder from Wal-Mart.

I screen the sulfur, dextrin, and glass together, mixing thoroughly.

Never screen chlorate with sulfur. Always use a different screen for the chlorate!

Then I screen the potassium chlorate separately, using a different screen, used only for the chlorate. Do not mix this with the previous ingredients. Keep it separate. Make sure it is reduced to a very fine powder, getting rid of any lumps.

First mix all the ingredients EXCEPT the potassium chlorate together with enough distilled water to create a slurry. It should be thick, but still runny, about the consistency of Elmer's Glue. Then stir in the potassium chlorate. If the mix becomes too thick, add a little more water. Add food coloring if you want. Then get one of your kid's paint brushes and paint it on a smooth round stone that you can find at your local creek.

Be sure the stone is fairly round, definitely not flat. If you don't want to paint the rock, you can dip the rock in the slurry. Let dry very well. If you are as impatient as I am, you could use a fan to speed things up a little. These things have to be very dry before you use them.

Don’t apply too thick a layer of slurry you don't want to put it on very thick. Sure, it’s a lot louder but it will most likely chip off if it’s too thick. If you put it on thin it's not as loud, but you get a lot of bangs for your buck. If you substitute nitrocellulose lacquer (thinned with acetone) for the dextrin and water you can put thicker coats on and it will be a lot louder, but more dangerous.

Use common sense when doing this because the rocks will actually start to fly! Try to use as round a rock as you can find. I made one crack ball with a rock about the size of a racquetball, but flat on one side. It landed on the flat spot and bounced straight up about 30 feet. No joke. The coating was only about 3/32 inch thick, so be very careful!

Emergency Fire Starter Pyrotechnic Formula

Pyrotechnic formula for creating a fire starter composition that is great for emergency fire starting.

Materials Needed

- Aluminum, 40-270 mesh
- Glycerin
- Iron oxide, red (CH8168)
- Magnesium, 3-10 mesh (CH1004)
- Magnesium, 10-60 mesh
- Potassium permanganate

Put about an ounce of this fire starter mixture underneath a pile of twigs and branches and put a few drops of glycerin on top of it. Stand back and in about 40 seconds the fire starter will burst into flames and set the twigs and branches on fire. Carry this fire starter composition in a Ziploc bag with a first aid kit. Parts are by weight. Keep dry and separate from glycerin.

Emergency Fire Starter Composition

Chemical	**Parts by Weight**
Aluminum, 40-270 mesh	20
Magnesium, 3-10 mesh	25
Magnesium, 10-60 mesh	40
Iron oxide, red	40
Potassium permanganate	125
Glycerin (keep separate)	

6

Equipment, Tools, and Processes

Using a Coffee/Spice Grinder to Pulverize Potassium Nitrate & Other Chemicals

By Ned Gorski

If one does not have a ball mill, coffee and spice grinders work well for grinding coarse potassium nitrate and other chemicals into a free flowing, fine powder.

Even though I have a ball mill, there are times when the coffee grinders come in handy for pulverizing smaller batches of chemicals. I have some Parlon, most of which will pass through a 40-mesh screen, but which has some larger particles as well. I'll take those larger bits and run them through the coffee grinder in order to reduce them to smaller particles.

Warning: Dedicate one grinder for use on oxidizers, and another one for use on fuels such as charcoal. We don't want fires or explosions when we're grinding chemicals. Never use a coffee grinder to grind complete or mixed compositions such as black powder.

I have found two kinds of coffee grinders: blade-grinders and burr-mills. Don't get a burr-mill; they don't work as well as blade-grinders. The blade-grinders have a stainless steel blender type blade that spins at high speeds in the bottom of the material cup, chopping the material into small bits in the process.

Blade Coffee Grinder for Pulverizing Chemicals

I have purchased many of the smaller, less expensive, blade-type coffee grinders. But here's the warning: they really don't last too long if you mill chemicals for a minute or two at a time. To use them, mill your chemicals in pulses of a few seconds at a time. I've found that shaking them while pulse-grinding gives me the fastest results.

Less Expensive Blade Coffee Grinders

Grinding Potassium Nitrate with a Blade Mill

The Kitchenaid blade mill has a larger hopper, and a larger, more powerful motor, and is rated to be used often. It costs a little more, but I'm hoping that it will last longer than the $13 WalMart models I've been using.

I put a half-cup, 4.6 ounces, of 12-mesh potassium nitrate into its hopper, pressed down on its lid to start it, and pulse-milled the powder for just under a minute, shaking the grinder now and then in the process.

Quite a bit of fine powder started to accumulate on the inside top of the clear lid as it milled. I dumped the ground up chemical onto my 100-mesh screen, and used a fine paint brush to clean off any that was clinging to the inside of the hopper or the lid.

About three-fourths of this milled powder would pass through the 100 mesh screen, and I set aside that which wouldn't to be ground again with the next batch.

Successfully Milling Potassium Nitrate with a Coffee Blade Grinder

Conclusion

Granular potassium nitrate can be dried if necessary, and ground easily with a ball mill or with a coffee blade mill, so that it passes through a 100-mesh screen and is ready to be used in pyrotechnic compositions.

Ball Milling 101

By Ned Gorski

Materials List

- Ball Mill (TL5010)
- Ball mill cabinet
- Barricading material
- Material to mill
- Milling media
- Tarp

How to Use a Ball Mill Safely and Effectively

I have some lump charcoal that just came out of my retort after I cooked it, and I want to turn it into airfloat charcoal. Or, the directions say to ball mill my rocket fuel for an hour. An article tells me to ball mill my star composition prior to pressing my stars.

Maybe I just got some crystalline potassium nitrate that looks like sugar, and I want to turn it into a fine, talc-like powder. And, perhaps most of all, I want to be able to make commercial-quality, high-performance black powder.

In Volume 1 of Bill Ofca's *Technique in Fire*, he states that "small particle size is important to good chemical reaction. The smaller the particle size, the greater the specific area, hence the most complete and fastest reaction."

Except for very small batches, ball milling is the best way for the amateur fireworker to reduce particle size of their chemicals. With small batches of individual chemicals, some folks use electric coffee mills to grind the chemicals into fine powder. NEVER grind mixed compositions in a coffee grinder, though. To do so would be to court disaster.

The Ball Mill

Lloyd Sponenburgh, in his *Ball Milling Theory and Practice for the Amateur Pyrotechnician*, tells us that his explorations into ball milling began when he was faced with having to do all that grinding with a mortar and pestle to achieve small particle size and intimately mix his chemicals. Lloyd's book is the most complete and practical resource for pyros I know of, for information on ball milling theory and for plans to actually build your own ball mill. Here's a shot of a nice, double-barrel mill I built based on his principles.

Homemade Double-Barrel Ball Mill

Ball milling replaces potentially unsafe hand grinding of chemicals and compositions. The crushing of the material is accomplished by the repeated falling of heavy balls onto it, over and over, inside the mill jar.

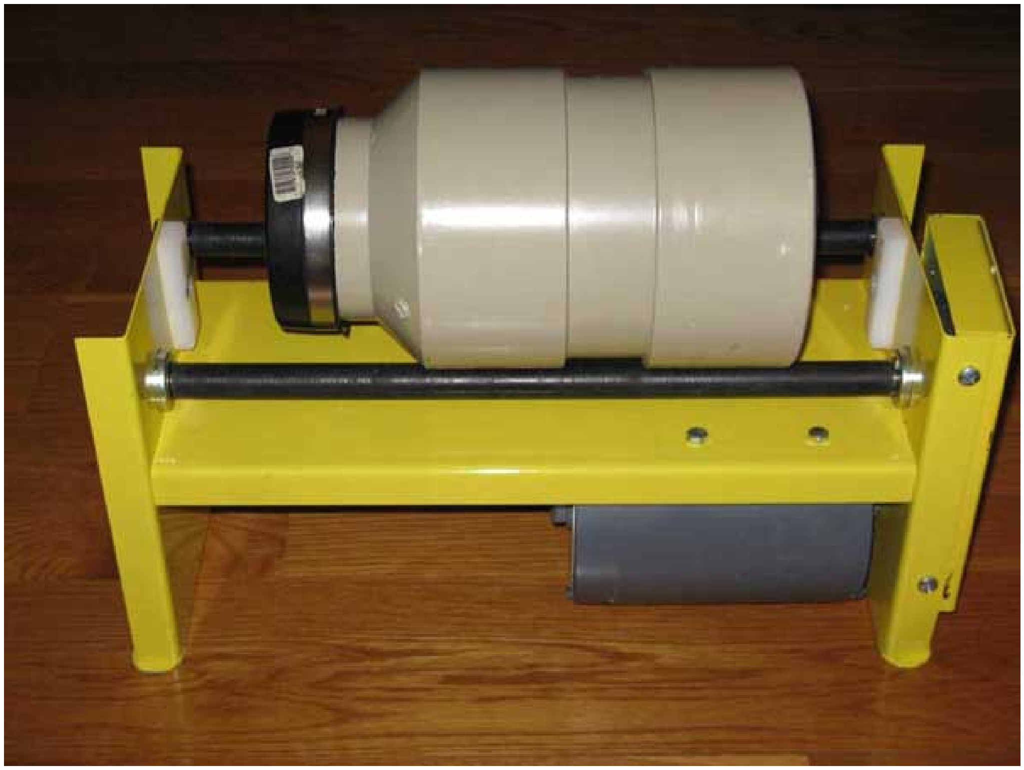
So, it sounds like I need a ball mill. I want my chemicals to have small particle size and be intimately mixed. What are my choices?

I can either get Lloyd's book and build my own ball mill, or I can purchase one. I'd still recommend getting the book for all of the other valuable milling information contained in it, though.

Skylighter sells a nice ball mill which comes with a mill jar. All you have to do is add milling media. More on that later in this article.

I'm also including how-to info for a few other milling accessories that will increase your milling productivity. You can make these yourself: a bucket screen to separate your milled powders from the media; a simple little soundproof cabinet to put your mill in: and weatherproof sandbags for safely barricading the mill.

Here's the ball mill you can get here at Skylighter. This model uses a one-gallon mill jar, as shown beow.



Skylighter's Ball Mill

This jar is constructed of PVC plumbing pipe and fittings per Lloyd's original instructions. How many jars or barrels do I need? If one is milling only black powder ("BP") compositions, or the individual chemicals that make them up (potassium nitrate, sulfur, charcoal, and dextrin), then only one barrel is needed.

If I am milling some other chemicals by themselves such as barium nitrate, strontium nitrate, or ammonium perchlorate, then I want a barrel/media combination dedicated to each of those individual chemicals. This prevents cross-contamination between the various chemicals that are milled.

Black powder compositions are the only mixed chemical compositions I mill, and they are never milled with any metals in them. If, say, a charcoal star formula calls for the inclusion of any metal, such as ferro-titanium or titanium, the metal is added to the black powder base composition after it is milled.

The Media

The ball mill consists of the mill base and the mill jar. There's one more important component to a ball mill, though: the media. The balls of heavy material which fall upon and crush the chemicals are called the milling media. Here's the media I bought to use in this mill. I got the packages of lead balls from my local gun shop, which sells them as muzzle loading bullets. They can also be purchased online.

Ball Milling Media - .50 Caliber Lead Balls

It took 12 boxes of these 1/2" diameter lead balls (from Bass Pro) to fill the mill jar half full, which is the ideal media "charge" in this1-gallon jar setup. The total weight of the media is 30 pounds.

That is an important note: Fill the mill jar half full of media for optimal milling. If you use less, your milling time will either be longer, or the grinding will be insufficient. The most frequently reported milling problem we hear at Skylighter is from people whose black powder was weak because they did not use enough media.

After I got these lead balls, I ran the mill with them in the jar along with 4 cups of airfloat charcoal I had on hand. This was in order to clean off the oil, grease, and/or wax that came coated on the new balls. Then I threw that batch of charcoal out. I did not want that "crud" to end up in any good chemicals or BP that I milled.

Each type of media has its advantages and disadvantages.

See Learn More About Milling Media Pro's and Cons, and How to Stay Safe.

The Material Charge

Well, now we have a mill base, a mill jar, and the media to go into it. How much material can we put into the jar, and how do we go about grinding it?

"Well, Ned, we just fill the jar the rest of the way with chemicals on top of the media and turn her on, right?"

"Nope," said Ned.

For efficient milling, the ideal amount of stuff we are grinding, the "material charge," is just enough to fill all the voids between the media and then just a little bit more. This turns out to be an amount of material that fills the empty mill jar 25%, or 1/4 of the volume of the mill jar, after the material has been milled.

Now, in practicality this can be a bit hard to determine. How do I know how much lump charcoal to add to the jar to end up with enough airfloat charcoal to fill one quarter of the jar? How can I tell how much potassium nitrate, charcoal, and sulfur will mill into just the right amount of black powder mill dust?

Trial and error, that's how. I have found that if I put my media in the jar and then add enough of my cooked and crushed lump charcoal to just loosely fill the jar the rest of the way, I will end up with about the right amount of airfloat to fill the voids in the media and cover it by a bit more when the run is done.

It's easy enough to take your empty mill jar and add individual cups of water to it to determine its volume. Then divide that by 4 and that's the amount of, say, potassium nitrate to add to a mill jar run to finely pulverize it. You get the idea. The jar and barrel shown above both have a one-gallon volume which is 16 kitchen measuring cups. So a milled material charge of 4 cups in volume is what we are shootin' for.

In making black powder, I've found that a material charge of 15 ounces of potassium nitrate, 3 ounces of airfloat charcoal, and 2 ounces of sulfur produces the most efficient quantity of BP mill dust.

The density of the mill dust, and therefore the volume it occupies, will vary a bit with the density of the charcoal used. Pine charcoal is quite a bit less dense, occupying more volume per ounce than commercial airfloat. Therefore the mill dust produced with the pine charcoal occupies more space after it has been milled than commercial charcoal would.

But we're shooting for a material charge that is approximately 25% of the jar's volume, and the 15/3/2 amounts that I listed above will be close enough, whatever charcoal one uses. If one is finicky, these amounts can be adjusted with experience and experimentation.

Ball milling can be noisy, especially when PVC jars are used. Those balls clattering around in the jar, over and over, for hours, can get on one's last nerve, even though the mill is a hundred feet away. See Build a Cabinet to Soundproof Your Ball Mill.

Locating the Ball Mill for Safety

Ball mills are noisy. And there is always the risk of explosion when BP comps are being milled. For these reasons, a remote milling site which is protected from people and property is necessary. Starting the mill remotely, either by plugging in a 100' extension cord that runs to it, or by setting the mill time on a timer, prevents you from standing next to it while it is running. (Notice the timer in the photo of my double-barrel mill and in the photo below.)

Once a nice, safe, remote location is determined, set up a level platform for your ball mill.

Remote and Level Location for Ball Mill

Barricading the Ball Mill

I've mentioned that a mill explosion is always a possibility when complete black powder compositions are being ball milled. So try and place your mill behind a natural barricade like a mound of earth, a rock, or a big tree. If you can't do that, barricading the ball mill with sandbags, stacks of firewood, 5 gallon buckets of water or dirt, or something similar is a great idea. This barricade will absorb the energy and flying debris in the event of an accidental explosion.

You can see in the photos that I have the mill at the end of an extension cord, on a timer, and nestled against a stack of firewood. I then surround the mill with bags of all-purpose sand that I've wrapped with heavy duty garbage bags and duct tape. I want my sandbags to withstand the weather and handling and last a long time.

Making Weather-Proof Sand Bags to Barricade the Ball Mill

Barricading and Tarping the Mill

Installing a tarp to protect the mill and timer from sudden inclement weather is a good idea.

Winter Protection

I check my mill temperature now and then during mill runs. I remotely stop the mill (by disconnecting the power cord at the end away from the mill). Then I adjust the vent holes and lid accordingly to maintain a 70-120 degree F temperature in the cabinet.

I do not want to overheat my motor and ruin it. I make notes in my notebook of the various air temperatures at which I do all of this so that in the future I can duplicate these adjustments.

Here's what my notes look like:

- Outside air temperature: 30 degrees F

- Bottom vent holes in cabinet open, lid on tight.
- Black powder mill run
- Start of mill run, cabinet temperature: 30 degrees F
- 10 minutes into run, mill temp: 57 degrees F
- 20 minutes into run, mill temp: 64 degrees F
- 30 minutes: 73 degrees
- 40 minutes: 81 degrees
- 50 minutes: 90 degrees
- 60 min.: 95 degrees
- 70 min.: 105 degrees
- 80 min.: 108 degrees
- 90 min.: 114 degrees
- 110 min.: 117 degrees

I then stopped the mill remotely and uncovered it. The inside of the cabinet felt warm. The thermometer's remote sensor had been placed down near the motor which felt pretty warm to the touch, but not so much that I would be worried about it being damaged.

Upon opening the jar, the mill dust was still loose and lying around the media and the dust was looking very fine and well milled. The media was only mildly warm to the touch, I'd guess in the 80-90 degree F range.

Conclusion: On a cold winter day like today, the configuration of the mill and the vents worked well. It got nice and warm, though, so I'll pay close attention to these readings on a hot summer day and adjust accordingly.

Keeping a notebook of info like this is very useful in the long run. Of course, if one has a farm out in the country and can set up a tent or erect a shed to use for ball milling, and there is no danger of unsuspecting bystanders getting near it during

Now, I can just hear some of you saying, "Jeez, all I want to do is make some homemade black powder and some stars and put a shell together and fire it. Do I really have to go to all this trouble? Aren't you being a bit finicky and paranoid, Ned?"

This ball mill, and the cabinet, and the sandbags, and the buckets I'm about to show you, and especially the efforts put forth to do all of this the right way all amount to an investment in an art which can reap rewards for a lifetime. There really is no substitute for preparing to perform these tasks safely and you'll sleep better at night knowing you have done so. Do you want to hurt some little kid?

I have never had a mill explosion, and I do not know anyone who has. I have heard of them, though. All of this is cheap insurance just in case your next mill run is the one that explodes.

The Mill Run

The jar is charged with media and material. The mill is set up and barricaded. The timer is set for the duration of the mill run. My thermometer is up and running. I plug my 100-foot extension cord into the mill, then go back to the house and plug that end in, and let 'er rip.

Coming back after the amount of time set on the timer, when she's stopped running, I uncover it all.

It's time to dump the contents. But, the media and the material are all mixed together. How can I separate them? The fastest way is to use bucket screens. Here's where you can learn to make them: How to Make a Bucket Screen for Separating Media and Material.

Separating Media and Material

Note: Even a cloud of charcoal dust can create an explosion if it is ignited. Do the following step outdoors away from sources of ignition, while wearing a good dust mask/respirator.

After a mill run, the mill jar is opened and the contents are carefully poured into the separation bucket screen, which is resting in the receiving bucket. After placing a lid loosely on the top of the separation bucket, with a swirling motion the material is easily separated from the media. The separation bucket is then removed, the lid is put onto the bottom bucket which has the milled material in it, and the media is poured back into the jar.

Keep the material covered by the bucket lid until it is transferred to a storage bucket and lid. If it is a completed black powder composition, always minimize the amount of time it is exposed to any possible source of ignition.

Rather than trying to pour the media directly from the separation bucket back into the jar, it's easier to pour the media into a smaller, more pliable bucket. This smaller bucket's mouth can then be bent into an oval for pouring the media back into the jar.

To keep from cracking the bottom of the PVC jar, tip the jar onto its edge, and pour the media back in slowly and carefully.

Pouring the Media Back into the Ball Mill Jar

Practice good housekeeping and maintenance with your mill. Clean up any spills immediately, and lubricate bearings as necessary. Tighten screws, nuts and bolts occasionally, and check the whole rig for wear and tear regularly.

You should never be near the mill when it is turned on, or when it's running, so there should be no danger of your shirt sleeve or ponytail getting caught in the moving rollers. Right? That is a directly driven drive shaft in there, so exercise appropriate caution around it.

Summary

So, we've covered ball milling, including:

- What purposes are served by milling.
- What can and cannot be milled.
- The mill base, jar, media, and material charge.
- A cabinet for the mill.
- Locating and barricading the mill and general mill safety.
- Monitoring the mill's temperature during milling.
- Mill run times.
- A nice separation screen for separating the media from the material.

Build a Cabinet to Soundproof Your Ball Mill

This article on building a ball mill cabinet, by Ned Gorski, is a side article that originally was part of the Ball Milling 101 article printed in Skylighter Fireworks Tips Newsletter #91.

Materials Needed

- Liquid Nails (Glue)
- Nails, screws or pneumatic stapler
- Plywood: 2 pcs. 24x48", 3/4" thick
- Razor knife
- Suspended ceiling tile: 4 pcs. 24x24", 1/2" thick
- Thermometer

Ball milling can be noisy, especially when PVC jars are used. Those balls clattering around in the jar, over and over, for hours, can get on one's last nerve, even though the mill is a hundred feet away. Another point is that milling efficiency can rise dramatically with temperature of the material being milled. BP made from mill dust milled at 40 degrees F might be only 2/3 as powerful as BP milled at 90 degrees F.

One additional goal is that we want to be able to easily pile sandbags, firewood, buckets of water, buckets of dirt, or the like, around and on top of the mill to barricade it for safety purposes. These three points lead us to a nifty little project for this milling discussion: an insulated cabinet to put the mill into. The cabinet really deadens sound, increases the temperature around the mill and jar, and easily supports any barricading materials that are stacked around and on top of it. You can make this cabinet in a couple of hours.

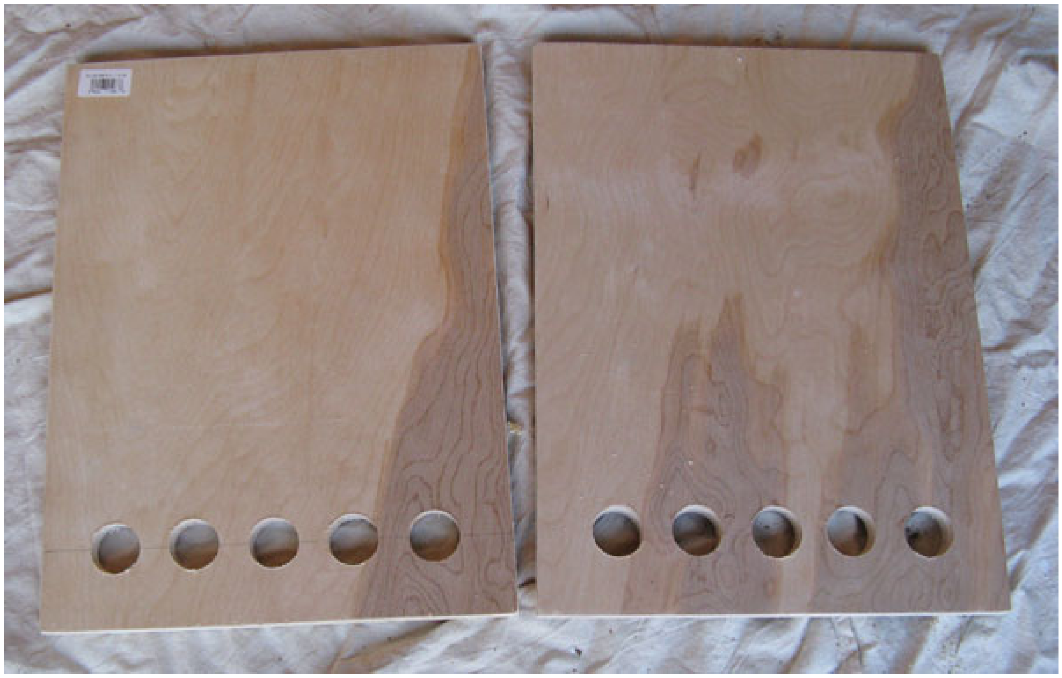
If you can build a plywood box, you can easily build this cabinet. I start with two pieces of 3/4" birch plywood - 24" x 48", and 4 pieces of half inch thick, suspended ceiling tile - 24" x 24".

Ceiling Tiles for Sound Insulation and Plywood

From the plywood, I cut a cabinet bottom - 13.5" x 24", two sides - 16" x 24", two sides - 12" x 16", and a top - 14.5" x 25".

Cabinet Bottom, Sides, and Top

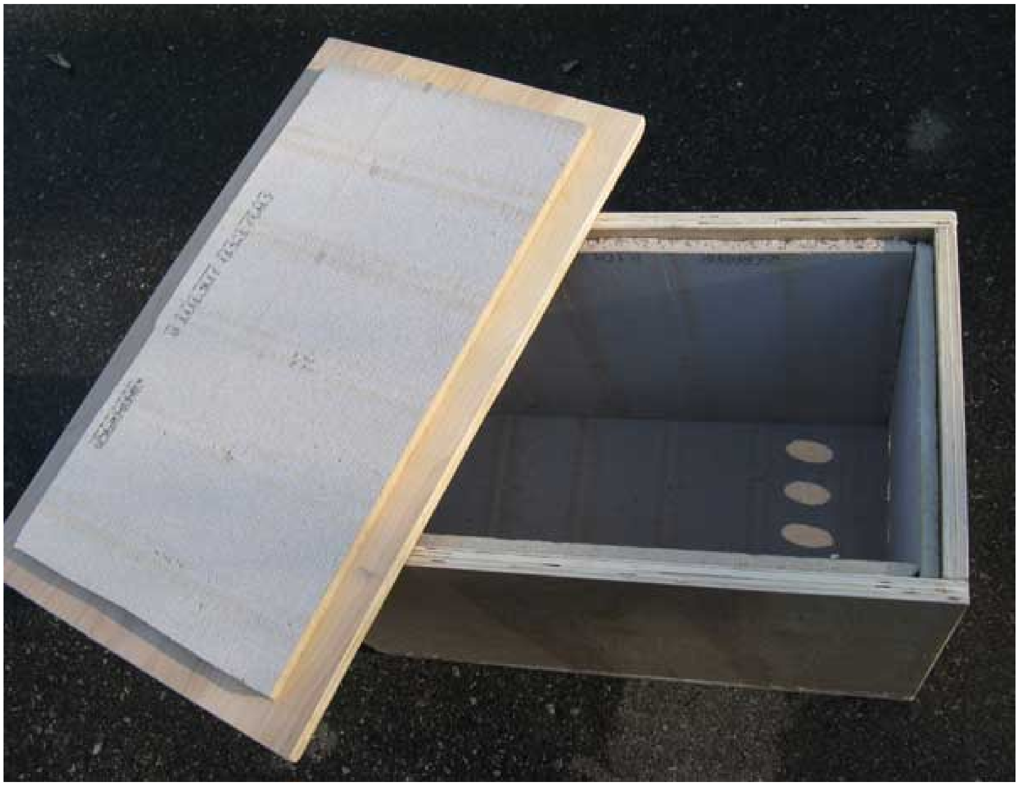
Then, I drill some ventilation holes in the sides as shown below. I want to be able to allow some air flow through the cabinet so the motor does not overheat.



Ventilation Holes Drilled in Cabinet Sides

Then, using Liquid Nails glue, and nails, screws, or a pneumatic stapler, I assemble the bottom and sides. Using more of the glue and a razor knife, I cut and install the ceiling tile insulation in the cabinet on the bottom and sides, and onto the bottom of the lid. Then I extend the ventilation holes through the insulation.

Assembled Box and Glued Insulation Tile



Completed Ball Mill Cabinet

When it is installed, the lid projects 1/2" beyond the sides of the box for easy installation and removal.

Now, the ball mill cord can be fed out of one of the vent holes, and the mill can be installed into the cabinet.

Completed Cabinet with Ball Mill Installed

One nice addition to this assembly is a little thermometer I picked up at Home Depot, placed in the cabinet or attached to the lid. We are shooting for an ideal milling temperature in the range of 70-120 degrees F. If the temperature is checked, it can be adjusted by opening or blocking the side vents, propping the lid open a bit with a block of wood, or the like. (Don't install any temporary blocking in a way that would allow it to drop onto the running mill and jam it--that could cause a fire.) I use this little wireless indoor/outdoor thermometer unit placing the sending unit in the mill cabinet, and the readout unit in my shop.

Wireless Thermometer

I have found, as did Lloyd Sponenburgh, that the hotter the mill is during operation, the hotter the BP that will result. I also concur with him that at the higher temperatures, the BP mill dust will start to form a solid clump at one end of the jar during milling. The time it takes to get to this point depends on what media is being used.

Lead media can cause this in about 2-3 hours at 90 degrees F. Other media can cause this to occur after only 1 to 1.5 hours of milling.

I try to time my mill runs to stop just as this aggregation begins to happen. As the powder clumps together, there is less and less of it between the media balls, causing them and the jar to wear out much more quickly.

How to Make a Bucket Screen for Separating Ball Mill Media from Ground Material

By Ned Gorski.

Materials Needed

- Drill
- Hardware cloth: 1/4", 24"x48"
- Jigsaw
- Plastic bucket: 4 pcs., 5 gallons
- Pop-rivets: 3/4"-11/16" long x 3/16" diameter
- Tape measure
- Sharpie marker

How to Make a Bucket Screen for Separating Media and Material

Here are the plans for a really useful addition to one's ball milling arsenal, -- a separating bucket-screen to quickly separate milling media from powder.

I start with 4 plastic, 5 gallon buckets, with the handles removed from them, and set one bucket aside. That will be the catch bucket that the milled material falls into as it is separated from the milling media.

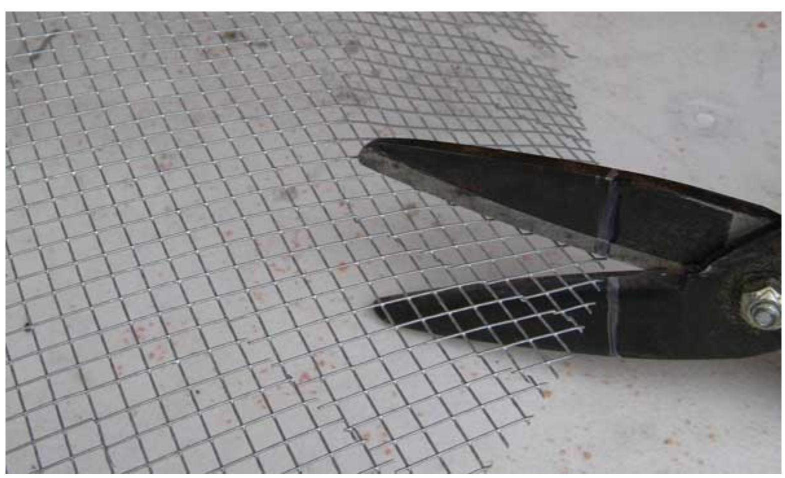
Tools and 3 Buckets to Be Modified

Using the tape measure, a Sharpie (magic marker), drill and jigsaw, I then cut the bottoms of two of the buckets off 9-1/2" down from the open top. I cut the third bucket off down 3" from the top, just below the last 'rib' on the outside.

Then I mark and cut a circle out of the 1/4" mesh wire hardware cloth that I bought, about 24" x 48". This circle is 3" larger in radius than the bottom of one of the buckets, or 16-1/2" in diameter.

Cutting a 16-1/2" Diameter Circle Out of the Screen

I cut some slices 2-1/2" into the edge of the screen, about every 1-1/2".



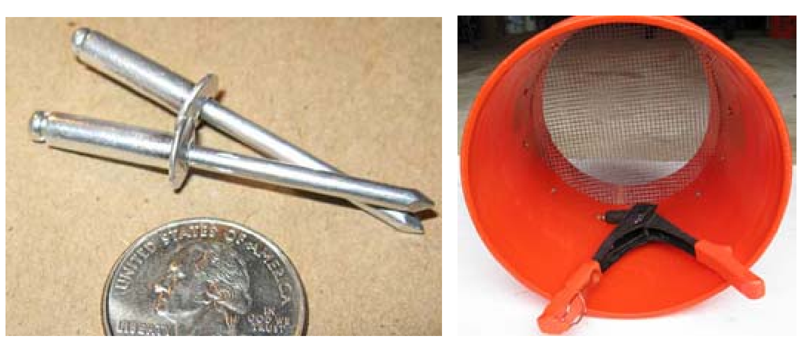
2-1/2" Long Slices Cut into Edge of Screen

Then, using gloved hands, I mold the screen onto the bottom of one of the 9-1/2" deep buckets.

Screen Folded onto One 9-1/2" Deep Bucket

Now, I push the other 9-1/2" long bucket down over the one with the screen folded onto it, sandwiching the screen between the two cut-off buckets. I then slide the 3" tall bucket section down onto the whole assembly. I drill 3/16" holes into the middle of that 3" bucket section, about every 3" to 4", making sure that the holes penetrate all 3 bucket sections and the sandwiched screen.

I then install 3/4"-11/16" long x 3/16" diameter pop-rivets into those holes, from the inside. These rivets pull the whole assembly together, and lock the screen in place.



Pop Rivets and Riveting

When the media and material are being poured into this separation screen, the screen takes a beating. It can wear out over time. So, to preserve the life of the assembly, I make one more little component. I cut a circle out of the screen just a tad larger than the inside of the bucket where the screen is locked into it. Then I push this 'sacrificial' piece of screen down onto the embedded screen, locking it into place.

Cutting the Reinforcing Screen and Locking It into Place

And that's it -- the completed separation bucket assembly. The final 3" bucket ring that was installed keeps the separation bucket-screen from settling too far into the receiving bucket so that it can be easily removed after the separation of the media and material.

Basic Pyrotechnic Hand Ramming Technique

By John Werner

Learn hand-ramming techniques used to ram pyrotechnic compositions into tubes for various pyrotechnic devices, and for making clay nozzles.

Materials Needed

- Bentonite clay (CH8078)
- Mallet (TL4040)
- Pyrotechnic compositions
- Rammers (drifts)
- Ramming post
- Tubes

For anyone wishing to progress beyond making items such as bangers or salutes, it is necessary to become familiar with the techniques of consolidating pyrotechnic compositions in a tube. Known as charging or ramming, the oldest and most common method is done by hand with a mallet and drift.

This hand ramming is easy to learn and can be used for making such items as sky rockets, fountains, gerbs, spolettes, saxons, and drivers. Hand ramming still widely used in large scale manufacturing plants and in many instances is a faster and definitely cheaper method of loading pyrotechnic composition than trying to use small hydraulic jacks and presses.

It is especially versatile when making up prototypes or small numbers of devices. A major drawback to hand ramming is that it is unsuitable for friction or shock sensitive pyrotechnic compositions, such as those used for strobe or whistle rockets.

Equipment Materials

Mallet: Generally wood, rawhide or rubber "dead blow" mallets work best. A broad face is preferable and the mallet should be large enough that its weight does most of the ramming work rather than your arm. Avoid steel carpenter or machinist's hammers. Some people like a round mallet of the type woodworker's use for striking chisels.

Rammers (drifts): These are simply rods or dowels made to fit the internal diameter (I.D.) of the tube being loaded. They should be an easy slide fit without binding on the walls of the tube. If too loose, however, the surface of the pyrotechnic composition will not be properly compacted near the tube walls.

Suitable materials include wood, brass, stainless steel, aluminum, and some plastics. Each material has a different "feel" when ramming.

Plastic, such as PVC rod, has limited use and has a very spongy feel when struck. However, it is cheap, easy to cut and holds up well. Wood is also cheap and easy to cut and shape. Hardwoods, like birch or maple, have a fine, even grain and have a more solid feel than plastic. Wood is simple to reduce in diameter without complicated machinery if a slightly looser fit is required. It is soft enough that if the face of the rammer accidentally strikes the spindle used to form a clay nozzle, there will be little or no damage done to the spindle (which is usually metal, and can be costly to replace).

There is less chance too of accidentally causing any pyrotechnic composition to ignite if pinched between spindle and rammer. Metal rammers made from brass, aluminum, or stainless steel have a very nice, heavy, solid feel, but may be expensive and hard to machine without a lathe.

Brass is especially nice to use in small (3/8" or less) diameters, when wood is not rigid enough. Wood is fine for most other instances and is an inexpensive way of building an inventory of rammers in different diameters and lengths. Steel should not be used because of spark hazards.

Ramming Post: In order to get even, solid consolidation of pyrotechnic compositions, a suitable support surface is needed underneath the item being loaded. There is nothing worse than trying to ram on a weak or springy surface. Ideally, the ramming surface should be a post with a smooth level top held upright by being buried part way in the ground.

The actual top does not need to be more than four to six inches square. It should be as heavy and solid as possible. Material can be wood or cast concrete. If a portable post is desired, it can be a section of railroad tie, a section of 6x6 beam, or a tall box made of plywood and filled with sand.

A cap made from medium density fiberboard (MDF board), solidly attached to the top of the post makes a great smooth surface that is easy to brush clean. Avoid cracks or crevices in the post where loose powder can collect. Always separate the ramming surface from whatever table or surface is used to hold the pyrotechnic composition being rammed. If this is not done, the vibrations from the ramming process will tend to separate the components of the unused pyrotechnic composition.

The arrangement of post and table should be of a convenient height and layout such that all pyrotechnic tools, pyrotechnic composition, and finished devices have a designated location to make the ramming process go smoothly.

Tubes or drifts rolling off the table interrupts the flow of work increase the chance for accidents. Locating everything within easy reach will make the work go much more quickly with fewer mistakes.

Tubes: For the most part, parallel or convolute wound tubes are used when hand ramming compositions. Wrapping a single sheet of paper around a metal mandrel makes a convolute wound tube. The mandrel's diameter is the required internal diameter of the tube. The length of the paper when rolled up completely will determine the wall thickness of the tube.

Convolute tubes can be machine rolled or hand rolled if an unusual size is needed. Generally, heavy walled tubes are used in order to withstand the blows from the ramming process and to keep the tube from splitting. Thinner walled tubes can be used also if properly supported in sleeves and molds.

Purchased tubes come either cut to length (with nice square ends) or in longer sections straight from the rolling machine (which you can cut to the length needed). Unless one owns a lathe to make a clean cut, a chop saw with a fine tooth blade will give a good square, albeit somewhat fuzzy, end.

Clay: The most convenient and widely used method for plugging tubes and making clay nozzle orifices is to use dry powdered clay. Bentonite clay works well, as is, for most applications. Some people like to treat the clay with additives such as wax, various oils, or graphite to cut down on dust and to facilitate the clay’s loading and packing qualities. Do not ever add water when making clay nozzles.

Pyrotechnic Compositions: Hand ramming as opposed to pressing with pneumatic or hydraulic presses, can be more dangerous when utilizing pyrotechnic compositions that are friction and shock sensitive. Black powder based formulas used in fountains, gerbs, and rockets are generally safe, although the inclusion of metals such as titanium should be treated with caution and respect. KNOW YOUR COMPONENTS.

Safety: Any loading and ramming of pyrotechnic devices should be done in a remote area, preferably outdoors in an area protected from the wind. Pyrotechnic composition in the area should be limited to only the material being used and in uncovered amounts not exceeding one or two pounds. A good quality dust mask should always be worn when hand ramming, as there will always be dust floating in the immediate area. Follow all standard safety rules concerning static, sources of ignition, etc., which one adheres to when working with any pyrotechnic process.

How to Make a Simple Star Dryer

Learn how to build a simple drying box for drying out firework stars and hygroscopic materials.

Materials Needed

- Desiccant bag/calcium chloride (CH8106)
- Glue
- Plastic container, rectangular. A shoebox-sized plastic container; Tupperware works fine.
- A piece of screen that fits on the bottom of the container; stainless steel is best
- Staples
- Two lengths of 1 x 1 wood that are as long as the longest sides of the container

The basic concept of a hygroscopic material storage box is to keep materials and components that absorb moisture from the air dry. You will need the following materials:

First, butt the 1 x 1’s up against the sides and bottom of the box, one on each side, inside the box. The 1 x 1's are just lying there. Apply some glue to help secure the wood in place. Then staple the screen to the pieces of wood. Now all that’s left to do is to sprinkle a 1/2’’ layer of calcium chloride on the bottom of the box.

The calcium chloride continuously absorbs any moisture in the air around it and keeps hygroscopic materials stored on the wire "shelf" dry. If any moisture is present in the material stored in the box, the calcium chloride will dry it out. Keep the top on the container as air-tightly closed as possible, because after awhile the calcium chloride will get mushy and will have to be replaced. Use this box to dry firework stars, comets, firework star compositions, oxidizers, or any other hygroscopic materials in your pyro projects.

How to Build an Electric Drying Chamber 1

This article on making a drying chamber, by Ned Gorski, is a side article that goes with the Nice Shells in 2-1/2 Days - Part 2 article printed in Skylighter Fireworks Tips Newsletter #92.

Materials Needed

- Ceramic disc portable heater
- Plastic tub or plywood box
- Vent grill

The chamber is simply a Rubbermaid plastic tub with a vent grill fitted into the lid and a small ceramic disc portable heater ducted into the side of it. IT IS IMPORTANT TO USE THIS TYPE OF HEATER, AND NOT ONE THAT HAS GLOWING ELECTRIC COILS. WE DON'T WANT BURNING SPARKS COMING OUT OF IT.

Simple Homemade Drying Chamber and Screens

The screens are simple wood frames with aluminum window screening stapled onto the bottom of them, and retaining wood strips applied over the screen. Note the little rubber bumper feet that have been installed on the bottom of the screens to allow for spacing and airflow between them.

There is one modification I might consider if this project was being carried out in very humid conditions. I'd think about ducting de-humidified air from a dehumidifier into the front, intake side of the space heater. Warm, moving, dry air makes for ideal drying conditions.

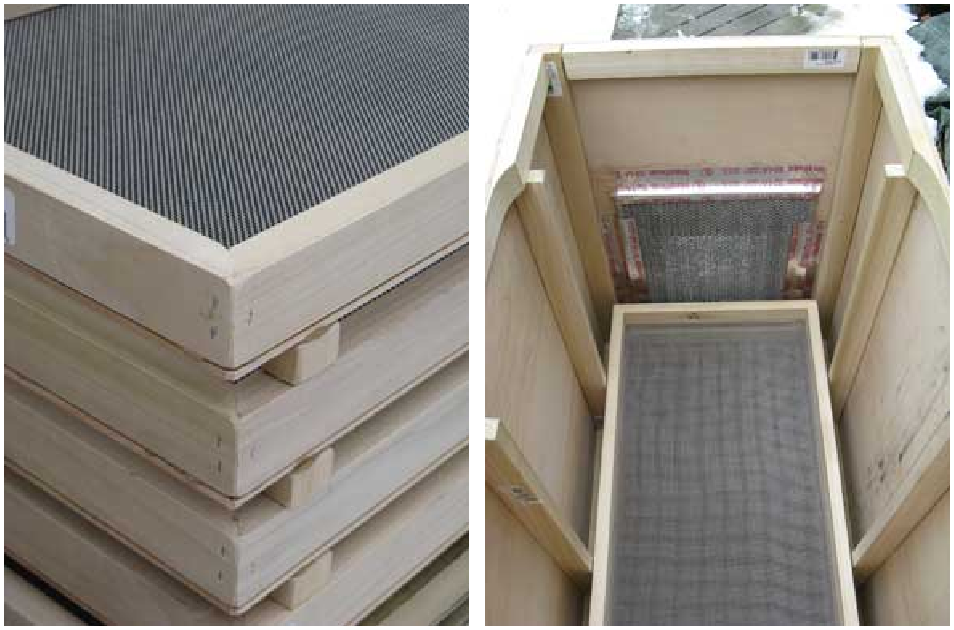
How to Build an Electric Drying Chamber 2

I recently upgraded my original portable drying chamber. I constructed a lightweight plywood box with a duct for the heater to sit in. I also made new screens, 14" x 24," using 12-mesh stainless-steel screening. This screen is much more rigid than the original window screen that I'd used.

It does not sag, so the components that are drying on the screens are more easily, uniformly distributed. They say, "A picture is worth a thousand words." Here are a few thousand words' worth, describing this new drying chamber.

Drying Chamber and Stackable Screens

Heater, Duct, and Cover Detail of Drying Chamber



Screen Detail and Interior Grill

The interior grill is a safety precaution to keep any critters and/or debris out of the chamber while the heater is running.

Screens Stacked in Drying Chamber

Notes on Milling Media

Lead-Antimony Alloy for Grinding Media

Lead is getting hard to find. My local scrap yards won't sell it to the public any more. Wheel weights seem to be coming in different alloys now too, and not knowing what's in it makes me a bit nervous. I did find a good source though - hit your local gun club or sporting goods store that carries reloading supplies and buy the lead shot they use to reload shot gun shells.

I paid around $15 for a 25 lb bag, so it's reasonably priced and you know what you are getting - pure lead with 5% antimony in it (and the antimony makes it a bit harder so it lasts a bit longer).

Faster Way to Cast Your Own Grinding Media

Spike Tharp, as deep-pocketed a pyro as I know, sent this one in for thou who art ball-milling media challenged. Thanks, Spike. You cain't hide money.

The procedure Lloyd outlined in his book for casting media works, but I'm just not patient enough for it! I found that using a cannon ball fishing sinker mold works great. For a Sponenmill 2 oz. individual media are about right. A company named "Do-It" makes cannon ball sinker molds, their model CB-4-AB mold has four molds in one unit - 1, 2, 3, and 4 oz. Do-It has a web site at: www.doitmolds.com, and their products are available from many mail order as well as online fishing supply stores. The aforementioned mold averages about $30 from many sources I found on the Internet.

Ball Milling Media for Pocket Change

Here's a tip for all those pyro types that mill their own black powder. Much has been discussed about using a non-sparking media, and whether or not ceramic balls will cause an explosion, possible health problems from lead media, etc.

I've been using good ole U.S. of A. currency discs for that purpose for the last five years with nary a problem. The nickel and quarter denominations work very well. They don't spark; They are about impossible to wear out, and they're cheap. I use 12 quarters and 20 nickels to mill 100 grams of lift in about 3 hours. The coins cascade in landslide fashion down the inside the tumbler and provide a shearing/rolling action to the mix.

I mill the charcoal and potassium nitrate for 2 hours and add the sulfur for the last hour. After pressing, corning, and screening, my lift BP is as good as any commercial product I've tried. My milling tumbler is an ancient '70s model Thumblers Tumbler with a rubber jar of about 3 pounds capacity. It is soooo… old I had to replace the jar and sealing ring last month, the motor let go about 1986 and I replaced it with a continuous duty rated fan motor which continues to grind on and on.

Cascading Comets Mortar Rack

Thanks to Geoffrey Kassin for this one.

Learn how to make a mortar rack to shoot individual firework stars like mini comets.

Materials Needed

- Black powder, Fg
- Dremel with sanding and routing bits
- Drill bit, 1/4"
- Firework stars
- Hole saw or butterfly bit, 13/16"
- Large wooden board
- Tubes, 1/2" ID (TU1028)
- Visco fuse (GN1000, GN1001, GN1004)

One summer, during the weekend following 4th Of July, some friends of mine who have a band were scheduled to play a private party. I furnished some flash pots, some small soup-can Cremoras (fireballs), and about 80 class C artillery shells. Everyone loved it.

Then at the Pyrotechnics Guild International convention in Fargo, North Dakota last August I saw the R.E.S. close-proximity display. WOW! I was inspired to try and figure out how I could do a similar show on a dime-store budget. I had about 400 1/2-inch diameter dragon egg (crackling) firework stars, about 300 3/4-inch emerald green to white flitter firework stars.

The question was how could I fire them in precise, rapid succession? I do not have the money for 700 electric matches and thousands of feet of shooting wire; and I cannot get quick match. I lay awake in bed for many hours trying to think of a solution.

The solution for the tubing came quickly. I would use 1/2-inch and 3/4-inch I.D. schedule-40 PVC conduit (you could also use 1/2-inch ID cardboard tubes from Skylighter, a little safer than PVC). That solved the tube problem, but how was I going to fire them in precise, rapid succession? Friday night, I finally figured it out.

Saturday, I began building one short rack of 50 1/2-inch tubes. I went to Home Depot and bought two 12-foot lengths of 1/2-inch I.D., schedule 40 PVC conduits and one 12-foot long 1 x 3 maple board. (I chose maple, because it is hard, the surface is smooth and straight and I can get a good seal between two pieces of it.) I cut the PVC into 4-inch lengths. I cut the 1 x 3 in half into two 6-foot pieces.

Next, I drilled a line of 47 13/16 diameter holes about 1.5 inches apart, all the way through one piece of 1 x 3. It's important that all the holes be in a straight line. Using my Dremel tool and a sanding-drum bit, I slightly enlarged each hole enough so that I could glue each 4-inch length of PVC tightly into a hole.

Once the glue dried, using the router base for my Dremel tool, and a slotting bit, I routed a slot 1/16-inch wide and 1/16-inch deep down the under side of the 1 x 3 mortar tubes base board. Now there was a 1/6-inch deep channel joining all the mortar tubes together.

I then drilled a 1/4-inch diameter hole through the end of the 1 x 3 into the first mortar tube. I tightly screwed the blank 1 x 3 to the bottom of the mortar tube rack, so that the 1/16-inch channel was now completely enclosed.

Next, I loaded one gram of Fg black powder into each of the mortar tubes, then dropped one dragon egg firework star into each mortar tube on top of the powder. I then took the whole thing to a friend's house that has a big front yard. I inserted an electric match into the 1/4-inch hole in the end of the board, all the way into the first mortar tube. I have a small electric firing system I made from radio shack parts. A length of visco fuse can also be used.

I hooked it up, pushed the button and 47 dragon egg firework stars launched 30 feet into the air in about one second! It was beautiful. The fire traveling down the 1/6-inch channel from the black powder in the first mortar tube is enough to ignite the 2nd lift charge and so on.

Weighing Chemicals, and Making and Using Screens in Fireworks Manufacture

By Ned Gorski

Introduction

Weighing out specific amounts of chemicals, and screening them together to form a composition, are the most basic firework making procedures. But, as with any skill required when making your own fireworks, these fundamental jobs can be done well or poorly, which will affect the final results of our efforts.

Indeed, weighing and screening are often the most time-consuming parts of making homemade fireworks. So, the faster and more efficiently you can learn to do these tasks, the more quickly you will be able to make fireworks.

Let's say that I want to make the silver titanium fountain fuel that was one of the compositions I made gerbs with in Fireworks Tips #108. This is one of my favorite fountain formulations and it is a simple one to start off with.

Silver Titanium Gerb/Fountain Fuel

Component

Chemical	%	16 Ounce Batch	450 Gram Batch
Potassium nitrate	0.51	8.15 ounces	229.5 grams
Sulfur	0.10	1.6 ounces	45 grams
Airfloat charcoal	0.09	1.45 ounces	40.5 grams
Spherical titanium	0.30	4.8 ounces	135 grams

The original formula gives me the percentages of each firework chemical. Then I pick a batch size that is suited for the project I'm working on. In this case, I want to make five of the 3/4-inch ID fireworks fountains I described in that gerb article. Each fountain will use about 3 ounces of the fuel, or about 85 grams (approximately 28.4 grams in an ounce).

So, I settled on the 16-ounce/450-gram batch size. I multiplied the percentage of each component times the total batch size to determine how much of each chemical to use. For example, 0.51, the potassium nitrate percentage, times 16 ounces, equals 8.16 ounces. I always round these ounce amounts off to the nearest 0.05-ounce, so the 8.16 ounces becomes 8.15 ounces.

Similarly, if I'm going to be working in grams, 0.51 times 450 grams equals 229.5 grams. I round gram measurements to the nearest 0.5 grams, so this result does not have to be rounded.

Once I have calculated the individual amounts of each fireworks chemical in that size batch, I add them up to make sure they do indeed total up to the desired batch size, and to verify that I didn't make some mathematical error in my calculations.

Now I have the weights of each individual chemical I'll be using in the project. I print that page out to have it before me as I'm performing the next steps.

Digital Electronic Scales

I have two electronic digital scales I use only for weighing chemicals used in fireworks, one for large batches of more than a few ounces, and one for small batches of only a few ounces. I got these from my favorite fireworks-supply house.

Skylighter TL5020 and TL5030 Digital Scales for Weighing Fireworks Chemicals and Compositions

The TL5030 scale will weigh up to 15-pounds/7000-grams with a precision of 0.05-ounce/1-gram. The TL5020 pocket scale will weigh up to 222-grams/7.8-ounces with a precision of 0.1gram/0.01 ounce. Both scales can be switched back and forth between ounces and grams.

Some pyros use mechanical, triple-beam scales to weigh firework chemicals. I've never done that, having started out with electronic digital scales and stuck with them ever since. Digital scales are faster to use; they give you an instant readout. You don't have to twiddle your thumbs waiting for that annoying beam to finally stop swinging up and down.

But, the electronic scales can go bad now and then. It is hard to tell when they have done so, since quite often they simply start to become inaccurate as they weigh stuff.

For this reason, I keep five quarters (US 25-cent pieces), which weigh exactly 1-ounce/28.5-grams, in a little plastic baggie in my shop. Before I weigh out the chemicals in a fireworks composition, I weigh my test-quarters to make sure the scale is still functioning accurately.

Testing the Accuracy of Digital Scales Using Five 25-Cent Pieces

Weighing Out Individual Chemicals for Fireworks

First, I get out the tubs of the 4 individual chemicals I'll be using, and place those containers on my workbench.

I leave the titanium off to the side for now, because I do not put metals through my screens while I'm screening and mixing compositions. Fine metal particles can get lodged in the screen openings and be very difficult to remove, permanently clogging the screen, and possibly contaminating other compositions in the future. I'll add the metal to the composition later.

I store my fireworks-making supplies in their original containers, inside the inner plastic baggies, with the bags twist-tied closed, and the lids on securely. This helps prevent the chemicals from absorbing moisture from the air over time.

I also keep a dedicated, disposable, paper cup in each firework-supplies container, with which to scoop out that chemical. This is a very good way to prevent cross-contamination of one's chemicals. I like to keep my chemicals as pure as possible.

If I were to ladle out sulfur with a scoop, put that sulfur in my weighing container, and then remove some potassium nitrate with the same scoop, I have introduced sulfur into my potassium nitrate. The next time I use the nitrate, I may be using it in a composition in which I do not want sulfur; but there will be some residual sulfur in the tub regardless of my best intentions. That's not good.

Unsealed Container of Fireworks Chemical with Dedicated Powder Scoop

If the chemicals are being weighed out for a batch, which will be going into the ball-mill, where they will be pulverized, I don't worry about the individual powders being finely screened prior to weighing them.

But, in cases such as this fountain formula, where I'll simply be mixing the components together, and I want the individual chemicals to be finely pulverized, I screen those individual chemicals through a 100-mesh screen before weighing them. If they will not pass that screen, I pulverize them individually with the coffee-mill.

Once all the individual chemicals will pass the 100-mesh screen, it's time to weigh them for my fountain-fuel batch. My large digital scale came with a nice bin to weigh powders into. I place that on the scale, and tare the scale so that the weight of the bin is not included in the displayed weight. Taring the scale simply requires placing the bin on the scale and pushing the "tare" button, which resets the scale's readout to zero. This way, only the chemical placed in the bin is weighed on the readout.

Next to the scale, I place the plastic tub into which I'll be pouring the ingredients after I weigh them. I could weigh one chemical at a time into the main scale-bin and just tare the scale between chemicals. But sooner or later (probably sooner) this will cause a problem. Too often, more chemical than I really want will pour out of my chemical scoop. If I am adding that chemical onto a previously weighed one, then I have to try to remove the excess second chemical without picking up any of the first one. This becomes a royal pain-in-the-butt and slows the process.

So, one chemical at a time is weighed out, and then poured from the scale's bin into the mixing tub. As I said, I'm saving the titanium for the last step, so I don't weigh it now.

Digital Scale, Weighing Bin and Mixing Tub

As a final double-check, I pour all the ingredients back into the weighing bin after they have been weighed individually and placed in the mixing tub. I see if the total weight is what I intended it to be - in this case, 11.2 ounces of the potassium nitrate/charcoal/sulfur mixture.

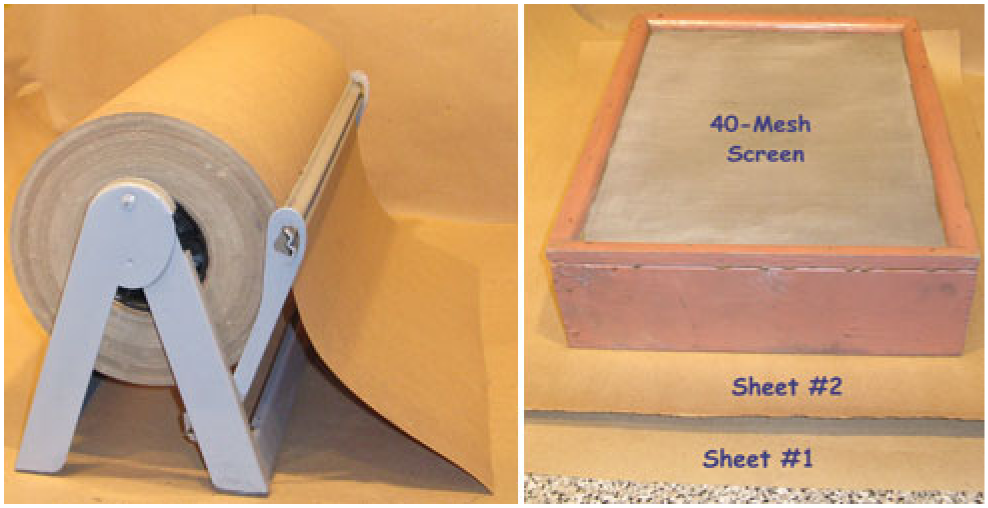
This final quality-control check ensures that I have not forgotten any chemical, which is easy to do in formulas containing many ingredients. It also verifies I weighed each individual chemical correctly. This step can save many problems down the line.

Screen-mixing the Chemicals

I know my chemicals all passed the 100-mesh screen individually, so after they have been weighed I use the 40-mesh screen for mixing them together. All of the screening and mixing is done outdoors because highly flammable dust will be created that I do not want to accumulate on my workshop surfaces.

Even working outdoors, I also wear a good dust-proof respirator and rubber gloves. Cotton clothing and eye protection are also musts. Long sleeve cotton shirts and long cotton pants save lives every year. In a flash fire resulting from accidental ignition of mixed fireworks chemicals, the cotton may singe, but will not catch fire. Synthetics, on the other hand, will melt onto the skin in a fire.

I tear two pieces of kraft paper, slightly larger than my screen, off of my roll and place them, one on top of the other, under my screen. There are various on-line sources such as www.uline.com or www.papermart.com for kraft paper and pull-and-tear dispensers for paper rolls.



40-Mesh Screen Sitting on Two Sheets of Kraft Paper

The batch is gently poured from the mixing tub onto the center of the screen. Then I gently rub the composition through the screen, back and forth with my gloved hands, until all of it has passed through the screen.

The screen is picked up and set aside for a moment. The edges of the top sheet of paper are raised slightly to "roll" the composition towards its center, and that paper is picked up, too. The screen is placed on the remaining sheet of paper, and the composition is poured back onto the screen from the paper which contains it.

The comp is rubbed through the screen a second time. The screen is set aside and the sheet of paper containing the composition is picked up. The empty sheet of paper is placed on the workbench, and the screen is placed on it. The composition is screened for the third and final time, after which it is poured back into the mixing tub.

Screening the powder three times like this breaks up any clumps of the individual chemicals and intimately mixes them together into a homogeneous mixture.

I simply bundle up the sheets of paper, which were used for the screening and dispose of them in my burn pile.

The spherical titanium is now weighed out on the scale, and that metal is added to the mixing tub. The lid is securely installed on the bucket and the metal is incorporated into the composition by gently shaking the tub.

The composition is now ready for the next steps in the manufacture of the fountains.

Uses for Screens in Fireworks Making

The framed screens we use in making fireworks can serve different purposes. These screens are typically specified in mesh-sizes. The mesh size refers to the number of wires there are in the screen, running one direction, per inch. So a 100-mesh screen has 100 wires running one direction per inch, and 100 wires running the other way per inch. That's some mighty fine wire.

I just described above how the 100-mesh screen is used to make sure chemicals are pulverized down to at least a particular small size before mixing them.

The screens are then used in the intimate mixing of the chemicals into a formulation as I did with the 40-mesh screen.

Screens can also be used to size particles so that only that size is used in a composition. Charcoal can be specified in a range of mesh sizes, for example: 20 mesh, 36 mesh, 80 mesh, and airfloat. These different particle sizes serve different purposes in a charcoal composition.

Now, if I buy these charcoals from a firework-supply outlet such as Skylighter, I don't have to worry about separating the different mesh sizes. I'll get tubs of each individual mesh size, already sorted. But if I make and crush my own charcoal, I'll have to have a way to separate, say, 80 mesh charcoal from 36 mesh charcoal from airfloat charcoal, if I want to use those particular mesh sizes, say, in a one-pound black-powder rocket fuel.

This is done by crushing my homemade charcoal and screening those crushed bits through various size screens to separate the specific sizes of particles.

If I have screens in various sizes, 10-mesh, 20-mesh, 40-mesh, 60-mesh, and 100-mesh, I can use them to sort out the various size charcoal particles.

I'll place my crushed charcoal on the 10 mesh screen and rub it on the screen. What falls through the screen is finer than 10-mesh, and what sits on the screen is coarser and will be set aside for more crushing.

I'll then put the charcoal that passed the 10-mesh on the 20-mesh screen and rub it with gloved hands. What won't pass the 20-mesh is sized between 10 and 20-mesh and is set aside.

What passes the 20-mesh is placed on the 40-mesh and rubbed again. What sits on the 40-mesh is sized between 20 and 40-mesh and is set aside. I keep doing this right down through my screens until what passes the 100-mesh screen would be considered airfloat charcoal, and might be ball-milled to ensure that it is as fine as possible.

So, I've ended up with charcoal in assorted particle sizes:

- Larger than 10 mesh to be crushed more
- 10-20 mesh
- 20-40 mesh
- 40-60 mesh
- 60-100 mesh
- Airfloat charcoal

Well, this is pretty cool. I've managed to get charcoal particle sizes, which are useful in my rocket fuel formula.

I have the airfloat charcoal specified in the formula. For the specified 80-mesh charcoal, I can use the charcoal I sized to be between 60-100 mesh. And, for anything that calls for 36-mesh charcoal, the 20-40-mesh charcoal ought to work just fine.

So, screens in various mesh sizes can be used to sort out different chemical particle sizes. They can also be used to sort rolled-star sizes if I have screens in larger mesh sizes.

Often, for sorting star sizes, 8-mesh, 4-mesh, 3-mesh, and 2-mesh (sometimes called 1/2-inch mesh screen) are used. The wire takes up just a little bit of the space per inch of screen, but in rough terms these screens could be used to separate rolled stars into these different sizes:

- Larger than 1/2-inch
- 5/16-inch to 1/2-inch
- 1/4-inch to 5/16-inch
- 1/8-inch to 1/4-inch
- Smaller than 1/8-inch

You get the idea. Different mesh-size screens come in very handy for sorting "things" into different size ranges.

How to Make Frames for Your Screens

Skylighter occasionally stocks pre-framed, round screens which are imported.

They also sell un-framed, square sections of stainless-steel screen, 11.75-inches square, in the 10, 20, 40, 60, and 100-mesh sizes.

Larger mesh sizes are available from various online sources. These stainless steel screens are not inexpensive, but being stainless steel, they can last a long time, especially if they are secured into a well-built wood frame.

Here's how I would frame a 20-mesh, 11.75-inch square screen.

I want to end up with a wood frame, which is 1/2-inch smaller than the unframed screen in both directions. Having the screen overlap the sides of the frame helps when it comes to stretching the screen tight.

I like to make the wood frame 3.5-inches deep so that plenty of chemical can drop through the screen and accumulate on the paper as I'm using the screen, without piling up and clogging the mesh.

For that reason, I use 1x4 lumber, which actually measures 3/4-inch by 3.5-inches.

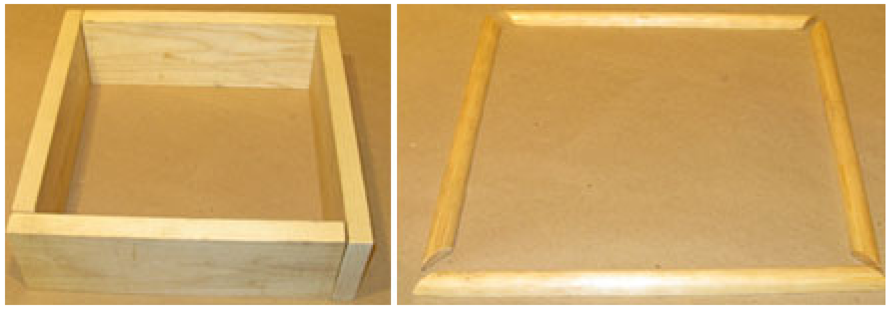
I prefer poplar wood, which is readily available from stores like Home Depot. Poplar doesn't have much grain, so it doesn't warp much. Although it is classified as a hardwood, it is soft enough for my nails and staples to be easily driven into the wood. Certainly other woods like fir, pine, oak or maple could be used, but I'd be afraid that my staples wouldn't drive well into the harder woods like the oak or maple.

I showed how I cut paper tubes with a hand miter box and saw in Fireworks Tips #107. If you don't have a power saw, this same setup can be used to cut the lumber in this project.

Cutting 1x4 Poplar Wood for a Fireworks Screen Frame

I cut four pieces of the 1x4, 10.5-inches long. This will result in a frame with 11.25-inch outside dimensions, which is 1/2-inch smaller than my screen.

At the same time I cut four, 11.25-inch-long pieces of 3/4-inch wide, pine half-round trim, also from Home Depot. These wood strips will form the trim, which will cover the edges of the screen once it is installed on the 1x4 frame.



Four 1x4x10.5-Inch Pieces of Wood Cut for Screen Frame, and Four 11.25-Inch Pieces of 3/4-Inch Half-Round, Cut for Top Trim

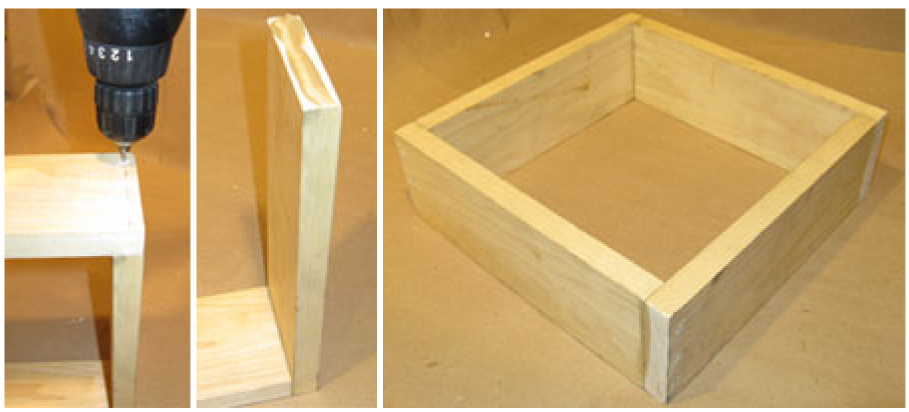
I use some sandpaper to smooth the corners, edges, and ends of my wood. Then I apply two coats of fast-drying, spray polyurethane to all the surfaces of the wood before assembly. This finish will prevent the wood from soaking up water or chemicals over the years of use and cleaning that the screen will get.

Sand All Wood Surfaces, and Apply Two Coats of Spray Polyurethane

After the polyurethane coats are dry, the 1x4 frame is glued and nailed together. I like to use 6d (2-inch) galvanized finish nails, and polyurethane construction adhesive when assembling the frame.

6d, 2-Inch, Galvanized Nails and Polyurethane Construction Glue, Used to Assemble Wood Screen Frame

I pre-drill the nail holes with a 1/16-inch drill bit to prevent the wood from splitting when the nails are driven in. Then I put a thin line of the glue onto the joint, after which I install 3 nails in the joint.



Pre-Drilling Holes, Gluing, and Nailing 1x4 Wood Screen Frame Together

Once the frame has been glued and nailed, I make sure it will sit flat on my workbench. I also check the two, diagonal, corner-to-corner measurements to make sure they are the same, which proves the frame is square. I make any adjustments necessary to ensure the frame is flat and square.

Time to install the screen: I use 1/4-inch long, galvanized staples and a staple gun to attach the screen to the frame.

I first staple one of the sides onto the frame, with the screen in about 1/16-inch from the edge of the wood on two of the sides. I don't want any wire sticking out from the sides of the framed screen once it's done. Such wires could stick and cut my hands while I'm using the screen.

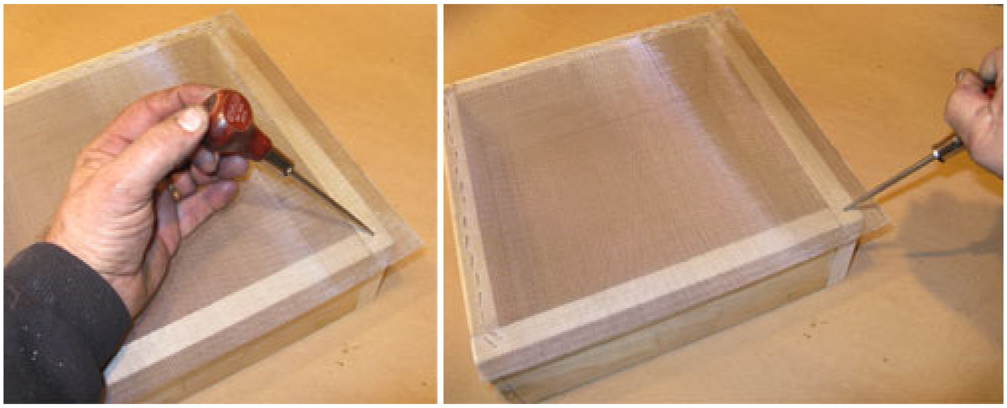
While I'm stapling this first side of the screen, I'm pulling it taut to make sure the side is stretched and straight as it is attached to the frame.

Stapling One Side of the Screen to the Wood Frame

Then, as I make sure the screen is lying flat and that the second side is pulled square, tight and straight, I staple that second side to the frame. After each side is stapled, I hammer all the staples flush into the wood.

Stretching and Stapling Second Side of the Screen

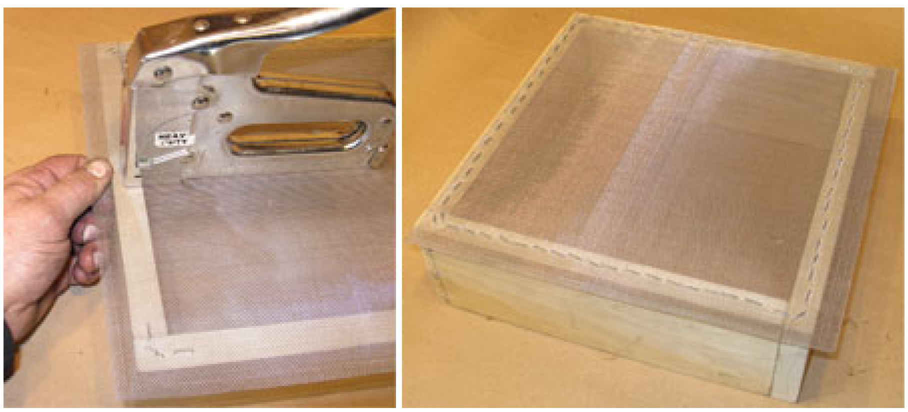
Now, I stretch the fourth, unsecured corner, out in the diagonal direction. This can be facilitated by inserting a sharp awl through the screen, and down into the wood. Then the awl can be "cranked" outward, stretching the screen in the process. This works best in the coarser-mesh screens. One has to be careful not to tear the screen when doing this with fine-mesh screens.



Stretching the Fourth Screen Corner with a Sharp Awl

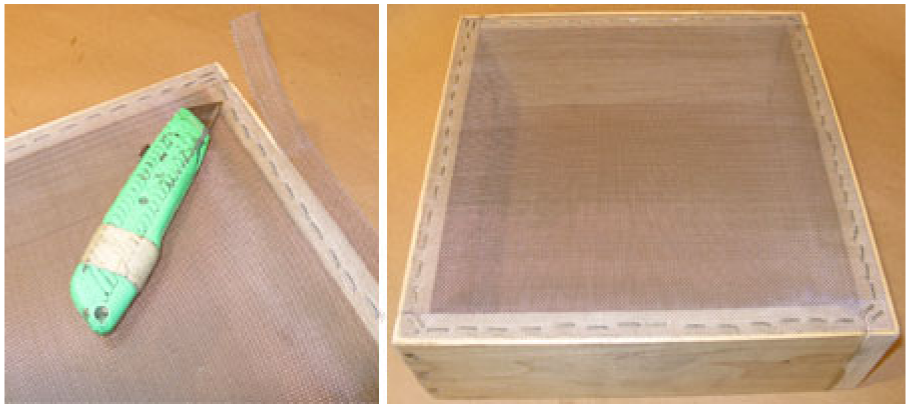
I staple the fourth screen corner while stretching it out tightly, and then I staple the third and fourth sides. As I staple those sides, I pull the screen outwards, holding onto the extra 1/2 inch of screen, and pushing the wood inward with my finger as I do so.

This slight inward bow of the wood will hold the screen tight once it's stapled. Having that 1/2 inch of screen to pull on, is why I made the wood frame 1/2 inch smaller than the screen in both directions in the first place.



Securing the Fourth Screen Corner, and Stretching and Stapling Third and Fourth Sides

Now, I can slice off the extra screen, in 1/16 inch from the outside edge of the wood, with a sharp razor knife. The knife can be used to cut screens up through 20-mesh. For coarser screens and wire, the screen must be cut to the final size initially, and the awl method must be used to stretch the screen throughout the process.



Final Trimming of Excess Screen with a Sharp Razor Knife

Warning: Please be careful when trimming with the razor knife. I've worked with power tools my whole life, and I've never injured myself worse than I have with one of these knives. They can slip during the cutting and stitches will be necessary. Keep your "other" hand out of the way as you use the knife. All of this is supposed to be fun. Let's keep it that way.

And, in a final step, I use more of the glue and some 1-inch, zinc-plated wire brads to install the 3/4-inch, half-round, trim strips. I like using this trim because the inner sloping edge directs the chemicals toward the screen, and the rounded profile is soft on the hands during use.

Finishing Up the Screen by Gluing and Nailing on Trim Strips

As I'm using the glue I'm careful to apply enough so that the screen ends up embedded in the glue, which is stuck to both the top and bottom wood surfaces. This ensures that even with pressure from the hands during use over the years, the screen will stay in place, good and taught and straight, instead of developing a downward bow.

But, I don't apply so much glue that excess oozes out as the trim is applied. That would make a mess and clog some of the pores in the screen. Any excess glue that is present once the wood trim has been installed is carefully wiped off with fingertips. Paint thinner will remove glue from the screen if this is necessary.

I make sure there are no wires or screen-edges sticking out before the glue is dry. If there are, I can trim them now and seal those edges with a bit more glue.

Conclusion

Well, there you have it - one of the basic tools of the firework-making trade, hand-made, and fit for years of service. It will be a pleasure to use the screen each time it is picked up, knowing that it was well made with quality materials.

When I'm done using the screen during a particular operation, I take the hose and thoroughly clean and dry it, storing it in a clean, dry location for future use. Enjoy and Stay Green!

How to Make a Rocket Press

By Ned Gorski with technical assistance from Lloyd Sponenburgh

In my experience, there are three basic machines, which become necessary as one gets deeply into fireworking: a ball mill, a star roller, and a hydraulic press. Ball mills were discussed extensively in Fireworks Tips #91, and I showed some options for star rollers in #92. Now it's time to look more deeply at rocket presses.

Commercial Rocket Presses

In past newsletters I have shown several of my hydraulic presses in action as I've made rockets, comets, pressed stars, black powder pucks, or fountains. Some devices, like simple gerbs or black powder rocket motors, can be made by simply hand-ramming them with a rawhide mallet and a pounding post. Or they can be pressed with a hydraulic press.

Other devices such as whistle rockets or strobe rockets utilize more sensitive fuels, and require hydraulic pressing for their manufacture. Hand-ramming these motors is simply asking for a disaster.

Since I'm about to present projects showing how to make whistles, whistle rockets, and strobe rockets, I thought an introductory essay on hydraulic presses would be in order.

In the previous articles mentioned above I've shown my small Hobby Fireworks press. It's a nice press and was not too expensive. It sits on top of my workbench and is light and portable. I can take it to club events like the PGI convention. Unfortunately, Hobby Fireworks has gone out of business.

Hobby Fireworks Hydraulic Press for Making Rockets, etc.

Over the years I made some modifications to the press so that it suited my needs better. I replaced the 1/4-inch-thick steel plate on the top of the bottle jack with one that is 3/4-inch thick. The thinner one started bending a bit, and I want that plate to be perfectly flat.

I replaced the original 4-ton bottle-jack with a fast-action 6-ton one. The new jack can exert forces up to 12,000 pounds, which is about all I ever need, even when pressing large 4-inch comets and large rockets. Additionally, the new jack raises very quickly compared to standard-lift models.

The jack is available at Northern Tool, and currently it sells for $28, including a nice, collapsible lug wrench.

I had the welding shop reinforce the press's adjustable cross "bridge" so that it would withstand the additional force exerted by the 6-ton jack.

I drilled holes in the back of each horizontal leg-support so that I could bolt the press down to the workbench to secure it during use. The pressure release knob had a hole drilled through it and a 3/16-inch rod-handle installed for fast and easy operation.

This press has gotten a lot of use over the years, and if I had welding capabilities and I wanted a nice little press, I'd duplicate this model.

There are H-frame shop-presses available at various suppliers. In the past I've referred to one such press sold by Greg Smith Equipment. It's a floor standing unit, and weighs over 150 pounds, but it looks like a pretty nice press, has a good range of adjustability, comes with a pressure gauge, and sells for only slightly more than $200.

12-Ton H-Frame Shop Press from Greg Smith Equipment

Simple Do-It-Yourself, Hydraulic Press

Note: My friend, Jim B, has a favorite saying; "For every 10 pyros, you'll get a dozen different ideas on how to do any task in pyro." The ideas I present in the following project are designed to simply get your creative juices flowing. I seriously doubt anyone will build a model that is exactly like mine. But maybe these ideas can point you in the right direction.

In addition to the commercially-manufactured options described above, I got to thinking about a sturdy, relatively lightweight, bench-top press which did not require much welding. I'll describe one possibility that came to mind.

Simple Homemade Hydraulic Rocket Press

The setup and operation of the hydraulic bottle-jack is similar to the Hobby Fireworks press. I had six, 4x4-inch, 3/4-inch-thick, steel-plate shims cut at my local steel supply, to augment the adjustability of the press. Between the 5.5-inch travel of the bottle jack's piston, and the 4.5-inches of adjustability the shims provide, the press has a total of 10 inches of travel between all the way down and all the way up.

This allows me to adjust the press's top plate with the hex-nuts only one time per the particular device that I'm pressing. I never needed more than those 10 inches of adjustability for any of the devices I make. I've tripled-up the top hex-nuts because of the forces they endure during pressing. I don't want to be stripping any threads.

The Press's Main Frame

The main frame of the press is made from four, 3/4-inch x 36-inch, threaded rods, nuts and washers from Home Depot. I had my local steel supply-house cut the bottom and top plates, which are 12-inch long pieces of 1-inch (thick) x 9-inch steel plate.

One-inch-thick steel plate is obviously very strong, and that strength is necessary to withstand the forces, which will be involved in pressing fireworks devices. I wouldn't want to use steel plates that are thinner than the ones I used, and I also wouldn't want to make them larger and spread the threaded rods out farther. This could lead to bending the plates.

The PVC plumbing pipe sections on the threaded rod uprights are there to keep me from cutting my knuckles on the threaded rod as I insert and remove devices in the press.

Installing a Blast-Shield

When I'm pressing whistle or strobe rocket motors, which use pressure sensitive, powerful fuels, the installation of a blast-shield is a good idea. The 1/2-inch thick plastic sheet will offer some protection just in case a motor "goes off" while it is being pressed.

The blast-shield is attached to the press and held in place with 3/8-inch eye-bolts, large fender washers, and hex nuts. Polycarbonate plastic such as Lexan is used in bullet-resistant windows, and serves well for blast-shields.

The other benefit of the PVC pipe on the threaded rods is to hold up the bottom blast-shield, eye-bolt supports.

Installing a Blast-Shield on a Hydraulic Rocket Press

Jack Return Springs

The two 7-inch springs, also from Home Depot, serve to return the bottle jack to its "down" position when the pressure-relief valve is opened. The top of each spring is attached to the 4x4-inch plate that is welded to the screw-out jack-post.

The bottoms of the springs are attached to eye-bolts that are mounted in holes drilled through the bottom steel plate.

I had my welding-shop weld on small hex nuts for the top spring attachment at the same time they welded the plate to the jack post. This was the only welding required in this project.

Hydraulic Jack Return-Springs

Pressure Relief Valve Handle

To create an easily-operated handle for the jack's pressure-relief valve, a hole was drilled through the end of the relief valve. A piece of 3/16-inch galvanized steel rod, bent in an L-shape was inserted through the hole, and the small end was pounded flat on a vise-anvil to hold it in place.

Improvised Pressure Relief-Valve Handle

Holes in the Steel Plates

The holes in the top and bottom steel plates were drilled using a drill-press. That was the only large piece of equipment that was necessary in the fabrication of the rocket press. The threaded-rod holes were drilled at 9.5-inch centers, side to side, and 5.5-inch centers, front to back.

The jack is attached to the bottom plate with three, 5/16-inch bolts, which go up through the steel plate and into holes I drilled and tapped in the bottom of the jack. (Threading holes in metal is done with a tool called a "tap.")

Two extra holes were drilled toward the back of the bottom steel plate, through which bolts will go to attach the press to my workbench. This will make the press nice and steady as I'm pressing rockets.

Attachment Holes, Bolts and Nuts in Bottom Steel Plate

I used a hand-held grinder to smooth all the edges and corners of the steel plates. Then I primed and painted the plates using spray primer and finish paint.

Hydraulic Pressure Gauge

There are a few pressure-to-force (PtoF) hydraulic pressure gauges available to the pyro-hobbyist community. These gauges employ a one-square-inch-area piston, so they directly read out the number of pounds of force being applied to the item being pressed.

For example, if the PtoF gauge is reading 2000 psi, the actual force being applied to the tooling is 2000 pounds, the equivalent of 2000 pounds of concrete sitting on top of the tool.

An advantage to using one of these gauges is that you won't need to install a pressure gauge on the press's bottle jack.

A Pressure-to-Force Gauge Being Used with the Hydraulic Press

I personally like to use a gauge that is actually installed in the bottom of the bottle-jack. Doing so enables me to eliminate one loose, movable component, like the PtoF gauge, when I'm aligning and pressing devices in the press.

Using a gauge on the jack, though, requires that the gauge's reading be multiplied by the area of the jack's piston, in order to determine the actual force being exerted by the jack. I'll show what that means in a minute.

Installing a gauge on the bottle-jack presents what is probably the most challenging aspect of this project--drilling and tapping/threading the bottom of the bottle-jack, and installing a hydraulic pressure gauge. But, it's good to know how to do this, even if a PtoF gauge is going to be used.

Installing a gauge on a bottle jack requires the partial disassembly of the jack, drilling a couple of holes, tapping/threading the hole where the gauge will be installed, cleaning debris out of the jack, and reassembling it.

One of the nice things about the bottle-jack I'm specifying in this project is that it is relatively easy to take apart and put back together.

First, the rubber drain/fill plug on the back of the jack's cylindrical body is removed, and the oil that fills the jack is emptied into a clean pot. This oil can be filtered through a coffee filter and reused in the jack when it is reassembled.

When draining the oil, it helps to remove the pressure-relief valve. This valve has a 1/4" steel ball bearing down in the hole into which it is screwed. Carefully set the ball and valve aside, and finish draining the oil. Pumping the lever assembly a few times works the rest of the oil out. Now is a good time to drill the hole in the pressure-relief valve and install the L-handle.

Bottle-Jack, Oil Drained Out

The lever-arm has a couple of steel pins, held in with spring-clips, and is easily disassembled. (You are making mental notes of how all this goes back together, right?)

It's time to remove the large hex-nut at the top of the jack now. This requires that the base of the jack be held securely in a vise or a rocket press. (Waitaminnit, I'm making my rocket press! How can I hold the jack in my rocket press? I have 3 presses, and this will be my fourth.)

The hex-nut is then loosened with channel-lock-pliers or a large pipe-wrench. It may be necessary to whack the wrench with a rubber mallet or similar heavy object. The nut is screwed off when it is loose, and the central jack piston and outer jack shell-body can also be removed. The nut has a plastic O-ring gasket on it where it hits the main body, but this gasket is usually "glued" on with paint and does not need to be removed.

There is a "tapered" large rubber O-ring which sits in the groove that the shell-body came out of. Remove this O-ring. Remember that it was in there with the thin edge up, and the wide edge down.

Inside the jack, there will be a small, wire-mesh filter shoved in one of the holes in the base. Make a note of which hole it's in, and then remove it. Actually, this is a good recommendation, which has never worked for me in real life. Each time I've disassembled a jack, the filter has dropped out before I get to notice where it was in the first place. I'm not sure how they get the darn thing to stay in during shipping and/or operation.

I'll show in a moment how to determine which hole the filter ought to go back into when the jack is reassembled.

The screw-post will only unscrew so far as it extends out of the jack's piston. It is not necessary to remove this screw-post all the way. The whole jack can be taken to the welding shop when the 4x4 plate is welded to the screw-post. If one wants to remove the post all the way, some filing/grinding is necessary to remove the small "indents" which have been knocked into the top of the cylinder to hold the post in place.

Now is a good time to measure and make note of the diameter of the bottom of the piston. In this case it measures 1.375 inches. Squaring half that diameter (the radius) and multiplying that by Pi (3.1416) yields an area of the bottom of the piston of 1.5 square inches. (3.1416 x .6875 x .6875 = 1.5 square inches)

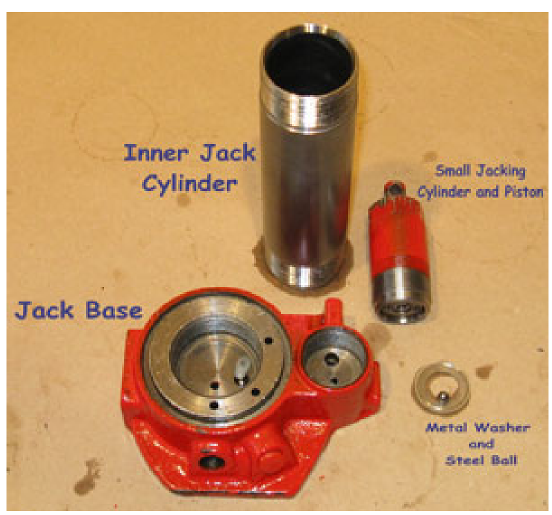
Because of that, when my new, jack-mounted pressure gauge is reading, say, 1000 pounds-per-square-inch (psi), I'll multiply that gauge's reading by 1.5 to determine the actual amount of force the jack is exerting on the tooling in the press, which in this example would be 1500 pounds.

Further Disassembled Bottle Jack

Once again holding the base of the jack in a vise or rocket press, I now carefully use a pipe wrench to loosen the jack's inner cylinder. I apply the wrench right down at the bottom of that cylinder in order to avoid crushing or distorting the tube as I loosen it.

Once the inner cylinder has been removed, another plastic O-ring gasket can be seen inside the base where the cylinder bottoms out. This O-ring does not need to be removed. Notice that there is a top and a bottom to the inner cylinder. The top is beveled on the inside lip to make insertion of the piston easy. The bottom has a flattened edge, which bears on the O-ring seal.

The small lever-operated jacking piston/cylinder should also be removed at this time. There is a metal washer and a 1/4" steel ball down in the base's recess which should also be removed.



Hydraulic Bottle-Jack, Further Disassembled

And, now, finally we've arrived at the final disassembly step. There is another 1/4-inch metal ball in the bottom recess of the base, held in with a plastic retainer. This can be seen in the base's large recess in the photo above. The retainer is removed by prying it with a screwdriver, and the ball is also removed.

I'm keeping all the little parts in a clean paper cup to prevent me from losing them as I go along. There is also an over-pressure, safety relief valve, covered by a plastic cap. This assembly, including the cap, screw-out post, spring, metal-mushroom, and very small metal ball, is all removed and placed in the paper cup.

Final Bottle-Jack Disassembly

I can just hear ya hollering, "Crikey, Ned, what the heck have you gotten me into?" It's really not as bad as it all sounds and looks. If you keep track of all the little parts, and remember how they all go back together, this can be fun. Really! There's learnin' happenin' here.

At this point, for my own education, I spent a bit of time envisioning how the jack works when it is being operated. The small jacking-piston and cylinder create high pressure using the principle of mechanical leverage. The pressurized oil is forced through the small hole in the bottom of that recess and up past the ball/hole/retainer in the large base recess.

All those balls in this device simply act as valves, sitting in nicely machined recesses, and only allowing oil to flow in one direction, pushing the ball slightly out of its recess. Oil pushing from the other direction forces the ball against the machined seal and shuts off the flow.

As it is needed, more oil is "sucked" into the small base recess from the main reservoir between the outer jack body and the inner cylinder. The pressure in the cylinder jacks the piston up a small amount. The process is repeated as the piston gradually is lifted.

If too much pressure is generated inside the main cylinder, the oil can push the small ball and spring in the over-pressure relief valve and allow the excess oil to escape back into the main oil reservoir between the outer jack body and the inner cylinder. This acts as a safety to prevent the jack from being over-pressurized and dangerously rupturing.

And finally, when we want the jack to retract and go down, the pressure-relief valve is loosened. This allows oil to move past the ball at the bottom of that valve, and back into the main reservoir.

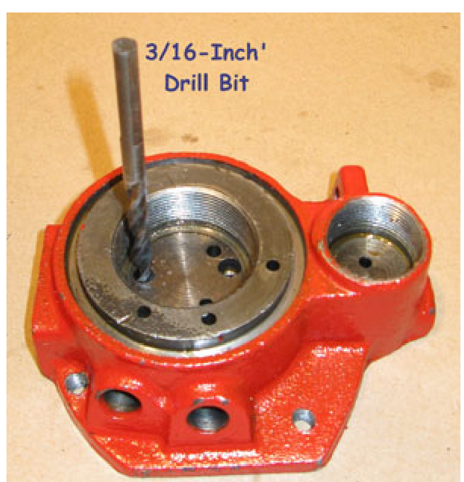
Since the only hole through which oil moves out of the main reservoir is the one leading to the bottom of the jacking-cylinder's small recess, that is the hole that the small filter will be replaced into (so it functions to remove debris from the oil as it circulates). I find which hole that is by blowing into it to make sure the air is coming out of the ball-blocked hole in the bottom of the small base recess.

And, keeping debris out of the whole jack is why I've completely disassembled it. After the next drilling and tapping steps are completed, all the parts will be completely cleaned before any reassembly. Small bits of metallic debris are the enemy of a properly functioning jack. They can become lodged in the various ball-valve assemblies and allow slow leakage, preventing optimal performance.

Drilling and Tapping the Jack-Base to Receive the Pressure Gauge

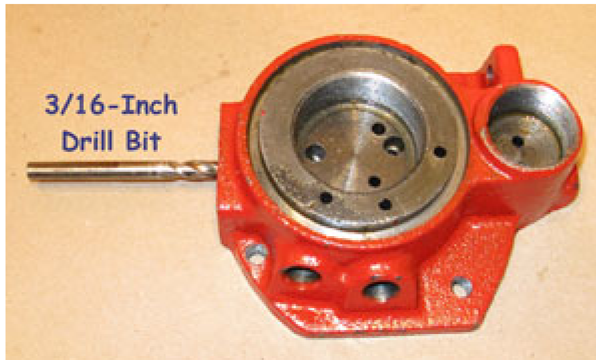
You'll notice, when looking at the jack base, that all the existing holes and inner "channels" that the oil flows through are located in the right side of the base. Conveniently, this jack's base has a nice flat area on its left side, and plenty of room on the left-inside of the large recess where a hole can be drilled.

This is the point we've been heading toward. I want to drill a 3/16-inch hole down from the bottom-inside of that main base recess, but not all the way through the base. I drill this hole about 3/8-Inch deep.



3/16-Inch Hole Drilled Down into Jack Base, Only 3/8-Inch Deep

I want to drill in from the left-outside of the base with the same 3/16-inch drill bit, until that hole hits the first hole that was drilled. I only want to drill as far as that first hole so that I don't hit any of the other inner channels in the base.

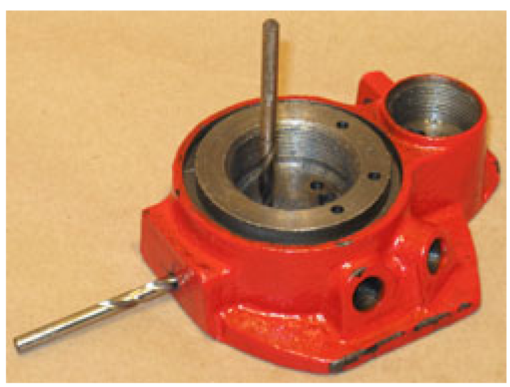


3/16-Inch Hole Drilled in from Side to Meet Up with Other Hole

The hole coming in from the side is drilled high enough from the bottom to allow the fittings I'm going to install later to clear the press's base plate. I also plan that hole so that it is centered in the bottom "thickness" of the base, so that the strength of the remaining metal surrounding my new fitting is maximized.

Drilling this hole centered up 1/2 inch from the bottom of the base accomplished all the above goals. And it kept the metal thickness between the hole and the bottom of the base no less than 5/16 inch, which is needed to withstand the internal jack pressures.

These two holes are gradually deepened until they hit each other, and no further.



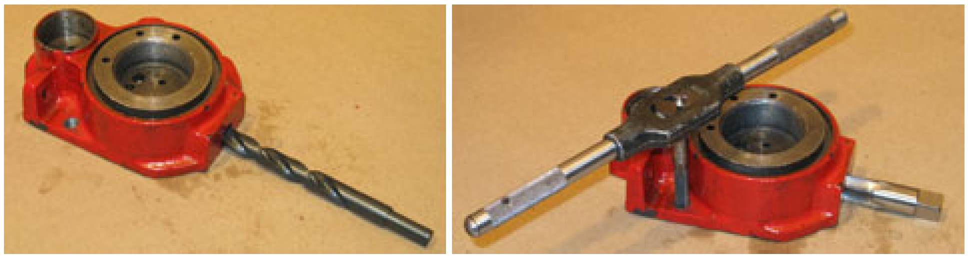
Drilling 3/16-Inch Holes Which Join with Each Other

The two holes will form a new channel which will allow the pressurized oil inside the inner jack cylinder to reach the new gauge which will read out the same pressure that exists inside the cylinder.

Warning: The main power tool I'm using in this process is a drill-press. Like Norm Abrams says, "Read and understand the safety precautions concerning this tool before you use it." I do this drilling at low speeds. I

firmly hold the piece I am drilling with a clamp and/or other tools. This drill-press can be my best friend, or it can slice my hands open and/or break bones. Be careful.

The hole in the side of the base is enlarged with a 5/16-inch drill bit (Q drill bit) enlarging a section about 3/4-inch deep. This side hole (only) then has threads cut in it with a 1/8-inch-pipe-thread tap.



Drilling and Tapping Holes in Bottle Jack Base

This is also a good time to drill and tap the bolt holes, in the flanges on the base, which will attach the jack to the press's bottom steel plate.

There, the hard part, the machining, is done. I now clean all the debris, excess paint, and metal shavings off of all the parts in a pot of clean kerosene or paint thinner. I pay special attention to the base to make sure all the small metal debris has been washed off of it and out of all its holes and channels.

After the parts have dried, the bottle jack is reassembled in the reverse order in which it was taken apart. Before adding the oil back into it, I attach the new pressure gauge using hydraulic fittings and Teflon tape. My local hydraulic-fitting supply-house was able to supply the fittings that I needed, and which would handle the pressure the jack will be exerting.

**Pressure Gauge, Hydraulic Fittings, and Teflon Tape,
Ready to Be Installed on Bottle Jack**

These fittings were inexpensive, and it pays to use fittings certified for hydraulic pressure, rather than plumbing fittings which might rupture under that pressure.

The gauge sells for about $22 at McMaster-Carr. It is a 2.5-inch diameter dial, glycerin filled, 0-10,000 psi range, 1/4-inch pipe-thread bottom-connected, Model #4053K16.

But, the same supply-house where I bought the fittings had a very similar gauge for only $16. I bought one for a spare while I was there.

I have temporarily hooked up gauges to lower-pressure jacks with iron pipe fittings. But those plumbing fittings are not rated for the 8000 psi that will be developed in this new jack when it is putting out the full 6 tons of force.

Remember that when the gauge reads 8000 psi, that reading is multiplied by 1.5 to determine the force that the jack is exerting. That means an 8000 psi reading equals 12,000 pounds of force, the maximum force this jack is rated for. That's why I chose a gauge with a range of 0-10,000 psi.

The Teflon tape is carefully wrapped on the pipe threads, in the direction that will tighten the tape wraps as the male threads are screwed into the female fittings. 4-5 wraps of the tape are put on each threaded section. I'm careful not to overlap the tape down onto the end of the fittings, where bits could break off and clog the channels or valves in the jack.

After the gauge was installed and all the fittings tightened up, I filtered the oil through a coffee filter and filled the jack back up with the oil through the fill hole on the back of the jack's body. I pumped the jack up and down a few times to work any trapped air out of the system. Then the jack was installed on the rocket press.

Hydraulic Bottle Jack with Gauge, Installed on Rocket Press

I topped the oil off with more, new hydraulic-jack oil until it started to run out of the fill-hole in the main jack body. Then I installed the rubber plug.

I put my Pressure-to-Force gauge on the jack-plate, and jacked the press up to various pressures. This was to make sure that, indeed, the PtoF gauge read 1.5 times what the gauge on the bottle jack was reading. I also removed the PtoF gauge, and jacked the press up to its maximum pressure and let it sit there for a while to make sure it wasn't losing any pressure through leaks or badly sealed steel-ball valves.

Final Test of the New Rocket Press, Bottle Jack, and Pressure Gauge

Everything worked great, so I moved the press into its permanent location on my work bench and attached it there with bolts which go through the two extra holes in the back of the bottom steel plate, and on through the workbench top.

Persuading Your End Plugs to Fit into Your Firework Tubes

Learn how to make your cardboard paper end plugs fit better into your firework tubes.

Sometimes when we buy paper end plugs, designed to fit down inside a firework tube, I have noticed that they seem to fit when we buy them, but later they don't fit so well. If the end plug is too tight, it will kind of buckle when pushed down into the firework tube. Or, if the end plug is too loose, it will just fall down into the firework tube.

When an end plug fits just right, it fits snugly into the firework tube. If you hold that firework tube up to a light and look toward the light through the open end of the firework tube, you should see no light around the end plug.

Paper end plugs are made commercially by ramming damp disks of thin cardboard into a hole using a "mandrel." These mandrels and holes are made in various sizes to produce the different size end plugs you buy from us.

After they are pressed into shape, they are heat-dried. Subsequent increases and decreases in moisture content of the end plug cause many of the end plug-sizing problems that we encounter. The end plug simply shrinks and enlarges on its own.

If your end plug is too loose in your firework tube, dump the end plugs into a big plastic bag, and lightly (just 2 or 3 spritzes) mist the batch with water. Shake them up, close the bag, and let the end plugs sit overnight. The end plugs will swell and may do so enough to fit your firework tubes.

Conversely, if your end plugs are too tight, drying them can shrink them enough to fit. Just spread your end plugs out on some flat surface and keep air moving over them for a day or so.

Even end plugs that are still too large can be made to fit properly into your firework tubes, if you will press them in using a wood or aluminum rammer whose diameter is just slightly smaller than the firework tube. Place the end plug over the end of the rammer. Then slide the firework tube down over the end plug on the rammer.

With any of the shrinking and expanding methods described above, you can test whether it works on one or two end plugs first.

7

Technical

Metal Particle Shapes: What They Mean

Fireworks makers: Right now, as you look at the aluminum powder options on the Skylighter chemicals list, you may be asking yourself: "what is the difference between spherical and spheroidal aluminum?" Or, for that matter, "what does it matter that a particle shape is granular, or flake, or atomized?"

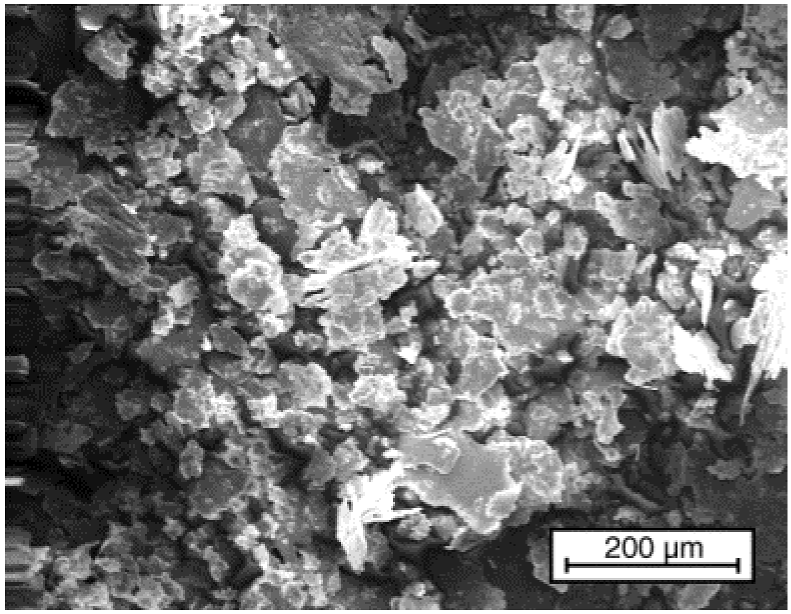
Particle Shapes 101

Before you embark on this little tour, keep in mind that particle shape is not the only factor influencing how a metal powder will perform in a fireworks composition. The size of a particle of metal, whether it is coated or not, and other factors are just as important as particle shape.

Particle shape matters mostly because of its impact on pyrotechnic composition reactivity. Think about it. Which is easier to light, a 3 x 3 inch piece of paper or a 3 x 3 inch piece of plywood? Chemically they're almost the same thing. But the little, bitty edge of the paper is a lot easier and faster to light than the edge of the plywood. And that's what separates the flakes from the atomized-ease of ignition.

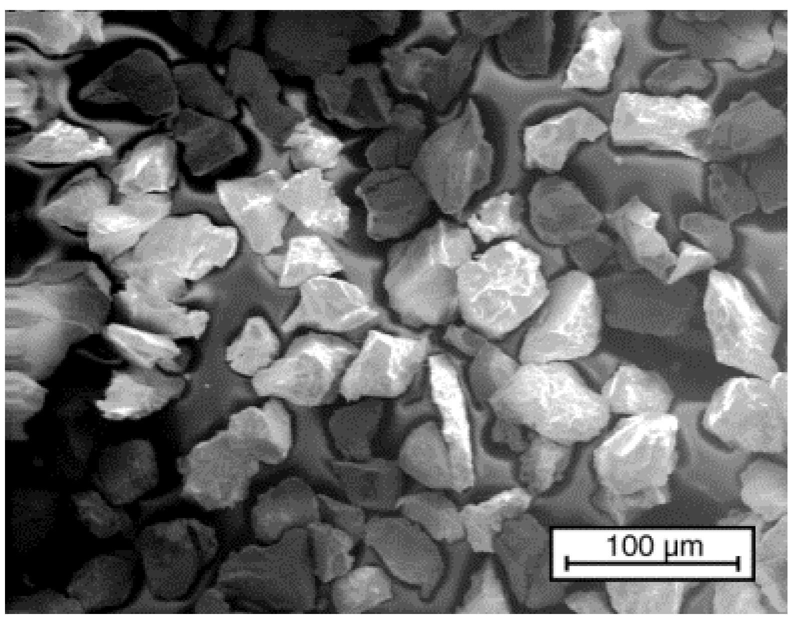
Whether you are trying to make a rocket fuel, a flash device, a glitter fountain, a flitter star, or a long-tailed comet, your success will depend in part on using the right particle shape. So pay careful attention to the type of aluminum prescribed in your pyrotechnic composition. If particle size or shape is not specified, and you are new to making fireworks, then it's a good idea to ask someone knowledgeable. Using the wrong one might be a waste or time and money, or could even be dangerous.

The following photographs show the most common particle shapes used in making fireworks. The scale on the bottom of each photograph shows a 200-micron long scale for your reference (that means 200 millionths of a meter, or a little bigger than a grain of fine, pesky, popcorn salt for alla yall who insist on watching television and munching popcorn in bed).



Flake-shaped aluminum particles (magnified 100 times)

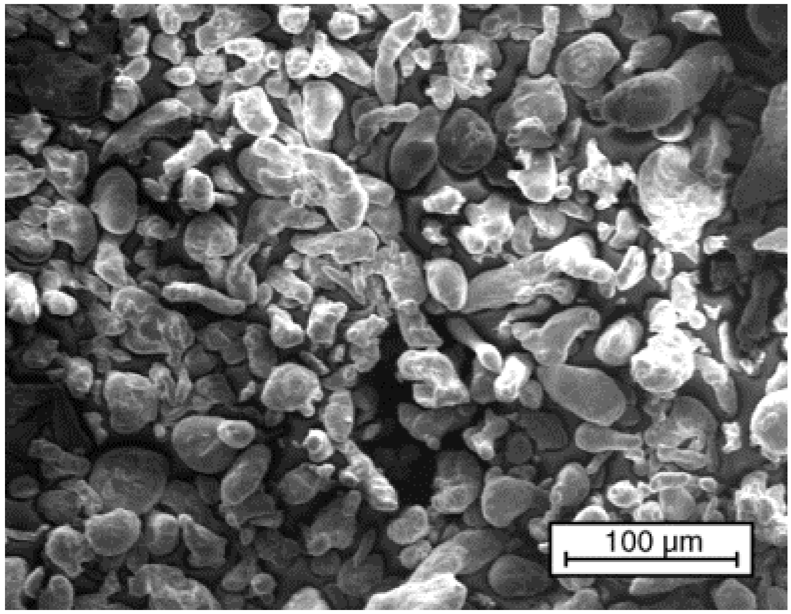
Notice how "edgy" the aluminum flakes are. These thin edges heat up and ignite faster than the rest of the particle. Flakes, because of this edginess and the fact they offer the greatest surface area, are generally the most reactive particle shape when used in a pyrotechnic composition.



Granular-Shaped Ferro-Aluminum Particles (magnified 100 times)

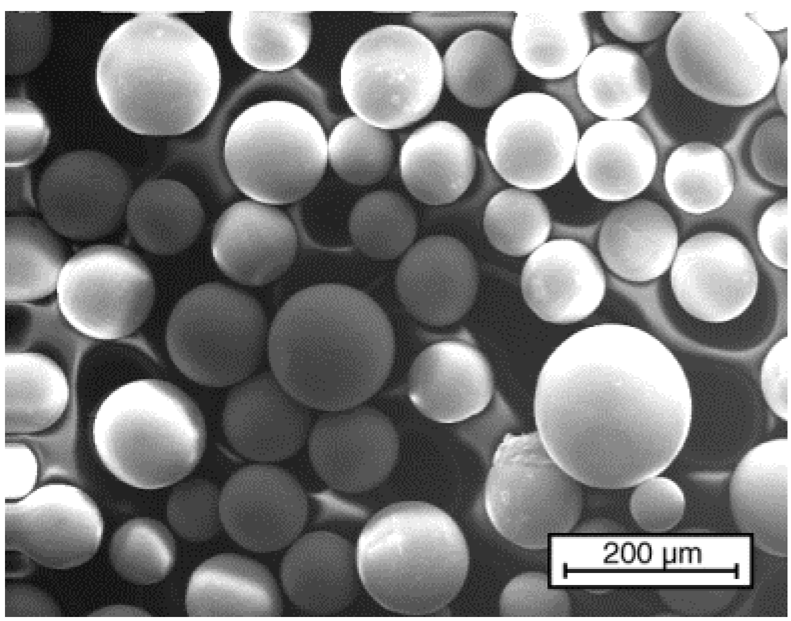
Granular (ground) metal particles have a characteristic, gravel-like shape. Like flakes, they have a lot of sharp edges, too. But they do not offer as much surface area, and so will not be quite as reactive as flake powders.

Atomized particles come in two basic shapes: those that are almost perfectly round called spherical, and those that have irregular, rounded shapes, called spheroidal.

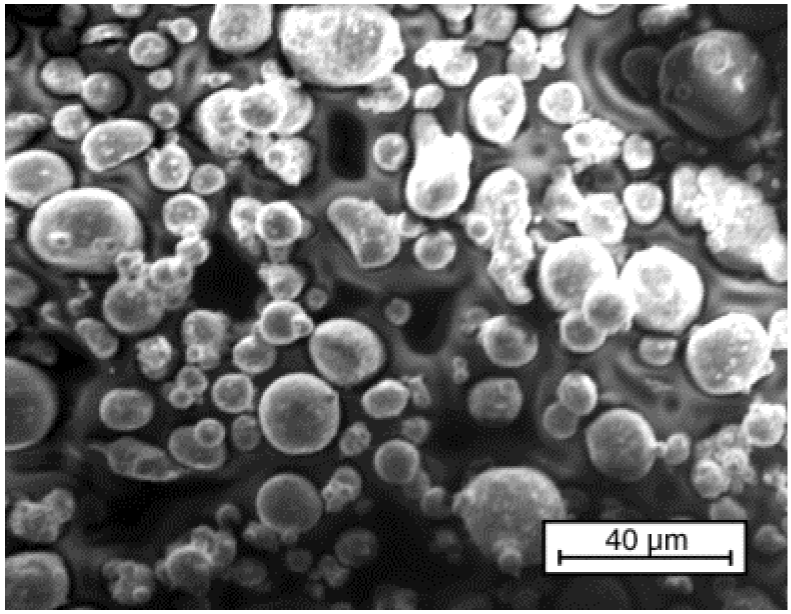


Atomized, Spheroidal Aluminum Particles (magnified 200 times)

Notice that spheroidal particles also have "edges," those irregularly shaped extensions you see in the aluminum photograph above. But because they are rounded, they are not as reactive as the flake and granular material.



Atomized, Spherical Titanium (magnified 100 times)



Atomized, Spherical Aluminum (magnified 500 times)

Spherical-shaped particles range from being perfectly round, shown in the titanium photo above to almost-round, as shown with the aluminum particles. These are the least reactive particle shapes of all, with very few, if any edges to take fire.

So, the bottom line is that all metal powders are not created equal. Whenever you are creating a new pyrotechnic composition, choosing the right metal fuel's particle shape is critical. And if one particle shape does not work in a given fireworks formula, consider which particle shape might be the best for your particular application. If in doubt, give us a call. We can nearly always steer you to the right one.

If you have any doubt what particle shape your aluminum powder is, you can check it yourself. Radio Shack sells inexpensive high-powered magnifiers. We use two, one with 30-power magnification, the other with 100-power.

For more detailed information on metal powders, their particle shapes, sizes, characteristics and uses, we highly recommend Selected Pyrotechnic Publications of K.L. and B.J. Kosanke, Part 3. The article there, "Aluminum Metal Powders Used in Pyrotechnics," is a must-read for anyone serious about making fireworks.

Another excellent article on the subject, and the source for the pictures in this article, is "Pyrotechnic Particle Morphologies - Metal Fuels," and can be found in Selected Pyrotechnic Publications of K.L. and B.J. Kosanke, Part 5. These articles go into extremely useful detail about which type of metal powder fuel to choose for which application. I cannot recommend them highly enough.

How Particle Size and Shape is Defined

By Brian Paonessa

In this article you'll learn how particle size is measured in both mesh (by screens) and microns (by microscope). You'll also learn how particle shape is defined.

Materials Needed

- Material to be measured
- Optical light microscope
- Screen Set (TL2010)

How Particle Size & Shape is Defined

You will often see chemical descriptions in fireworks formulas that look like these:

- Aluminum, atomized, 22 micron
- Aluminum, -325 mesh
- Aluminum, -325 mesh, spherical, 22 micron

Do you really know what those particle sizes really mean? What is really being described? When they say "-325 mesh" and "22 micron", what's the difference? And why does it matter to you?

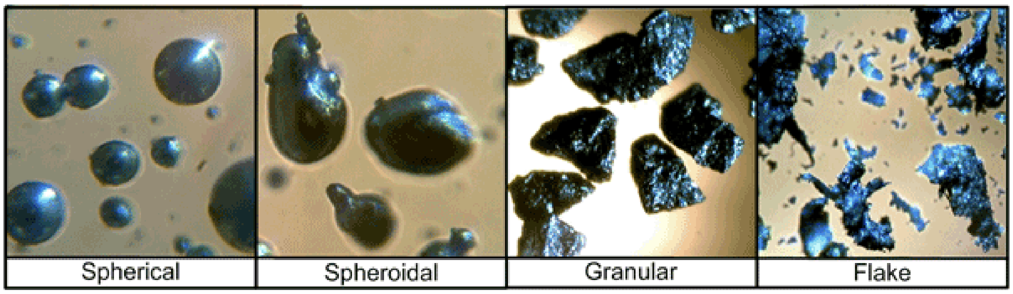
Well it can definitely help you to know how the particle "size" ratings get assigned to metal powders. Most of the size ratings come directly from the wholesaler or manufacturer. But every so often we buy surplus materials which may not come with any additional information about the manufacturer, the size or shape of the powder.

Recently, we received a surplus lot of magnesium powder, including several drums with almost no information available from the seller. Before we can sell it to you, we need to be able to tell you what it is, so you can figure out if it suits your purposes.

The first step in the identification process is a visual inspection. You may be surprised how much you can tell about a sample just by looking at it. By observing the flow characteristics of a powder, and how it feels between your fingers, you can approximate particle size and shape.

If you have experience with metal powders, for instance, you can often tell if a sample is granular (rough feeling), or atomized (round particles, feels smooth, pours and flows quickly and smoothly). If you cannot feel any particles between your fingers, you can assume the powder is probably finer than 200 mesh, or even less than 325 mesh (written as "-325 mesh.")

The next step is to verify those assumptions though quantitative and qualitative testing. To determine if a material is appropriate to be used in a given formula you'll need to know the particle's shape (morphology), size, and distribution (granulometry). Shape is easily determined under a microscope and classified as atomized (spherical or spheroidal), granular, or flake.



Particle size is reported in one of two ways: either by mesh size (large and medium particles, generally larger than 325 mesh) or by microns (very small particles).

Why Use Two Measurements?

US mesh size describes the number of openings per inch in a screen. So if a material is listed as -60 mesh it will all pass though a 60 mesh screen (the minus sign in front of the 60 means that all particles are smaller then 60 mesh). Conversely, if the material is described as +60 mesh, it would mean that all particles would be retained on a 60 mesh screen and are therefore larger than 60 mesh.

But mesh sizes can only go so far. After a point the individual wires that make up the screen are so close together it is no longer practical to measure using screens. In practice, particles smaller than 325 mesh are usually described in microns. A micron is one thousandth of a millimeter, or one millionth of a meter. The unaided human eye can see particles of about 40 microns. Smaller than that, you need magnification.

There is no truly accurate conversion from mesh size to microns, because the wire thicknesses in screens vary all over the place. But approximate conversion tables are commonly used anyway. (In the table below, screen sizes of smaller than 600 mesh are shown, even though they don't exist in practice.)

U.S. Mesh	MICRONS
10	2000
20	841
40	400
60	250
80	177
100	149
200	74
325	44
400	37
625	20
1250	10
2500	5

"Mass fraction analysis" is used to determine large-to-medium size particle distribution in a sample. The powder is sifted through a set of nesting screens, each with progressively smaller openings (higher mesh numbers). By measuring the percent of material that remains on each screen, we can classify a material by its size distribution.

If you were to sift Skylighter's #CH2080 Magnesium-Aluminum (described as 180-325 mesh) through a stack of 180 mesh, 200 mesh, and 325 mesh screens, a mass fraction analysis yields a particle size range that looks like this:

+180 mesh	26%
180-200 mesh	31%
200-325 mesh	21%
-325 mesh	22%

If the 180 mesh size was critical to your firework formula, you can interpret this to mean that 26% would remain on the 180 mesh screen (larger then 180 mesh) and 74% would pass through it (be smaller than 180 mesh).

Mass fraction by sieve analysis is a very helpful method of classifying coarse-to-medium particles, but what about the really small stuff?

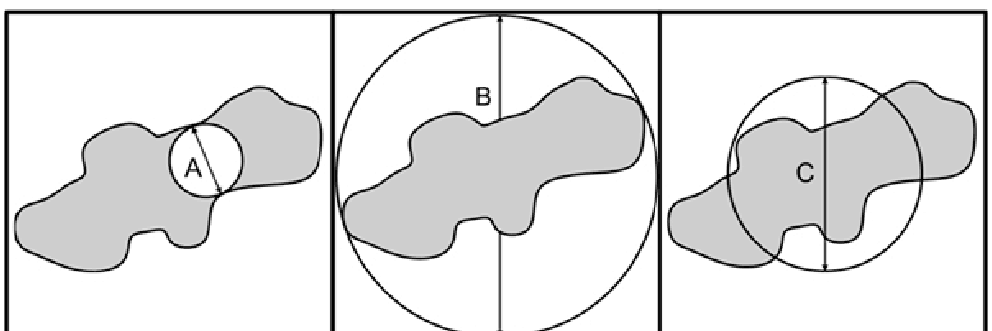
When the average particle size is around 50 microns, sieve analysis is no longer practical, and doesn't adequately describe the particle sizes. Several methods are commonly used to measure really fine stuff: gravitational sedimentation, laser light diffraction, optical light microscopes, scanning electron microscopes (SEM) and transmission electron microscopes (TEM). The most accessible method to an amateur is an optical light microscope.

So how is a particle measured with a microscope? Do you need some kind of tiny ruler? As funny as that might sound, that's exactly how it's done. The microscope can be fitted with a gizmo called a reticule micrometer. After it is calibrated, it can be used to measure the size of individual particles in a powder sample right down to 1 micron.

But just because you can measure it doesn't mean it's a simple task. Sure, measuring spherical material is fairly straightforward. After all, you're really just measuring the diameter of little balls. But what about flake, granular, and spheroidal samples?

Digital imaging and software can drastically decrease the time needed to perform measurements and reduce error rates. But it appears that most if not all of the automated equipment measures any particle shape as if it is spherical. Because of this, there is not really a standard method for assigning a particle size.

Selecting the method seems to be based mostly on what you'd like your results to state. Below is an imaginary particle and three circles representing different measurement methodologies.



A = 3 microns	**B** = 13 microns	**C** = 8 microns
Minimum diameter	Maximum diameter	Median diameter

In the first example the measurement is across the smallest dimension of the particle. This method might be used to describe the particle in terms of its reactivity by describing the particle in the smallest possible size. Method B might be used conversely—to describe the particle's largest dimension. Arguably the most accurate methodology would be using example C, where an average size is calculated.

No matter what method is used, the results would normally be presented to you, the buyer, as an average size (3 micron), a particle range (3 to 15 micron) or a frequency distribution (30% <5 micron, 10% 5-10 micron, 60% 10-15 micron), or some variation thereof

So why does particle size or shape matter? Many amateur fireworks makers only consider particle shape and size when a formula calls for a specific material. Even fewer consider particle size distributions. The shape and size of a particle has a huge impact on its reactivity. Flake particles have a large surface area that can be in contact with an oxidizer when compared with a spherical particle. Granular particles often have sharp edges that can ignite more easily than the smooth, round edges of an atomized powder.

Selecting powder with a different particle size or shape can create a wide variety of changes in the pyrotechnic effect, from hang time of a spark to delay of strobing. Even controlling the burn time can be accomplished by altering the particle size and shape.

Look what happens when we change particles in a real example. The glitter formula below calls for -325 mesh spherical aluminum. Skylighter sells 3 aluminums that are -325 mesh spherical. One is further described as 5 micron (CH0100), one is 12 micron (CH0103) and another is 22 micron (CH0105).

D1 Glitter Formula

Chemical	Percent
Potassium nitrate	53%
Sulfur	18%
Charcoal (airfloat)	11%
Aluminum (-325 mesh, spherical)	7%
Sodium bicarbonate	7%
Dextrin	4%

Using the 5 micron aluminum did not produce a usable glitter. Instead it produced a bright star with an unattractive, dense, short-lived flitter-like tail. This aluminum was simply too reactive and started burning both in the flame envelope as well as after, creating poorly defined flashes.

The 12 micron aluminum produced a wonderfully dense, but short tail of fairly evenly-spaced flashes. Because the particle size distribution was within a fairly small range (mostly 6-18 microns), the glitter effect appeared fairly closely behind the star.

The 22 micron produced the best effect of all, creating a long tail that maintained good distribution of flashes over its entire length (with a few long delay pops). The 22 micron contains particles over a very wide range with most particles appearing between 5 to 38 micron.

It is clear from the results of the test above that tracking the average particle size and shape may not be enough to reproduce a specific effect, tracking the particle size distribution (if you know it) may also be worth noting in your formula book.

Understanding Mesh Sizes and Microns

Learn how to understand mesh sizes and microns and what size screens different mesh sizes will fit through.

Introduction

What does mesh size mean? Figuring out mesh sizes is simple. All you do is count the number of openings in one inch of screen (in the United States, anyway). The number of openings is the mesh size. So a 4 mesh screen means there are four little squares across one linear inch of screen. A 100 mesh screen has 100 openings, and so on.

Note, therefore, that as the number describing the mesh size increases, the particle size decreases. Higher numbers = finer powder. Mesh size is not a precise measurement of particle size. Screens can be made with different thicknesses of wire. The thicker the wires, the smaller the particle size passing through that screen, and vice versa.

What do the minus (-) and plus (+) plus signs mean when describing mesh sizes? Here's a simple example of how they work. -200 mesh aluminum would mean that all particles would pass through a 200 mesh screen. A +200 mesh aluminum means that all the particles are retained on a 200 mesh screen.

How fine do screens get? That depends on the wire thickness. If you think about it, the finer the weave, the closer the wires get together, eventually leaving no space between them at all. So, beyond 325-400 mesh, we usually describe particle size in "microns."

What is a micron? A micron is another measurement we use for measuring particle size. A micron is one-millionth of a meter or one twenty-five thousandth of an inch.

This table is adapted from a post made by Ken Kosanke to the Pyrotechnic Mailing List and previously published in a PGI Bulletin.

U.S. Standard *	**Space between wires**		
Sieve Mesh No.	Inches	Microns	Typical material
14	0.056	1400	
28	0.028	700	Beach sand
60	0.0098	250	Fine sand
100	0.0059	150	
200	0.0030	74	Portland cement
325	0.0017	Silt	44
400	0.0015	37	Plant Pollen
(1200)	0.0005	12	Red Blood Cell
(2400)	0.0002	6	
(4800)	0.0001	2	Cigarette smoke

* The mesh numbers in parentheses are too small to exist as actual screen sizes; they are estimated and included just for reference.

Protecting Aluminum Powder from Water with Boric Acid

Learn how to coat aluminum powder with boric acid to stop corrosion of the aluminum powder in firework star compositions and to prevent unwanted reactions with other chemicals in a mix.

Materials Needed

- Aluminum powder
- Boric acid (CH8042)
- Distilled water

Joel Harmon was in a discussion on the Pyrotechnic Mailing List about how to reduce the risk of a runaway reaction between aluminum powder and water in a star composition. Boric acid powder is commonly added to star compositions for this purpose, but Joel suggests a more effective approach. Thanks Joel.

"I use boric acid only in solution. I usually buy distilled water and put 2% (by weight) boric acid powder in it and let it dissolve. If the boric acid in solution that you are referring to is in water then you can probably use it as is. See how concentrated the solution is and use it appropriately.

I once had a very well-respected firework builder tell me that putting boric acid in star compositions dry is a waste of effort because it can never really protect all that aluminum powder very effectively, as the boric acid doesn't fully dissolve (boric acid takes a while to dissolve and is very hard to dissolve). When boric acid is in solution it can coat every particle of aluminum powder in your star composition evenly. I have always used this solution idea and have never had degradation of effect."

How to Convert Pyrotechnic Formulas

By John Werner

Learn how to rewrite pyrotechnic formulas from parts by weight to percentages.

Quite often, pyrotechnic formulas, especially older ones, do not have the ingredients listed as a percentage of the total pyrotechnic formula, only as parts of the total weight of the mix. An example of this would be the saxon pyrotechnic formula out of the Weingart book, which is:

Meal powder	4
Sulfur	2
Potassium nitrate	2
Mixed charcoal	1
Total	9

In order to compare pyrotechnic formulas from different sources, they must both be percentage-based formulas, such as this saxon pyrotechnic formula from Lancaster:

Meal powder	50
Potassium nitrate	30
Charcoal 40/10 mesh	10
Sulfur	10
Total	100

Here we see the pyrotechnic formula totals 100, so that now we can express each ingredient as a percentage of the total - for instance, potassium nitrate makes up 30% of the total. In order to compare the Weingart pyrotechnic formula to the Lancaster pyrotechnic formula, it is necessary to convert Weingart's pyrotechnic formula so that the total adds up to 100.

Fortunately, this is easy to do. First divide 100 by the total of the pyrotechnic formula you wish to convert (in this case, 9).

100 / 9 = 11.111

Using the result of this computation, multiply each ingredient in the pyrotechnic formula to be converted and round to the nearest whole number:

Meal powder	4 x 11.111 = 44.444 = 45
Sulfur	2 x 11.111 = 22.222 = 22
Potassium nitrate	2 x 11.111 = 22.222 = 22
Mixed charcoal	1 x 11.111 = 11.111 = 11
Total	100

Rounding fractions will sometimes yield a total of 99 or 101. It okay to adjust the largest amount of material up or down 1% to get the total at 100.

We can now clearly see that the Lancaster pyrotechnic formula uses 5% more meal powder, 8% more potassium nitrate, 1% less sulfur and 12% less charcoal. Therefore, even before we mix an ounce of precious chemical we can make an educated guess that the Lancaster pyrotechnic formula will probably burn faster due to the increased meal and oxidizer content.

Any weight-based pyrotechnic formula can be converted to a percentage-based formula by using this technique.

You will be surprised how many of the seemingly different pyrotechnic formulas in a lot of the older books turn out to be nearly identical when converted to percentages. Making these conversions in your lab notebook can be very enlightening and should be done as a matter of habit. You are keeping a notebook, aren't you? Remember: apples to apples.

Many times pyrotechnic formulas for fountains, gerbs and glitter stars, (among others) are given as having a certain amount of meal powder included with the rest of the chemicals. Most of these will work just fine, although normally a bit less vigorously, if the components of meal powder, potassium Nitrate, charcoal and sulfur, are substituted in the pyrotechnic formula. The problem is figuring the individual amounts of each of these three to add in.

Begin by converting the pyrotechnic formula to percentages. As an example, here is a pyrotechnic formula from Weingart for a simple gerb:

	Original in "Parts"	**Converted to Percent**
Meal powder	6	55%
Potassium nitrate	2	18%
Sulfur	1	9%
Charcoal	1	9%
Steel filings	1	9%
Total:	11	100%

In this pyrotechnic formula, meal powder makes up 55% of the mix. Since meal powder is 75% potassium nitrate, 15% charcoal, and 10 % sulfur, all that is needed is to take 55% of each of those values and add them back into the pyrotechnic formula; so you have:

55% of 75 = 41.25
55% of 15 = 8.25
55% of 10 = 5.50
55.00

Rounding off to the nearest whole number we now have:

Potassium nitrate	41
Charcoal	8
Sulfur	6

Potassium nitrate	18
Charcoal	9
Sulfur	9
Steel filings	9
Total	100

Combining like terms, the final pyrotechnic formula works out to be:

Potassium nitrate	59
Charcoal	17
Sulfur	15
Steel filings	9
Total	100

Note that the final values still add up to 100% - a good way to check your work.

Chlorine Donor Chemicals

By Charley Wilson

Learn about which firework chemicals are commonly used as chlorine donors in pyrotechnic formulas, and why, and the amount of chlorine they give off.

In *Fireworks, the Art, Science, and Technique*, Takeo Shimizu gives a very good explanation of color production. For blue, the color-producing firework chemical is thought to be copper monochloride, a molecular species that only exists in the colored flame. (This is NOT the same as cuprous chloride, CuCl). If there is no free chlorine in the flame, there can be no blue color from copper. Copper oxide, hydroxide, carbonate, and other copper compounds in a colored flame will emit green and red bands of light, and hardly any light in the blue spectrum.

To complicate matters, the cupric monochloride is destroyed at high temperatures, so to produce a good blue firework star the colored flame must be relatively cool by pyrotechnic standards. This is another reason why blue firework star compositions should not contain metal fuel.

The discovery of colors produced by chlorine along with other elements belongs to Chertier, who described the phenomena in 1836. As electricity began to become widely available, so did the chlorates to be used as oxidizers for color compositions. Potassium chlorate can be considered to be somewhat of a chlorine donor during combustion, which allows free chlorine to combine with other elements in the colored flame.

Where potassium perchlorate or a nitrate is used as the oxidizer, some supplemental chlorine must be included in the firework star composition. In years past, mercurous chloride, also known as calomel, was used. Calomel decomposes at ordinary flame temperatures into chlorine and mercury metal vapor.

Even when potassium chlorate was used as the oxidizer in older blue firework star compositions, calomel was often included to insure that plenty of chlorine was available. Calomel was relatively safe to handle because of its very low solubility, and was even used medicinally.

Today we know that mercury is a very bad actor in the environment, witness the birth defects in Japan resulting from mercury poisoning, not to mention the deaths! Unfortunately, the mechanism of calomel's production of chlorine is unique.

Other metal chlorides have been tried in an attempt to mimic calomel. The alkaline earth metal chlorides typically have such a high decomposition temperature that they yield no free chlorine. Notably Tessier in good blue and blue related firework star compositions, with similar environmental problems, has used lead chloride.

Other means of supplying chlorine in the colored flame include organic compounds that contain chlorine. It is perhaps ironic that some of these chlorinated hydrocarbons are as nasty to the environment as mercury, perhaps even worse.

After all, the broad class of insecticides that includes DDT is chlorocarbons. One such insecticide is Mirex, also known as Dechlorane, with an empirical formula of $C_{10}Cl_{12}$. Although no longer manufactured in the United States, it is in use as a chlorine donor for pyrotechnics today. As "Dechlorane," the product was intended for use in plastics as a fire retardant. The now infamous Hooker Chemical Company, from 1957 to 1976, produced Dechlorane.

When an otherwise flammable plastic contains a chlorine donor along with antimony oxide, charring is promoted which in turn inhibits flame. In a flame, antimony oxide halides form an inert gas, which can preclude further oxygen from reaching the plastic. Again it is ironic that the same chlorine donor prevents fire in some cases and provides chlorine for colored flames in others. Bromine, the next halogen down from chlorine, has largely supplanted chlorine in the role of fire retardant. Metal bromides can also produce nice colored flames, but that is another topic!

It is the author's untested assertion that the cinder formation in some color firework star compositions is due to the fire retardant action of metal oxide chlorides.

Other chemicals that contain high percentages of chlorine include ammonium chloride (NH_4Cl), hexachlorobenzene (C_6Cl_6), and hexachloroethane (C_2Cl_6). Hexachlorobenzene (HCB) was used extensively as a chlorine donor due to the aromatic carbon structure and high chlorine content.

On paper, ammonium chloride and hexachloroethane (HCE) both look ideal. In reality, they both tend to vaporize out of the colored flame before contributing a significant amount of chlorine. They might find use as chlorine donors in the colored alcohol fireballs in vogue today.

There is an interesting use of the name benzene in the Shimizu text. There is an insecticide with the trade name of Lindane which is specifically 1, 2, 3, 4, 5, 6 hexachloro gamma cyclohexane ($C_6H_6Cl_6$). This compound is also referred to as benzene (gamma) hexachloride, even though it does not contain the benzene ring. Shimizu states that it is not as good for color production as PVC. Apparently, the good doctor had never tried true hexachlorobenzene, which is superior.

Where a firework star composition actually calls for HCB, Dechlorane can be used as a substitute. Dechlorane in amounts higher than about five percent seems to increase the whiteness of the colored flame.

Most of the above-chlorinated compounds are carcinogenic. Production of HCB was banned in this country (USA) several years ago. Much nicer to work with are the chlorinated plastics, beginning with Parlon.

Parlon was made by Hercules Chemical many years ago, and is a chlorinated natural rubber. They no longer make it, but overseas sources of "Superchlon" and "Pergut" are apparently the same material. These are probably what the chemical suppliers are selling. Parlon is relatively safe to handle, and it dissolves in ketones such as acetone or MEK.

The most confounded chlorine donor name is "Saran.” Dow Chemical produces various types of Saran resin for different applications. Ideally for firework stars, Saran should be pure PVDC (polyvinylidene chloride) powder. This would be the best choice if it were available. However, there are seemingly hundreds of different versions of "Saran," which are copolymers of PVDC with some other plastic, including PVC and acrylonitrile. When these copolymers are mostly not PVDC, the chlorine content is lowered and the burning characteristics become worse.

A simple test for a given sample of Saran is to test for solubility in acetone or MEK. If the powder eventually dissolves at room temperature, it has a high copolymer component. If it does not dissolve, or requires high heat to dissolve, then it can be recommended for use in pyrotechnics. Saran with a high percentage of PVDC is highly recommended for any firework star composition which requires a chlorine donor, and typically gives the best color purity, burning speed, and ignition.

Similar to Saran in the aspect of identity crisis is "Chlorowax," produced by Occidental Chemical. There are at least ten different Chlorowax compounds, which range from white powder to oily liquid. The material, which has been reported as a good pyrotechnic chlorine donor, notably by Joel Baechle, is the waxy substance, which behaves like paraffin. Chlorowax was intended for use as a flame retardant.

PVC (polyvinyl chloride) is another plastic that is used as a chlorine donor. PVC produces hydrogen chloride gas when it burns, which can be environmentally bad but pyrotechnically good. It does not contain as much chlorine as PVDC or Parlon, and also acts as a fuel more so than they do.

It works very well as an adjunct chlorine donor in chlorate firework star compositions, and it is typically the least expensive compound of those discussed here. It also works well in combination with magnesium, where the HCl gas reacts with the metal oxides in the colored flame to improve the color. PVC will dissolve in MEK.

There are many potential pyrotechnic chlorine donors, which have never been tested. Some of the newer flame-retardants may be superior in fact. One in particular that should be tested is TCPA, tetrachlorophthalic acid. This should be similar to HCB, and would supply the aromatic ring, which seems to make better colors.

In conclusion, mention must be made of ammonium perchlorate. NH4ClO4 is unique among oxidizers in that it combusts to produce HCl gas, and is superior as a chlorine donor in this respect. Most of today's "award winning" firework star compositions are made with ammonium perchlorate.

In the following table, percentages of chlorine are given from either the calculated maximum by molecular weight or from the manufacturers own data when the molecular structure is irregular (such as Parlon).

Chlorine Donor Component	**Percentage Chlorine**
Ammonium chloride	66
Chlorowax	30-70
Dechlorane	78
Hexachlorobenzene (HCB)	75
Hexachloroethane (HCE)	90
Lead chloride	25
Lindane	73
Mercurous chloride	15
Parlon	64-68
PVC	57
PVDC (Saran)	73

A Test for Potassium Chlorate

Here is a good and fun way to test for potassium chlorate. You will need:

- 1 part powdered sugar
- 2 parts potassium chlorate
- 1 drop concentrated sulfuric acid

Mix the dry mixtures well, place in a paper cup. Add 1 drop of acid, and in about 1 second you'll have ignition. It won't blow up unless contained.

Understanding Kraft Paper Grain

by John Werner

Learn to understand Kraft paper grain and how to use the grain to your advantage while building fireworks.

Materials Needed

Kraft paper

What is Kraft paper grain, and why is it important? One of the most important aspects of working with Kraft paper when pasting shells, rolling tubes, or making leaders is being able to determine the "grain" of the Kraft paper. Kraft paper grain has characteristics similar to wood grain, and in the same way that a furniture maker needs to understand the properties of the wood he is using, the firework maker must understand the properties of Kraft paper grain so that he can use his Kraft paper to his best advantage.

When Kraft paper is manufactured, the individual fibers of the Kraft paper pulp tend to orient themselves in lines or rows. A good way to visualize the structure is to look at or imagine the bamboo place mats or window blinds, in which thin strips of bamboo are laced together with fine string to form a material which can only be rolled up in one direction.

It is easy to see that if one tried to roll this mat around a mandrel or tube that there would be only one way in which this could be accomplished without bending or breaking the bamboo strips. With Kraft paper, this would be referred to as rolling "with the grain" as opposed to rolling "against the grain." Kraft paper, especially heavier weight Kraft paper and thin cardboard, exhibits this same characteristic, and the direction of the fibers should be noted for several reasons before beginning to utilize the Kraft paper on a project.

First, as was noted with the bamboo mat, Kraft paper and cardboard are distinctly easier to roll around a mandrel when making tubes, cylinder shell liners, or quick match leaders for instance, if the material is oriented to roll with the grain. Secondly, Kraft paper, like wood, expands when wet and contracts when dry. Again, the fiber structure explains why this happens. Imagine the bamboo mat, with its strips of bamboo rather loosely held together. If something like sand were poured on the surface of the mat and forced or pressed into the spaces between the strips, the mat would get slightly wider but not longer.

With Kraft paper, cardboard or wood the same thing happens on a molecular scale when water is applied to the material. The Kraft paper will swell, but mainly in one direction. This property of Kraft paper grain is very useful when pasting shells, especially cylinder shells, where larger sheets of Kraft paper are used. The Kraft paper is first pasted overall, causing it to expand, after which it is rolled with the grain around the body of the shell. As it dries the Kraft paper shrinks down to fit very tightly around the shell, making a hard smooth surface. If the Kraft paper is rolled against the grain, the shrinkage will not be nearly as great and the final product will not have the same smooth, tight appearance.

Several methods are available to determine Kraft paper grain: folding, tearing or wetting. For heavy Kraft papers and cardboard, merely folding and creasing the material first in one direction parallel to an edge and then making a fold perpendicular to the first fold works well. The fold on the grain of the Kraft paper (which will be parallel to the direction of the fibers) will be easier to make and will have a sharper appearance.

Tearing is another quick method that works on either thin or thick Kraft papers. Tearing a line down the length of the fibers produces a straighter separation and is somewhat easier to do than tearing across the fibers. The best method however is by taking a small square of the Kraft paper and quickly wetting one side only.

As the water starts to expand the fibers on that side, the Kraft paper will begin to curl and hump up. The curl will clearly indicate the proper orientation the paper needs to be in for rolling tubes, leaders, shell casings, or anything else in which the grain direction is important.

Coating Paper Mortar Tubes for Longer Life

Learn how to coat your fireworks paper mortar tubes with a varnish to help protect them for longer use.

Materials Needed

- Mortar tubes, cardboard (1.75 inch, TU2100) (2 inch, TU2200)
- Varnish or polyurethane

Around The Fourth and New Year's, we always have a flurry of orders from people who are buying class C (1.4G) festival balls, only to belatedly discover that they only got one mortar tube to shoot them out of. We sell 1.75 inch and 2 inch paper mortar tubes to accommodate these unfortunates.

Cardboard mortar tubes are notorious for unraveling after they have been used once or twice. The problem is that the potassium nitrate residue left in the mortar tube absorbs water. The dampness causes the glue in the mortar tube to loosen up, and your mortar tube is now history. You can extend your mortar tubes life considerably by waterproofing them.

Put some thinned varnish or polyurethane in a shallow tray that's big enough to accommodate your mortar tube. I prefer varnish even though it takes longer to dry. Varnish penetrates the cardboard, but polyurethane coats it and makes the ID slightly smaller. Then dip the mortar tube, completely coating it inside and out with goo. Hang it up to dry. I use straightened wire coat hangers and decorate my dogwood trees with them for a couple of days.

We don't offer plastic bases for these mortar tubes, because they tip over. You can make a good base by getting a hole saw (adjustable or otherwise) and cutting about a 3/8 to 1/2 inch deep hole in a piece of lumber. Then use white carpenter's (or Elmer's) glue (do NOT use hot melt!) to mount the mortar tubes to this base. Et voila!

8

Black Powder

Finding the Right Black Powder for Fireworks

Learn the differences between the different grades of black powder and their uses in pyrotechnics

Size Does Matter: What Is the Right Black Powder?

Having a hard time finding the "right" size black powder or confused about it? The manufacturers classify black powder types and grain sizes by the numbers and letters shown below. Most black powder sold in the US is either "sporting grade" ("G" black powders), or "blasting grade" ("A" black powders).

Professional fireworks manufacturers prefer the "A" series black powders, but you are required to have an ATF license to buy them legally. However you don't need an ATF license to purchase up to 50 lbs. of sporting grade (G) black powders, which are chemically identical.

Since the composition of the two types of black powders is identical, you can, in fact, substitute G black powder for A black powder in your fireworks, if you understand the following: the black powder manufacturers created completely different grading schemes for each type of black powder, (for example, sporting vs. blasting powder). Hence, FFg black powder is not the same size as 2FA.

By using the table below you can see how to substitute G grade black powders for the harder-to-obtain A grade black powder. In the USA, gun stores will sell you cannon grade, 1Fg, and FFFFFg black powders as suitable substitutes respectively for the most commonly used 2FA (for lift and burst), 4FA (for lift and burst), and Meal D (for rice hulls and priming).

If you are making your own black powder, you can use this chart for approximate screen sizes for granulating powders to standard grain sizes.

Black Powder Grades and Equivalent Sizes (in mm)

Sporting Grades (G)	Grain Size (in mm)	Blasting Grades (A)	Grain Size (in mm)
Cannon grade	4.76-1.68	1FA	8.0-4.0
Fg	1.68-1.19	2FA	4.76-1.68
FFg	1.19-0.59	4FA	1.68-0.84
FFFg	0.84-0.29	5FA	0.84-0.297
FFFFg	0.42-0.15	7FA	0.42-0.149
		Meal D	0.42
FFFFFg 0.14	9	Fine	0.149

Making and Testing High-Powered Black Powder

By Ned Gorski

Black powder (BP) is an almost ridiculously simple pyro ingredient - mostly just three chemicals, blended together in simple ways, but producing wonderful results. Black powder exemplifies for me the endless learning, experimentation, and creativity that fireworking holds for us. If so much fun can be had with BP, imagine what else fireworks-making has in store for you.

Materials Needed

Black powder, for testing

Introduction

In this article I'll be writing about two basic skills:

1. How to make black powder using four basic methods, ranging from the use of only two simple screens, through the use of a star-roller, hydraulic press, and/or a ball-mill.

2. How to test various black powders to compare their power, and to determine how much to use when lifting a typical fireworks aerial shell.

I hope this article will be useful for both the novice fireworker, and for the most experienced one.

What is Black Powder (BP)?

Have you ever taken the covering off of the bottom of an aerial shell and observed the black granules which are used as the shell's "lift powder?"

Black Powder Used as Shell Lift Powder

Black powder is perhaps the most basic and useful of all fireworks ingredients. It is used to lift shells, comets, mines, Roman candle stars, and as a base-composition in some rockets and many other fireworks components and devices.

Here is the definition of black powder taken straight out of the The Illustrated Dictionary of Pyrotechnics (Skylighter #BK0043):

"Black Powder - An intimate mixture of finely powdered potassium nitrate (75%), charcoal (15%), and sulfur (10%). Commercial black powder may be granular or finely powdered. It serves as a propellant and has a wide variety of uses. Black powder should not be confused with smokeless powder, which is not a suitable substitute for black powder (in fireworks)."

So, What Is "High-Quality" Black Powder?

For the sake of this article, at least, let's define high-quality BP as that black powder which will adequately serve the needs of the fireworker, and which comes close to, or exceeds, the quality and explosive power of commercially available black powder. Goex brand is a well-known, and often referred to, example of commercial powder.

Goex Brand Black Powder

Well, Can't I Just Buy the Black Powder I Need?

First of all, didn't we say, "Hey, I'd like to learn how to make fireworks." You can buy some types of black powder. There are two types available, sporting and blasting. The sporting grades of BP, made by Goex and others, are readily available from some gun and sporting goods shops, and some online sources. These are the "Fg, FFg, FFFg, FFFFg, " and so on. Grades listed in the black powder grain size charts.

The blasting grade, "A" powders are most frequently used in fireworks. 2FA, 4FA, and Meal-D are the sizes we need the most. (See the article on black powder sizes and grades Size Does Matter in Skylighter Fireworks Tips #44.) They are available only to holders of a BATFE explosives license.

If you can find BP at your local gun shop, it usually retails for $16 - $24 per pound. Beginner shell makers can easily use more than 50 pounds of 2FA per year. That's about $1,200 at retail! It doesn't take long, buying commercial BP, before you start asking yourself, "Self, ain't there a less expensive way?"

Even if one has the BATFE license to buy commercial 2FA in bulk (50 or 100 lbs at a time), the current price of it is $7-8 per pound.

So, economics, practicality, availability, and the pride of actual fireworks-making, all eventually make it inevitable that most pyro-hobbyists will make their own BP. And the good news is that it is federally legal to make it yourself, without an ATF license. But, check your state and local laws first to make sure you can comply with them as well.

Many would argue that the very first, important step to learning the art of fireworking is tackling the skill of making high-quality black powder.

What Affects the Quality of Homemade Black Powder?

Typically, these are the key variables in making powerful, high-quality BP:

1. The quality of the chemicals and the type of charcoal (wood species) that is used. Willow charcoal is often being referred to as the wood of choice for BP charcoal. I use spruce/pine as the wood that I turn into homemade charcoal. (This subject is discussed in the Making Charcoal article, Skylighter Fireworks Tips #90.) I'll be comparing BP made with this pine charcoal, with that made with commercial airfloat charcoal.

2. The method used to pulverize and intimately mix the ingredients. Screening through a fine-mesh screen or ball-milling can be employed. (This subject is thoroughly explored in Ball Milling 101, Skylighter Fireworks Tips #91.)

3. How the mixed ingredients are consolidated and granulated.

4. The size of the granules, especially with BP that is made into pucks that are broken up (corned).

Four Methods of Making Black Powder

I have played with several methods of making BP. Now I'm going to make black powder in four of those ways:

- Pressing BP pucks and breaking them up. (This method has been detailed in Skylighter Fireworks Tips #92 and #93.)

- Coating the BP onto rice hulls. (This method was detailed in Skylighter Fireworks Tips #92.)

- Ball-milling the composition, wetting the BP with red gum and alcohol, and granulating it through a 4 mesh screen.

- Simple screening of the chemicals through a 100 mesh screen, and using the red gum/alcohol granulation method.

First Step

I ball mill four 20-ounce batches of mill-dust BP, two batches using pine charcoal, two more using commercial airfloat. Each batch has 15 ounces of potassium nitrate, 3 ounces of charcoal, and 2 ounces of sulfur. I run the ball mill for 2 hours for each batch. I end up with 40 ounces of pine charcoal mill-dust, and 40 ounces of commercial charcoal mill-dust.

(Mill-dust is the term that is used for BP as it comes straight out of the ball mill, before any granulation.)

Second Step

I take 16 ounces of the pine charcoal mill-dust, add 1.6 ounces of water (10%) to it, and thoroughly incorporate the water into the powder with my gloved hands. Then I further incorporate the water with a screen colander. I press 1/8" thick pucks with that powder. I have found that if I apply about 1600 psi of pressure on the pucks when I press them, that they are as solidly consolidated as they are going to get. I put the finished pucks into the drying chamber to dry.

I do the same with 16 ounces of the commercial charcoal mill-dust.

(I have found that it is quite easy to break the pucks up a bit by hand while they are still damp. This makes it easier to granulate them later on.)

Black Powder Pucks, Pressed and Crumbled

Third Step

I take 16 ounces of the dry pine charcoal mill-dust, add 0.8 ounce of dextrin (+5%) to it, screen it to thoroughly incorporate it, and coat that BP onto 2.4 ounces of rice hulls in the star roller (7/1 ratio of BP to rice hulls). (See the Nice Shells in 2-1/2 Days, Part 2 article in Skylighter Fireworks Tips #92.) I put the coated hulls on screens and into the dryer. Although puffed rice cereal can be used in this process, rice hulls make more durable grains.

I repeat the process with 16 ounces of the commercial charcoal mill-dust.

Plain and Black Powder Coated Rice Hulls

Fourth Step

I take 8 ounces of the dry pine charcoal mill-dust, and dampen it with 1/3 cup of denatured alcohol (from Home Depot) which has 1/10 ounce of red gum (about 1% of the mill-dust weight) dissolved in it. I slowly add enough additional alcohol to the mill dust, only as much as necessary, to end up with a nice, putty-like "dough ball." Then I granulate that dough-ball through a 1/4" (4 mesh) screen onto a kraft-paper lined tray for drying.

Black Powder with Red Gum and Alcohol, Granulated

I repeat the process using commercial charcoal mill-dust.

Warning: When working with alcohol or any other solvent that puts a lot of fumes into the air, I do so outdoors so fumes cannot collect and be ignited, and I wear a mask-respirator to avoid breathing the fumes.

Fifth Step

I simply take 15 oz. of potassium nitrate and screen it through a 100 mesh screen. If all of it won't pass the screen, I mill it a bit in a small coffee grinder until it will pass the screen.

Warning: I never mill anything but individual chemicals in the coffee grinder. I use one coffee grinder only for oxidizers, and a different one for fuels. I thoroughly clean it after using it for one chemical.

Then I combine that 15 oz. of potassium nitrate with 3 oz. of pine airfloat charcoal and 2 oz. of sulfur, and pass them twice through the 100 mesh screen to thoroughly mix them.

This 20 oz. batch of BP chemicals is then wet with about 3/4 cup of the denatured alcohol which has 0.2 oz. of red gum dissolved in it. More alcohol is added as needed and the putty is granulated as in Step 4 above.

I do the same for a similar batch using the commercial airfloat charcoal.

Many of you are now saying, "Aw, he's never gonna get a useful BP with that simple screening method. It has to be ball-milled." You just wait.

All of the powders produced above are left in the drying chamber until they are completely dry. (Skylighter Fireworks Tips #92 shows you how to make and use a drying chamber.)

Granulating and Sizing the Black Powders

Once the powders have dried in the drying chamber for a day or two, I process them in various ways. For processing black powder pucks see how to granulate black powder pucks in Fireworks Tips #93.

With the pine charcoal pucks, I end up with 10.7 ounces of the 2FA, and 1.75 ounces of the 3FA. (In reality, commercial 2FA powder contains grains from 4 to 12 mesh, but my 2FA consists of only the coarser grains.)

With the commercial charcoal pucks, I ended up with 10.15 oz. of 2FA powder, and 2.05 ounces of 3FA.

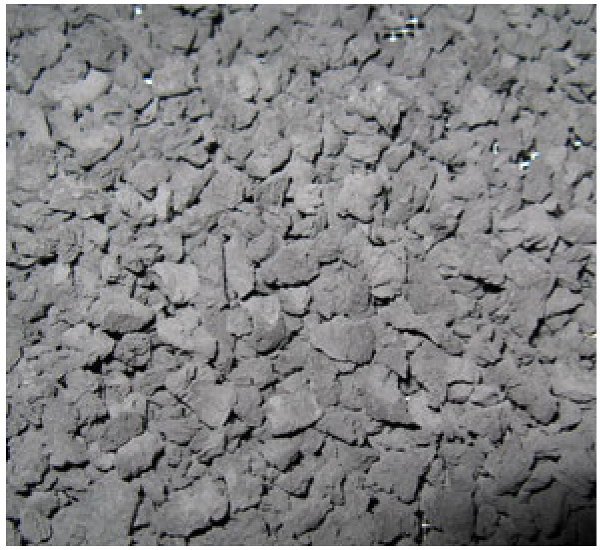
Note: I don't really like the process of pressing all these pucks, and then crushing and granulating them. It's a painstaking, time consuming, and messy process. On the other hand, it is nice to end up with such hard, durable grains, which are practically indistinguishable from commercial black powders.

Processing Black Powder Coated Rice Hulls

After dumping the BP coated rice hulls from the drying screens into a rectangular tub, I then simply screened them on my 12 mesh screen to sift out the fine BP grains and dust. There was not a whole lot of that, but I wanted to end up with just the coated hulls.

Processing Red Gum Black Powder

With the red gum/alcohol granulated powders, I dumped them from the drying screens and forced them through my 4 mesh screen to break up the larger clumps. Then I screened that powder on my 12 mesh screen to remove the fines and dust, ending up with nice, hard grains in the 4-12 mesh size.



Black Powder with Red Gum and Alcohol, Granulated

Some Observations

Coating the rice hulls and processing the resulting grains is relatively easy, and the alcohol/red gum granulated powder is probably the easiest to produce. It is a bit more expensive to make, though, since the red gum and alcohol cost a little more than dextrin and plain water.

Results

So, now I have my 10 homemade powders to compare with each other. I also have some German Wano 2FA powder (equivalent to Goex 2FA) which I screen and separate into 4-8 mesh and 8-12 mesh powders, as I did with the homemade powder made from pucks.

1. Pine charcoal 2FA
2. Commercial charcoal 2FA
3. Pine charcoal 3FA
4. Commercial charcoal 3FA
5. Pine charcoal BP coated rice hulls
6. Commercial charcoal BP coated rice hulls
7. Pine charcoal, ball-milled BP, processed with alcohol and red gum

8. Commercial charcoal, ball-milled BP, processed with alcohol and red gum

9. Pine charcoal, simply screened BP, processed with alcohol and red gum

10. Commercial charcoal, simply screened BP, processed with alcohol and red gum

11. Wano 2FA

12. Wano 3FA

Now I'd like to test these 12 BP's and compare their relative performances.

The Big Experiment

So far, all of this is very interesting information, but quantitatively it does not tell me a whole lot that is useful for me in making fireworks. I have some big questions I'd like answers to:

- To what extent does the type of charcoal affect the power of the BP?
- Consolidated and granulated using 4 different methods, how much variation in the BP's power will result?
- How do these homemade BP's compare in power with commercially produced powders? How can this be tested and quantified?
- How much should I use of one of these BP's to lift an aerial shell?
- How do the various methods of production compare as far as expense and labor? Are some methods significantly easier than others for the manufacture of BP?

I have to admit that the process I'm about to describe is where my creative juices really start flowing in this hobby. Being curious about something, thinking about it, doing some experimenting, pondering the results, and coming to some conclusions that are useful in my future activities--that's what this is all about for me.

We have quite a few variables in the above information when it comes to choosing how to make powerful BP and how to use it in our pyro projects.

I want to design an experiment to compare black powders which incorporate these different variables, in order to know how each of those variables affects the BP's power, and to be able to determine which materials and techniques are preferable when making my BP.

I have my 12 different types of black powder sitting in front of me. Now I'll test them in various amounts, lifting dummy shells, to compare their relative performances, and to find out exactly how much of each of them to use when lifting an actual fireworks shell.

Testing the Black Powders.

In years past there has been a "game," played at the Pyrotechnics Guild International's annual convention, called "pyro-golf." Folks brought samples of their prize black powders, and a fixed amount of each was used in a mortar to shoot golf balls into the air. The flights were timed, and the longest flight time would be declared the First Prize black powder. This is a good method for comparing the power of different powders.

Homemade powders could also be compared to commercial BP's at the same time. Usually the homemade powders outperformed the commercial ones by quite a sizable margin.

There are other ways to compare black powder performances, but I like the golf ball test because it duplicates the real-life application of using black powder to lift aerial shells.

For testing my 12 BP's, I'm going to use my version: "Pyro-Baseball." With "Pyro-Baseball," I use baseballs and a 3" mortar to simulate the lifting of 3" spherical fireworks shells. Baseballs are just the right size and weight. They save me the time, expense, and hassle of having to build actual dummy shells.

For my tests, I'm using a one-piece, HDPE (high-density polyethylene) "gun." Whichever gun you use, it is a good idea to use the same mortar for all of the comparison shots. This will minimize variations from one test to another.

On page 140 of The Best of AFN II (BAFN II) are some charts showing recommended BP lift amounts for various types and sizes of shells. Table 1 indicates that, for lifting a 3" ball shell, 0.6 oz. of FFg, or 0.75 oz. of 2FA would be appropriate amounts of commercial lift powder.

And, on Page 17 of the PGI's Display Fireworks Operator Certification Study Guide, one can find a nifty table that shows the typical (desired) heights that various size fireworks shells ascend to before bursting. This table shows that a 3" fireworks shell would rise to about 300 feet and then burst.

That's good information to have. Using about 0.6 to 0.75 ounces of my Wano BP ought to send one of my baseballs up to about 300 feet. I can weigh that amount, drop it down into the bottom of a 3" mortar, insert 4" of visco into the fuse hole at the bottom, drop a baseball into the gun, and light 'er up.

3" Mortar Loaded and Ready for "Bear"

But, how do I know if the ball actually ascends to 300 feet before it peaks out (at apogee) and starts to descend? One simple physics equation is all that is necessary to figger that out. If you drop an object and time its descent to the ground, the distance the object has fallen, in feet, is given by the equation, Distance = 16 x time x time (16 x time squared), when the time is measured in seconds.

For example, if I fire my baseball, and start a stopwatch when its flight peaks out at apogee, and then stop the stopwatch when the ball hits the ground, I'll be able to read the time it took the ball to fall to the ground from that peak. Let's say that my stopwatch indicates a time-of-fall of 4.18 seconds.

Timing the Fall of a Dummy Shell

To see how high the baseball was when it started to fall (at apogee), all I have to do is multiply 16 x 4.18 x 4.18 and I get a height of 279.55 feet. That's pretty close to my desired 300 feet. So I know that using the amount of lift powder that I used, or maybe just a tad more, would be a good quantity of that BP to use in the future for this size and weight shell.

This is what I'll be attempting to determine with each of the 12 experimental powders. Once I know those amounts for each powder, I'll then be able to compare their relative powers with each other. I'll tabulate that info and have some very useful results and conclusions - just what I was looking for to begin with.

Note: An interesting relationship that I've noted during past tests is the amount of time a dummy shell takes to rise to apogee after being fired from the mortar, compared to the time it takes to fall to the ground. I've noted that it takes a spherical dummy shell approximately half the time to rise to apogee that it takes the shell to fall to the ground from apogee.

Another way of saying this is that, of the total flight time from launch of the dummy shell from the gun to it hitting the ground, one third of the flight time is spent rising to apogee, and two thirds of the time is spent falling to the ground from the apogee.

So, if I use various amounts of a lift powder and time the baseball's flight from the apogee to the ground, adjusting the powder amounts as I go along, until that time of fall equals 4.33 seconds, then I'll know exactly how much of that powder to use again to duplicate that height. 300' = 16 x 4.33 x 4.33.

If I want a slightly higher flight for a shell, for example one with a long burning willow star shell, then I'd use a bit more powder.

Pyro-Baseball Testing of Black Powders

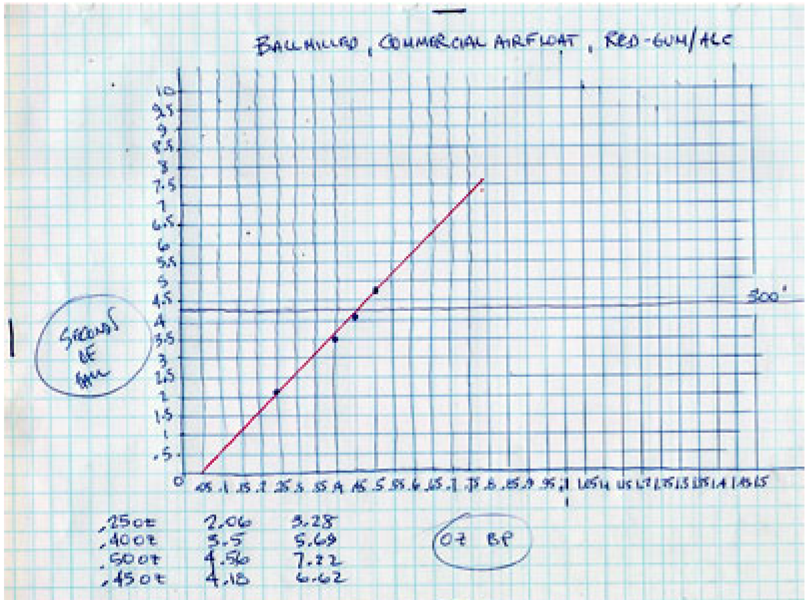
So, I go out to my shoot site with my lovely assistant and all my testing materials: BP's, scale, spoon, paper cups, notebook, pen, baseballs, mortars, visco, anvil-cutter (I never cut fuses with scissors, only with razor blade anvil-cutters), chairs, table, stopwatches, sunglasses, camera, re-bar, and duct tape.

My Lovely Assistant, Ready to Take the Field, and the Ammo

No, she didn't really try to catch the balls. She had to man (woman) one of the stopwatches instead.

The mortar was taped to a piece of rebar driven into the ground, angled away from us, and the ammunition was prepared. I had previously drilled a small fuse hole near the bottom of the mortar.

I had prepared some charts in advance to take notes for each powder test. The vertical axis represents the time of fall in seconds, and the horizontal axis represents ounces of black powder in 0.05 ounce increments. I drew a horizontal line at 4.33 seconds since that time of fall represents a height of 300 ft., which is what I'm shootin' for.



One of My Hand-Plotted Graphs

Then, it was just a matter of starting to fire baseballs with measured amounts of one of the experimental BP's, such as the one in the above chart: ball-milled, commercial charcoal, alcohol/red gum granulated. We used two stopwatches, recording the total time of flight, and the time of fall from the apogee to the ground.

Judging the exact apex of the flight can be a bit tricky, since there is a second before the apogee where the flight up really slows down, and there is also a bit of time after the apogee before the ball really starts to pick up speed. But, we just did the best we could. It's probably a bit more accurate to use a time that is 2/3 of the total flight time, from lift to landing.

Baseballs After Being Fired from the Mortar

Warning: After each baseball firing, there may be hot sparks remaining in the mortar. I am careful to wait a bit before reloading. Then I insert the visco fuse, drop the next portion of BP in, and then carefully drop the baseball in. I avoid getting any body part over the mouth of the gun when

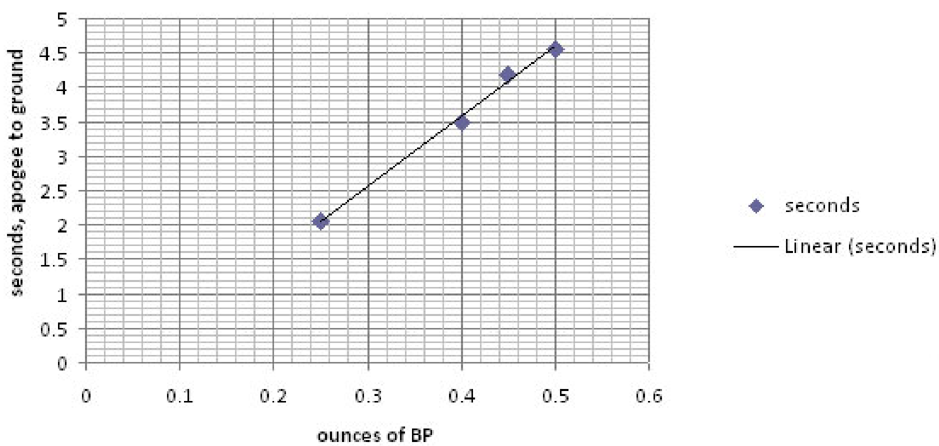
doing this, regardless of whether I know the fuse is lit. A baseball fired at this speed could easily kill a person or remove a hand or arm.

I wanted to start with a small amount of the powder, gradually increasing it until I started to get flights that were a bit too high. I figured that would give me the spread of data which I could use to determine the right amount of powder for a 300' high flight. The following is a listing of the amounts of this one particular powder that I used, and the resulting flight times that we recorded.

Ball Milled, Commercial Charcoal, Red Gum/Alcohol Granulation

Amount of BP	Time from Apogee to Ground	Total Flight Time
0.25 oz.	2.06 seconds	3.28 seconds
0.40 oz.	3.50 seconds	5.69 seconds
0.50 oz.	4.56 seconds	7.22 seconds
0.45 oz.	4.18 seconds	6.62 seconds

Below is a computer-generated graph of the data above.



Ball-milled, Commercial Charcoal BP, Red Gum/Alcohol Granulation

When these coordinates were entered into the graph, a couple of things became obvious. There is a linear relationship between the amount of lift powder that is used, and the corresponding flight time.

This graphed line, if extended down to the bottom of the chart, points to an amount of BP which would not even get the ball out of the gun, about 0.05 ounce in this case. That graphed line crosses the 4.33 seconds/300' line, between 0.45 and 0.5 ounces of the BP.

Indeed, when the average time from apogee to the ground, is divided by the average total flight-time, the time from apogee to ground is about 2/3 of the total flight time from lift to landing. With this powder, I'd use 0.5 oz. to reliably lift a 3" ball to 300'.

We did this with each powder, firing baseballs about 40 times into the air.

Results

Repeating the tests described above with each of the 12 BP's, I was able to determine the optimum amount of each powder for lifting a baseball to 300'.

Optimum Amount	BP Type
0.30 oz.	Milled pine charcoal, red gum/alcohol
0.35 oz.	Milled pine charcoal, pucks sized to 3FA
0.40 oz.	Milled pine charcoal, coated on rice hulls
0.45 oz.	Milled commercial charcoal, pucks sized to 3FA
0.50 oz.	Milled commercial charcoal, red gum/alcohol or on rice hulls
0.55 oz.	Commercial Wano BP, 3FA
0.60 oz.	Commercial FFg recommendation from BAFN II chart
0.75 oz.	Commercial 2FA recommendation from BAFN II chart
0.75 oz.	Commercial Wano BP, 2FA
0.75 oz.	Milled commercial charcoal, pucks sized to 2FA
0.75 oz.	Milled pine charcoal, pucks sized to 2FA
0.75 oz.	Simply-screened, pine charcoal, red gum/alcohol
0.90 oz.	Simply-screened, commercial airfloat charcoal, red gum/alcohol

Note: It was almost difficult to use a small enough amount of the pine-charcoal/red gum-alcohol powder. A third of an ounce is a mighty small amount of lift powder.

Answers

To what extent does the type of charcoal affect the quality of the resulting black powder? Homemade pine charcoal produced powder that was marginally better than that produced with the commercial charcoal, but both can produce BP's that far outperform commercial black powders.

How did the four methods of processing/granulating the BP's compare when the resulting powders were tested? All three methods that employed ball-milling produced powders that were very comparable. The method that used simply-screened chemicals produced BP that, while not as powerful, was very functional in amounts comparable to commercial 2FA.

How does the size of the granulation of pressed pucks affect performance? For these 3" dummy shells, the finer 3FA (8-12 mesh) granulation far outperformed the coarser 2FA (4-8 mesh) granulation.

How much lift powder should I use for a shell? The amounts in the chart above indicate how much of each type of powder to use for a 3" ball shell. These amounts can be dialed in when manufacturing actual fireworks shells. In general, if I were to multiply the recommended amount of lift powder listed in the BAFN II table by 0.6 for the milled, pine charcoal BP's, or by .75 for the milled, commercial charcoal BP's, I'd arrive at a good starting amount of homemade lift powder.

How do the three methods of processing/granulating the homemade powders compare as far as difficulty and expense? The easiest powder to make is the screened red gum/alcohol granulated BP, followed closely by the milled red gum/alcohol BP, and then the BP on rice hulls. Pressing pucks and corning them is significantly more difficult and messy.

The red gum and alcohol make that method slightly more expensive in material cost than the other two methods. Milling requires an up front investment in a machine and milling media. Rice hulls are cheap, so using them does not make that method much more expensive than pressing the pucks. All of the methods of making homemade BP are much less expensive than purchasing commercial black powder.

Conclusion

For my purposes, either homemade or commercial charcoal produces completely satisfactory powder. I really like the ease of production, and the final resulting powder when the red gum/alcohol method is employed to make BP, so I'll probably use that method when making lift powder for aerial fireworks shells.

To me, the simply-screened, red gum/alcohol method looks like the method-of-choice for simple, field-expedient, very functional black powder, and it can be produced without any complex or expensive machinery. This method is ideal for the beginning fireworker.

I think I'll bring my bucket of baseballs and a couple of 3" mortars to the next PGI convention, and whoever is interested can take to the field with me to go head-to-head with our prize black powders. May the best pyro win!

Making Palm Tree Charcoal

Here is something I found out, which may be fun for some of your readers to do. I've made some tests with charcoals for black powder. I'd noticed that palm fronds burn very fast in a campfire. So, in one of my tests I used palm tree wood (taken from the base of a frond) to make charcoal. The charcoal was a bit crumbly, rather soft, and very easy to handle. As far as I could tell, the charcoal had some fiber in it, so the charcoal may still have contained some wood, but if so, it was a very small fraction.

Point is that when I made black powder using it, it sucked as a rocket propellant, but it was beautiful to watch! The charcoal gave long-burning "flakes" (yellow, of course) that burned all the way to the ground from an apogee of about 30 meters. I am currently using the charcoal to make beautiful comets. The pyrotechnic formula is:

Component	**Parts by Weight**
Potassium nitrate	59.7 grams
Charcoal	19.3 grams
Sulfur	21 grams

All ball milled for 3.5 hours with 20% water/ethanol (1:1)

9

Stars

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Using a Star Gun: Testing Stars and Making a Reusable "Cake"

By Ned Gorski

Materials List

- Black Powder, FFg or FFFg
- Firework stars
- Flying Fish Fuse
- Star gun (TL4030)
- Visco Fuse (GN1000)

Introduction

A fellow pyro on Passfire.com was recently mentioning that he was having problems with some stars he had made. He related that he had ignited some of them while they were sitting on the ground, and although they had burnt all the way through, there was not much effect from them and they had left a large ash on the ground once they had gone out.

Why is a star gun necessary? Well, technically it's not. I've lit and thrown many stars to test-burn them in the air, and usually could do so without burning my fingers if I licked them first. Sometimes I'd grab the leather glove, but then sometimes I was too lazy for that move.

I have made Super Bottle-Rockets using Steve Majdali's tooling, available in the ads in the back of the PGI Bulletin. Taping a test-star atop one of these nifty little rockets is a great way to get the star way up in the air where it is ignited. But, making a rocket to test each star can become a bit too much work.

Way back when, I got the bright idea of getting a slingshot, taping a piece of visco fuse to a star, loading it all into the slingshot, firing up the visco, pulling back on the rubbers, waiting until the star just ignited, and letting 'er fly. I just knew I'd invented a new useful pyro device. I even called it my "Kentucky star gun."

I posted my "unique" invention on a pyro discussion list, and a well known fireworker responded that he'd been doing just that for years, and that he had some good welder's gloves (which covered the arm in addition to the hand), which he could sell me, and which were handy for that operation.

Darn. I'd reinvented the wheel once again. That happens a lot in hobbyist fireworking.

But, with all these devices, the idea is to test-burn a star or comet flying through the air at some distance from us.

Often color stars don't show their true colors if we are too close to them while they are burning. They'll look quite different at a distance of 100 feet. And they burn differently when flying through the air than they do sitting still.

For instance, willow stars and glitter stars won't create their unique effects at all if they are just sitting on the ground burning. But put them up flying through the air, and we can begin to appreciate their effects and visualize what hundreds of them flying out of a shell-burst will look like.

And, honestly, a slingshot or hand-tossing will not get the star very far from me or very high in the air. They will often burn me. If half of my attention is on not getting burnt, I won't really focus on noticing how the star performs.

Enter the tried and true star gun.

Star Gun and Accessories

Using a Star Gun

My star gun has 5 tubes on it: 3/8-inch, 1/2-inch, 5/8-inch, 7/8-inch, and 1 1/8-inch inside diameters. Using FFg or FFFg sporting grade black powder, I use lift powder loads as follows:

Tube Size	Black Powder
3/8-inch	Shallow 1/8 teaspoonful
1/2-inch	Flat 1/8 teaspoonful
5/8-inch	Heaping 1/8 teaspoonful
7/8-inch	Flat 1/4 teaspoonful
1 1/8-inch	Heaping 1/4 teaspoonful

To test a star, I determine which of the tubes will be a close fit for the star, while still allowing it to freely fall to the bottom of the tube. Occasionally it is necessary to persuade the star to get to the tube bottom with a thin wood dowel.

I insert 3 or 4 inches of visco fuse into the tube's fuse hole, drop the correct amount of lift powder into the tube through a funnel, and insert the star. Fire up the visco, retreat, and prepare to observe the test star in flight. Heck, single one-inch comets fired out of the large tube can be a little show all in themselves if it's a night when I simply must "smell the smoke" from something.

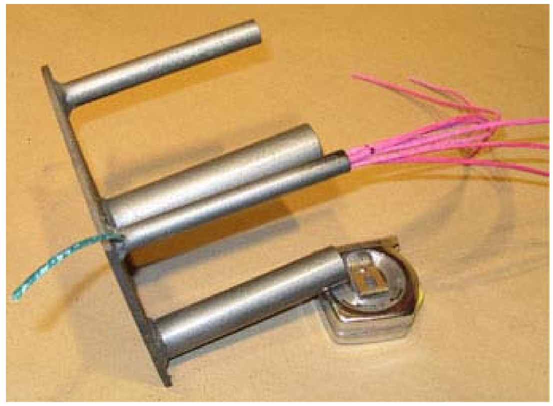
A Special Little Project Using the Star Gun

OK, that's using a star gun for what God intended it to be used for, but now let's get creative. I got to thinking that a star gun could be used to create a small 5 shot repeater cake device, progressing from the smaller tubes up to the largest of them, and making an increasingly impressive little display in the process.

Stars in ever-increasing sizes could easily be rigged up to create such a cake. But I have a complete assortment of Skylighter special effects fuses: falling leaves and flying fish in various effects and colors. Why not play with these a bit to see what would make the most fun and impressive little show?

I'll test these fuses one at a time to see which of them I like best, and which light best when shot, unprimed, out of the star gun. First I insert the 4-inch piece of visco fuse, and then dump the correct amount of black powder into the tube. Then I tip the star gun over, keeping the mouths of the tubes slightly higher than their fused ends.

I'm thinking that about 3 seconds of burn time for the special-effects fuse will be a good display duration. The burn time is shown on the Skylighter label for each fuse. In this case I'm testing red-crackling flying-fish fuse, which burns at about 1.9 seconds per inch, so I mark the bundle of fuse at 1.5 inches with a Sharpie.



Star Gun, Loaded with Visco Fuse and Black Powder, and with Flying Fish Fuse Inserted

Then I cut the flying-fish fuse with my anvil-cutters, and push the fuse into the tube with a wooden dowel.

Cutting Flying-Fish Fuse and Inserting It into Tube with Dowel

With this particular fuse, ignition was very good as all the fuses lit when they came out of the star gun. The display was very nice, and the fuses burned out just before they came back down to the ground.

Warning: I do not reload the star gun in my pyro shop or anywhere else where I am around pyrotechnic devices. The star gun may still have a glowing ember in it and I don't want flaming black powder to be ejected from it, along with a star or fish-fuse inside my shop. I treat the star gun as if it could go off at any time once it has been fired once.

The rest of the special effects fuses worked as follows:

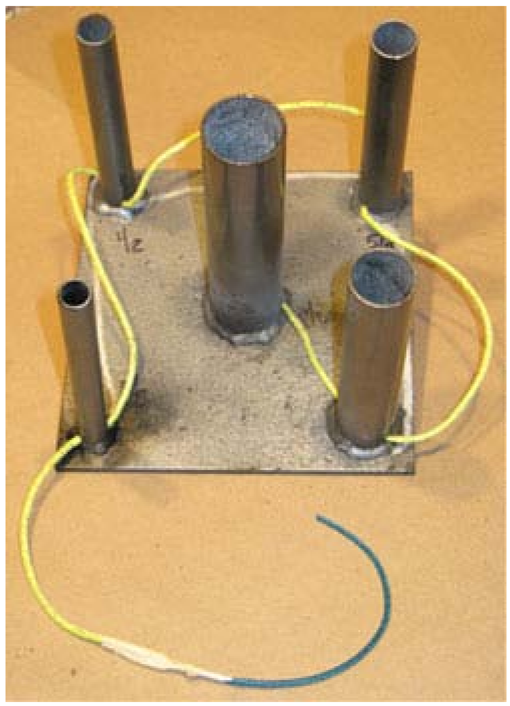
The falling leaves fuses really don't work well in this little device. They burn too long and come back to the ground before creating their signature effect.

All of the flying fish fuses worked well, but one-inch lengths worked better than the one-and-a-half inch pieces. The shorter lengths ensured that they burned in the air rather than on the ground.

Fusing the Star-Gun to Make a "Repeater"

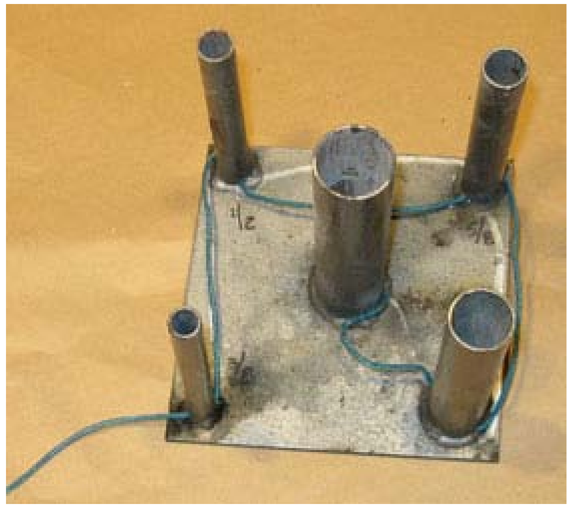
The first thing I did was plan a route that the fuse would take. Then I drilled the bottoms of the star-gun tubes to allow the fuse to pass through them on that route. The center tube fuse-hole was left as-is.

The first time I constructed the repeating cake, I used fast-visco fuse as shown in the photo below.



Star Gun Cake Set Up with Fast-Visco Fuse

This configuration burned a little too quickly for my tastes, and there was not much delay between the last two shots because of the short length of fuse in that section. So, I constructed the cake again using Chinese visco fuse, as shown here.



Star Gun Cake Using Chinese Visco Fuse

This configuration burned much more to my liking, and the extra fuse between the final two shots lengthened the delay between them.

Star-gun, Flying-Fish-Fuse Cake in Action

(Click Image to Play Video)

Easy Ways to Dampen Star Compositions

By John Werner.

Learn how to evenly dampen small and large batches of star compositions with water.

Materials Needed

- Star composition
- Kraft paper
- Screen, 1/4" x 1/4"
- Spray bottle
- Tubs
- Water

Dampening Small Amounts of Composition

A great way to dampen five pounds or less of star formulations requires only a large (3'x 3') sheet of heavy Kraft paper and a spray bottle. First, lay out the Kraft paper on a flat surface and spread the star mix out in a thin layer roughly two feet in diameter on the paper.

Set the spray bottle to deliver a fine mist of water (assuming the mix is water dampened) and begin to spray the surface of the star powder. Try to avoid hitting the paper directly with the spray. The idea is to keep the paper as dry as possible. Do not spray so heavily on the powder that balls of wet star composition begin to form.

Go slowly with the spray and mix the powder around on the paper frequently, always reforming it into a round thin mass like a pizza crust before applying more water. Test the powder periodically by squeezing a handful into a ball. Be careful not to over-dampen the star mixture. Most beginners tend to get their star compositions way too wet.

The mix is about right when the ball of powder holds together well but does not glisten on the surfaces (it still retains a matte finish) and does not leave the skin on your hand particularly dirty.

When you get close to the point where you think the star mixture is damp enough, let it sit for ten or fifteen minutes before doing any more spraying. Quite often after sitting, the powder will seem to get wetter by itself as the moisture content evens out throughout the star composition.

The nice thing about this method is that the spray bottle makes it very easy to control how much water is added at a time, and once you get the hang of using it, over-dampening can usually be avoided.

For future reference, keep careful notes on how much water was sprayed from the bottle (by weight) so that if you scale up the amount of composition being mixed, you will have a good idea how much water per pound of powder is needed.

This method is also nice because it is easier to work the water into the powder than if the water was just poured in on top of the powder in a mixing bowl. And with no bowls or utensils, cleanup is fast and easy.

Note: You can insure against accidental over-wetting by setting aside about 10% of the dry-mixed star composition at the beginning. Then, if you do get the mix too wet, you can add some of the dry star composition in to compensate.

Dampening Large Amounts of Composition

This is a good, fast way to dampen production quantities of star compositions (up to one hundred pounds or so). It requires two tubs and a 1/4" by 1/4" mesh stainless steel screen mounted in a frame, which will fit over one of the tubs.

The tubs should be large enough so that the amount of star composition you intend to work with would fill one tub no more than about half way. Place the powder in one of the tubs and add the correct amount of water to dampen the mixture. Wearing heavy rubber gloves that extend past your elbows, mix the composition and water together with your hands.

Until the mix gets thoroughly dampened, it is necessary to wear a well fitting dust mask, dust hood and coveralls. Since the water has been just dumped in with the dry powder, it will tend to ball up and not mix evenly with the star composition.

The problem is corrected by running the mix through the 1/4” mesh screen into the second tub. The holes in the screen will act to break up any clumps of powder and even out the moisture content nicely. If necessary the powder can be run through the screen twice. The screen should not clog if the star composition has been dampened with the correct percentage of water.

How to Make Cut Stars in an Hour or Less

By Ian von Maltitz.

An article on how to make cut stars in an hour or less.

Materials Needed

- Drying screen
- Knife
- Mallet
- Mixing bowl
- Mixing spoon or spatula
- One-gallon Zip-lock bags
- Pyrotechnic star composition
- Rolling pin (if a frame is not used)
- Rubber gloves
- Scale
- Star frame, optional
- Waxed paper

Introduction

Cut stars are the simplest and easiest stars to make. They are generally also the cheapest. One can make large quantities of cut stars in a short space of time. Cut stars can be made with or without special tools or equipment. Cut stars can be used in:

- Shells
- Rockets
- Mines
- Fountains

Small cut stars can also be used as cores for making round stars. These are typically small cubes with sides about one eighth of an inch in length. Cut stars are not the best choice for Roman candles. For those, round or cylindrical (pumped) stars are better.

There are a variety of different ways to make cut stars. Some use a frame specifically designed for cut star making. Other simpler ways dispense with frames entirely. Both methods are discussed here.

Various Requirements for Cut Stars

The materials needed to make cut stars are dependent on the formula used and on the formula of the prime if a prime is used. The most popular type of prime used is meal powder, which is black powder in fine powder form rather than in granules. It is generally recommended that stars be primed. An exception to this rule is chlorate stars, which usually do not need priming, and are rarely primed with black powder.

Some kraft paper is needed to line certain types of star frames. One gallon zip-lock bags are useful if one is mixing just one or two pounds of star mix.

Another useful material is a roll of waxed paper, the type normally found in the kitchen.

We assume that a flat, smooth working surface is available. Do not use a knife with serrated edges. Preferably get one large enough to make each cut with a single cleaving (as opposed to slicing) action.

A useful addition to the above is a drying screen that need be nothing more than a window screen. Stars dry out a lot quicker on a drying screen than if one just places them on a flat surface.

Use rubber gloves as general hand protection against toxic chemicals. Gloves are essential if one decides to knead the star mix by hand.

Alternatives to Knives

Some makers of cut stars do not believe in using something with as sharp an edge as a knife and prefer to use a blunt blade made from a sheet of metal or a tool that is used for plastering walls. You can try these options if you prefer. However, knives with sharp edges do work just fine.

A 20-mesh mixing sieve is nice to have when mixing the dry ingredients. Although most firework makers consider a mixing sieve to be absolutely essential, I beg to differ with them. A good mix can be got without a sieve but normally takes longer. Sieving can also cause certain very fine powders such as lampblack and bismuth trioxide to agglomerate into tiny balls.

A star frame (or set of frames) is a good investment if you are planning to make large quantities of cut stars. The process is quicker and more accurate with a good star frame.

Before describing the steps in making cut stars, an important consideration needs to be borne in mind: Small is beautiful.

Small is Beautiful

Whether you are a beginner or a pro the clever way to make cut stars using a new untried formula is to make very small quantities in the beginning. These small quantities of stars are tested to determine how well the stars perform before larger quantities are used. One way is to make a small quantity of star mix and burn it in a small lance tube. Another way is to make a very small batch of stars without a star frame, then dry and test these. This method gives a better test but takes a lot longer because the stars need to dry out before use.

Measuring Dry Materials

All dry materials are measured by weight, not by volume. Thus if the formula you are using calls for five parts of potassium nitrate and two of sulfur, this could be translated as five grams of potassium nitrate to two grams of sulfur, rather than five teaspoons of potassium nitrate to two teaspoons of sulfur.

The gram measurements are given just as an example. Five ounces of potassium nitrate would be mixed with two ounces of sulfur, five pounds with two pounds, and so on.

Mixing Dry Materials

As discussed above, dry mixing can be done with or without mixing sieves. The goal is to have all the ingredients intimately blended with each other. It pays to do a proper job at this stage of cut star making. Many have made the mistake of assuming that one can compensate for inadequate dry mixing by just taking a bit longer mixing the ingredients when wet.

Sometimes this works; other times it does not, depending on the formula used. It is not uncommon to discover small pockets of unmixed dry chemicals in a wet mix that has been mixed for some time. This is a sure indicator that the materials were not mixed properly when dry.

Adding Solvent (Water or Other Solvent)

Before adding the solvent, you should put aside some of the dry material. This can be used for dusting the surface that the dampened star composition will be cut on. It can also be used in controlling the consistency of the wet mix, especially in the all-too-common situations when too much solvent is added. A good amount to be set aside is about one quarter of the dry mix. This amount can be reduced eventually with more practice.

Weight vs. Volume

Is there a way to convert weight into volume and measure by volume rather than weight? No, not really. The thought behind converting weight to volume is influenced by the idea that if one knows the density of a material one can easily convert its weight to volume or its volume to weight. This is true of solid pieces of material but not of material that has been reduced to powder or granular form.

This does not have a true density because the material is actually a mixture of the material and air. In place of true density such a material has what is called bulk density.

Bulk density is a density measure of solids that have been divided into small pieces or crushed into powders. Thus potassium nitrate in powder or granular form has a bulk density, as does sugar and salt. Black powder has a bulk density, and so does instant coffee and corn flakes.

Add the solvent by slowly pouring or spray-misting it into the dry mix while stirring continuously, or working it in with your hands. Both these actions are important to ensure good mixing. If the solvent is added too quickly or the mix not stirred thoroughly, separation of the ingredients can occur. Here lighter materials will tend to float on the surface of the solvent and soluble materials can be dissolved and separated from surrounding materials.

Mixing Dry and Wet Materials

The trick in making good cut stars is to ensure that the wet mix is neither too dry nor too wet. The consistency should be that of putty or modeling clay. To get to this point, slowly add the solvent while continuing to stir the mix. If too much solvent ends up being added, add some dry material to get the mix back to its proper consistency.

Priming

Cut stars are often primed just after they are cut. Many prefer this method because it simplifies the operation. You do not have to prime your cut stars at this stage. You can prime them after they have dried.

So much for the general discussion on cut stars. The above is put into practice by actually doing a cut star project. Here is how you go about it.

Making Cut Stars, Step by Step

1. **Mixing the Ingredients**

Weigh out the dry ingredients to yield approximately one pound of dry mix.

Mix the dry ingredients by first sieving (if you have a sieve) and then by stirring them together in a bowl. When the dry ingredients are thoroughly mixed place about 75% of them on a one gallon zip-lock plastic bag. A one gallon freezer bag is ideal. Keep the other dry 25% to one side.

Measure out the solvent used by weight. If you know its density you can measure it by volume and then convert this volume to weight. A rough guide to the amount of solvent needed is between five and ten percent of the weight of the dry ingredients.

Add the solvent to the dry materials in the zip-lock bag.

Knead the materials inside the zip-lock bag by squeezing them with one or both hands as shown in the figure.

Kneading the Materials

When the material inside the bag is thoroughly mixed take out a small handful for testing. Close your hand around it, and squeeze it. It should hold its shape, and no water should come out between your fingers. If the sample crumbles add more solvent. If it is too wet add some of the dry ingredients you set aside. Note the sample shown below is a bit too wet.

Squeezed Sample

2. Star Making without a Star Frame

Star frames enable you to make cut stars more accurately and can yield stars that are physically stronger because you are able to compress the mix more. However, you can make adequate cut stars without a frame by doing the following:

Take the mix out of the plastic bag and place it on some wax paper on your working surface (table, workbench, and so on.).

Knead the mix with your hands and form it into one solid lump.

Press down on the mix with the palms of your hands until it forms a large patty about an inch thick.

Roll the mix flatter with a rolling pin until you reach the desired star thickness.

One way you can more accurately get a consistent thickness is to get two strips of wood the thickness you desire and place them on the work surface spaced apart about two inches less than the length of the rolling pin. Place the lump of mix midway between the two strips of wood. Then flatten the lump first with your hands and then with the rolling pin running along the two strips of wood.

Some hardware stores sell square strips of wood in sizes like 1/4" and 3/8" often in the wooden dowels section.

When you have flattened the mix to the required thickness cut the stars according to the instructions in step 4.

3. Making Stars with a Star Frame

This section describes how to use the star frame shown. This star frame has a compression lid that enables you to press the mix by putting pressure on the lid. Star frames that differ from this design will require slightly different methods. But the same basic principles apply to all star frames.

Cut two pieces of kraft paper into squares to fit the inside of the star frame. Remove the lid from the frame and place one of the pieces of paper inside the frame so that it lines its bottom. I have used very thick kraft paper here, almost as thick as thin cardboard. If you are using thinner paper then use two sheets to line the bottom.

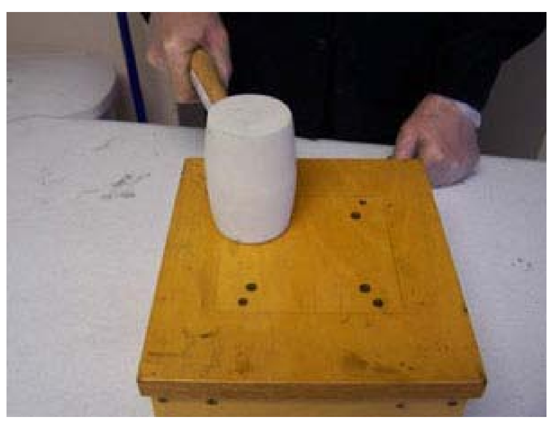
Remove the material from the plastic bag and spoon it into the star frame. Disperse the material evenly around the frame using either a spoon or a spatula as shown in the figure below. When the materials are properly dispersed, place the other square of kraft paper on top of the material.

Dispersing the Material

Replace the lid of the frame and press down on the frame by leaning on it as shown in the next figure.

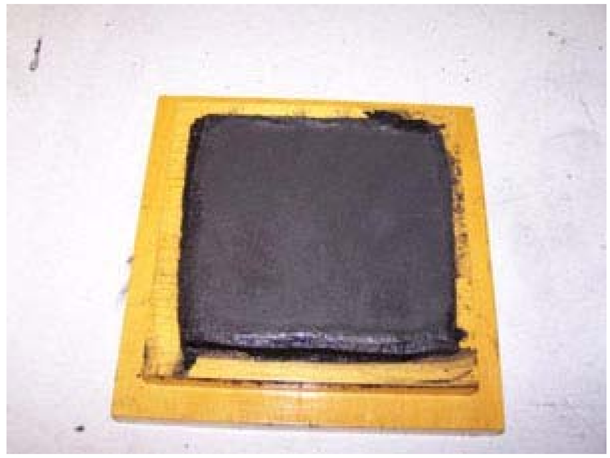
Pressing Down on the Frame

Hammer on the lid with a rubber mallet to compress the material even more as shown in the following figure.



Hammering the Frame Lid

Remove the lid from the frame and then separate the frame from its bottom. The star mix will be compressed to a flat plate as shown below.



Compressed Star Mix

Slide the slab of star mix onto a cutting board.

Moving Slab onto Cutting Board

4. Cutting the Stars

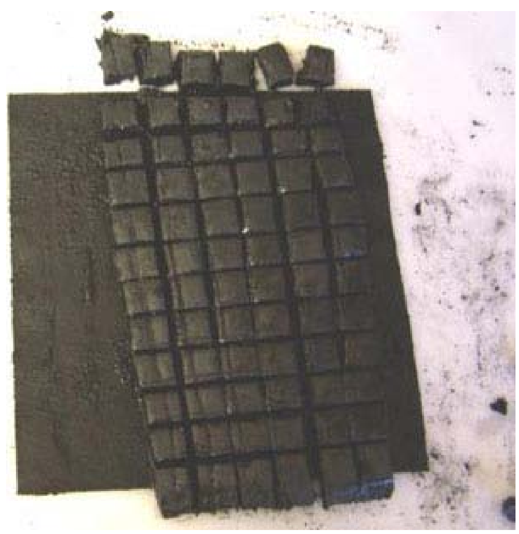
Fireworks makers have their individual preferences when cutting cut stars. Some prefer to immediately slice the slab into strips; others prefer to mark out the strips as equally-spaced lines on the slab before cutting. This second method helps you to get better consistency in star sizes, and is the method shown.

Marking out the Strips

Continuing the strip marking method, mark the slab into cubes before cutting as shown in the next figure.

Marking out the Cubes

Finally, cut into individual cubes.



Cutting into Cubes

The above method describes using the star frame with about a pound of mix. This is about enough to make the single slab shown. Using more mix, such as four to five pounds gives you a brick rather than a thin slab. Here you cut the brick into slabs first. This procedure is described in more detail in a later section.

5. Priming the Cut Stars

For most applications, it's best to prime your stars. This section describes the preferred method on how to prime stars. It is the "preferred method" because it is the safest method. It is called the "diaper method."

Place the stars in the middle of a large sheet of paper.

Note: Newspaper is often used for this purpose.

Pour some prime mix over the stars.

Stars on Paper Sheet

Pick up one corner of the sheet of paper and move it towards the other corner, rolling the stars over in the prime mix in the process as shown in the following figure.

Repeat this process with the opposite corner and then with the two other corners until the stars are thoroughly coated with prime.

Stars Being Covered with Prime

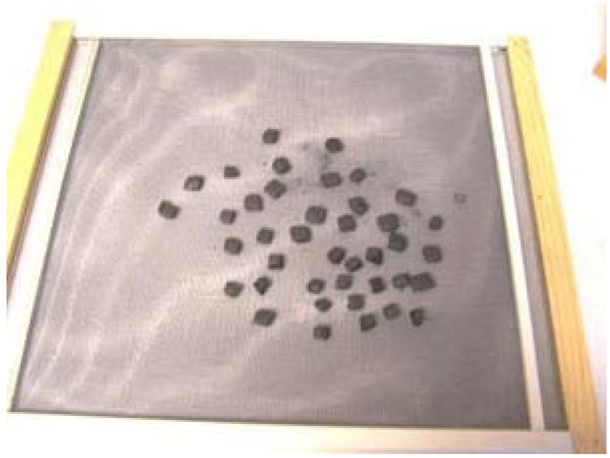
6. Drying

Having got this far, taking great care to do everything properly, it seems a crying shame that one's cut stars can end up being a dismal flop. Unhappily they can, due mostly to that very common human weakness - impatience. Having made presentable looking stars, you now want to try them out. It can take days to properly dry out stars and there is the natural tendency to want to speed this process up.

Most speed-up drying processes have a tendency to degrade the performance of the stars or dry them on the outside while trapping moisture or solvent on the inside. Others are downright dangerous! Do not try to dry stars near an open fire, in an oven, nor in a microwave oven. Do not dry them in direct sunlight, which can trap moisture inside ("driven-in" moisture). Ultraviolet radiation and heat from direct sunlight has caused some star mixes to spontaneously ignite!

The best way to dry stars is to place them on a screen in a shady, well-ventilated area outdoors. What you want is air moving over the stars; heat is not necessary.

Warning: Locate your drying stars in a safe place. If they were to ignite spontaneously, where would you want them to be? The best practice is to try and anticipate what the worst case situation would be and take preventive measures accordingly. I cannot overemphasize this enough: drying stars can and do self-ignite!



Stars Drying on Window Screen

How Not to Dry Stars

Do NOT place stars in a microwave oven

Do NOT place stars in a conventional oven

Do NOT place stars in toaster oven

Do NOT place stars near an open fire

Do NOT place stars on a hot surface

Do NOT blow hot air on the stars

Do NOT place stars in direct sunlight

Patience is the key to ensuring that your stars dry properly. Typically stars take a few days to dry out. Some large stars that absorb a lot of moisture while being made can take a few weeks of drying before they are properly dried.

7. Testing Dried Stars

How do you know when the stars are dry and ready for use? One way of finding out is to weigh the stars. The total weight of the stars plus any left over dry material and pieces of star scrap should be approximately the same as the weight of the original dry mix.

While some might put a lot of faith in this method, the real world dictates that this will only get you into the ballpark. Inaccuracies are inevitable because some material will always be lost in the star making process. Another factor is that some pyrotechnic mixes tend to retain a small percentage of the solvent used.

A typical example is black powder that can retain between 0.3% and 1% of water. Commercial black powder that I have tested has contained between 0.4% and 1.2% of water.

The above two inaccuracies work against each other and it is possible that in certain circumstances they cancel each other out.

A simple way you can test a star to find out if it is dry or nearly dry is to try and crush it between your thumb and forefinger. If the star crumbles easily it is far too wet. If it crumbles only with difficulty or does not crumble at all, the star is either dry or close to being dry.

If your stars have passed the second test, the next step is to place a star on a hard surface and hit it lightly with a hammer until it breaks. Do NOT use a steel hammer as this can cause sparks that could ignite the star. Use a mallet or a hammer made from leather, brass, aluminum, rubber, or plastic. Note than plastic hammers are often steel hammers that are encased in plastic. These are fine to use because the steel cannot come into contact with anything else.

If you tap your star with a hammer and it just crumbles to powder it is probably still moist. Dry stars are usually rock-hard and rarely crumble easily. An exception to this rule is if you have a mix with large particles and insufficient binder.

The next test is to actually light a star (or number of stars) and see how they perform. You can perform a quick "ground" test by placing the star on a non-combustible surface such as a brick, stone, or cinder block and lighting it.

For safety's sake do not use a regular match or cigarette lighter to light the star. I learned this the hard way when I literally burned my fingers. You can buy a variety of extra-length matches that are three inches long or even longer. Some charcoal lighters have a short barrel that keeps the flame a distance of about six inches (or even longer) away from one's hand. These are another good choice. They are inexpensive and are often sold in supermarkets.

Lighting a star on the ground can tell you if the star is dry enough, but does not give a clear picture as to how the star will perform when flying through the air.

The ultimate test for your stars is, of course, in the actual device you are using them in. However, it's good to know up front if your stars are likely to perform properly before committing a lot of time, effort, and perhaps money in making a lot of stars and loading them into your rockets, shells, mines or whatever else you are using them for. An easy way to perform such a test is to use a star gun. You can either purchase one or make your own. Follow this link for more information on testing using star guns.

8. Priming Again

Some fireworks makers prefer to prime their stars after they have dried out. Others choose to prime their stars only if the star gun tests or actual applications in devices such as shells demonstrate the need for prime. Fortunately it's an easy matter to prime dry stars.

The trick in priming dry stars is to coat them with just enough solvent to cause the prime to stick to the star. This is rarely achieved by dipping the stars in the solvent. The best way to thinly coat the stars with solvent is to spray the stars with a misting bottle and using a fine mist. It's best to adjust the nozzle of the sprayer and test it on something other than the stars before spraying the stars.

The wet stars are then primed as described before in step 5 and then dried following the normal drying procedure. As you are only drying prime, the drying process should be over quite quickly.

9. Using Cut Stars

Cut stars are typically used in shells, rockets, mines and fountains. You can find out more about these by following these links:

To find out sizes of cut stars used in round shells go to:

http://www.skylighter.com/fireworks/help/shell-building-charts-and-tables.asp

To use cut stars in mines go to:

http://www.skylighter.com/fireworks/how-to-make/fireworks-mine.asp

10. Safety and Other Matters

One very important safety rule when making fireworks is to clean up after you have finished your project. The preferred way to clean up scrap star mix is to burn it. This includes scrap that has stuck in small quantities to pieces of kraft paper, etc. Ensure that any burning is done in a safe manner where all the necessary precautions are taken to ensure that nothing else can be accidentally burned in the process.

The "Small is Beautiful" slogan applies especially in safety. The larger the amount of materials you are working with the less safe you are. Larger amounts mean more chance of having an accident and the greater the consequences of the accident. However, there are other issues you need to pay attention to. Large amounts of wet star composition can, depending on the circumstances, heat up and unpredictably create a fire. This has happened to more than one very experienced fireworks maker, resulting in severe-to-fatal burns! Don't let it happen to you.

Safety also applies to storage. Never store your stars or any other fireworks mixture in glass containers. Use paper, cardboard, or plastic bags. Do not mix different types of stars when storing them. "Small is beautiful" also applies to storage. The larger the quantity stored, the less safe it is. Also, ten pounds of stars stored in ten one-pound containers is safer than ten pounds stored in a single larger container.

It goes without saying that your stars must be stored in a place where they cannot be ignited from any source of ignition such as an open flame, a space heater, etc. Regardless of whether you have a BATFE license or not, you are legally required to store your stars in a magazine which conforms to BATFE regulations.

Star Frames Revisited

The just-described project showed you how to make cut stars using a particular type of star frame or no frame at all if you chose the method described in step 2. The star frame used in the project above had a bottom plate and a lid. Some star frames come with neither. Here are pictures of the star frame used in the project and some others.

Shown in the next figure is the star frame described in the project. In the top left-hand side is the lid, followed by the frame and its bottom plate.

Star Frame Used in Project

Shown in the next figure is the "baby brother" of the star frame shown above. This star frame is smaller and its lid and bottom plate are identical.

Smaller Star Frame

This is about the simplest star frame one can get. It has four sides with no lid or bottom plate.

Simple Star Frame

The star frame shown above is very simple and easy to make. Because it has no bottom plate or lid it requires a slightly different technique in making stars. One such technique is to cut two strips of kraft paper the internal width of the frame (5.5") and about 20 inches long.

Lay the pieces of kraft paper perpendicular to each other across the top of the frame so that their centers are in line with the center of the frame.

Press the centers of the pieces of paper down into the frame and scoop the star mix into the frame.

When all the mix is in the frame press it down so that it is flat as possible and then fold the pieces of kraft paper that are sticking out of the frame over the top of the mix.

Get a piece of two-by-four about eight to ten inches long and press down hard on the top of the mix, moving the two-by-four all over the frame.

Tap down hard on the mix with the two-by-four to compress it as much as possible.

Grab the frame and lift it so that the paper-wrapped "brick" of star mix slides out of the frame.

Pull the paper away from the sides of the brick and cut it into slices like one would do with a loaf of bread. Dice the slices into cubes as described in the project.

Wonderful Zinc Stars, and How to Make Them

By Ned Gorski

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Materials Needed

- Black powder prime
- Charcoal, fine
- Dextrin
- Dowels, 5/16"
- Drying screen
- Knife
- Plastic bucket
- Potassium nitrate

- Respirator
- Rubber gloves
- Screen, 100 mesh
- Screen, 40 mesh
- Sulfur
- Waxed paper
- Zinc dust

Introduction

Now and then on the pyro discussion lists someone will bring up the subject of zinc stars. Usually several folks will chime in with, "Oh, man, those stars are some of my favorites, so subtle and beautiful."

In Chapter 15 on Fireworks, of Alexander Hardt's Pyrotechnics, (this chapter written by Barry Bush after Dr. Hardt's death), it is stated, "Good zinc stars are blue-green with tails of delicate gold, and seem rather exotic today."

This is a color star where the color is produced by an elemental metal, rather than a metallic salt, such as when a blue is produced with a copper oxide or carbonate. So, this blue-green color star may be among the oldest star colors that were produced.

Back in the early 90's when I first started making stars, there was not much fireworking information available. I was able to get my hands on a copy of the then recently reprinted Pyrotechnics, by George Weingart. Some of my first star-making efforts were based on a few of the formulae contained in that book, and perhaps my favorite of them was the Granite Star.

An added bonus is that this is one of the easiest cut stars to make that I've tried.

Granite Star formula (all parts are by weight)

Component	Parts	Percent	Decimal
Potassium nitrate (KNO3)	14	22%	(0.22)
Zinc dust	40	62%	(0.62)
Fine charcoal	7	11%	(0.11)
Sulfur	2.5	4%	(0.04)
Dextrin	1	2%	(0.02)
Totals	64.5	101%	(1.01)

(The percentages, because of number rounding, actually add up to 101%, but that's OK, and they'll work just fine. The percentages of each individual chemical in the composition are calculated by taking the original number of parts of that chemical, say 14 parts of KNO3, and dividing that number by the total number of parts, 64.5 in this case. 14/64.5=.217, which can be rounded to .22, which is 22 hundredths or 22%.)

Note: You may be saying to yourself, "I wonder why he's including those decimal numbers after the percentage numbers." I'll show ya in a minute. The decimals are much more useful than the percentages.

Recently, Harry Gilliam, in a Skylighter Fireworks Tips Newsletter, published the formulae that he inherited from the Kosankes when he purchased the business that became Skylighter. In that list of formulae is one called Pearl, and it is a slightly different version of a zinc star:

Pearl Formula

Component	Parts by Weight	Percent	Decimal
Potassium nitrate	35	35%	(0.35)
Airfloat charcoal	15	15%	(0.15)
Zinc dust	40	40%	(0.40)
Sulfur	5	5%	(0.05)
Dextrin	5	5%	(0.05)
Totals	100	100%	(1.00)

I always like to look at star formulae and see how they differ from each other. It can be seen that the second formula uses less zinc, more KNO3, and slightly more charcoal, sulfur, and dextrin.

There is a formula in Hardt's book that is similar to the Kosanke formula above, but the zinc is increased to 45%, and some Meal D black powder is used in it, as well as potassium nitrate, charcoal and dextrin.

I, personally, have only made zinc stars using the first formula, from Weingart, the Granite Star.

In a recent discussion in the Passfire.com Forum, a fellow fireworker, who has worked quite a bit with this star, recommended that that the charcoal used in the formula be half airfloat and half 80 mesh. This improves the charcoal tail that the star leaves behind as it burns. Back in the '90's when I made the star, I'd only use airfloat, so this is another area of experimentation as an individual fine tunes the formula to his own personal tastes.

These stars light easily, especially when made as cut stars with all the corners and edges to take and hold fire, so I've always just primed them with a "scratch-mixed" (mixed by hand, no milling) black powder prime, simply screened through a 40 mesh screen.

Black Powder Prime

Component	Parts by Weight	Percent	Decimal
Potassium nitrate	75 OR 15	75%	(0.75)
Airfloat charcoal	15 OR 3	15%	(0.15)
Sulfur	10 OR 2	10%	(0.10)
Dextrin	5 OR 1	+5%	(0.05)
Totals	105 OR 21	105%	(1.05)

Note: This is simply 75/15/10, KNO3/charcoal/sulfur (the classic black powder proportions), with an additional 5 parts of dextrin added as a binder (additional 5%). One of the few formulae that I can always remember off the top of my head is the 15/3/2/1 parts proportion of this composition. If I want to make 21 ounces of prime, I simply weigh out 15/3/2/1 ounces of each chemical and screen them together.

How Much of This Star Should I Make?

This is a very heavy and dense star, perhaps the heaviest I have ever made. (I haven't made stars using gold powder yet!) A 4" ball shell will use a little less than a pound of these primed stars. A 4" mine would use about the same amount. In my small-scale, hobbyist fireworking endeavors, I actually like making stars a pound at a time, especially when experimenting with new formulae.

One Pound of Zinc Granite Stars

Using the first (Granite Star) formula, above:

Component	Decimal		Batch Weight		Weight
Potassium Nitrate	0.22	x	16 oz.	=	3.5 oz.
Zinc dust	0.62	x	16 oz.	=	9.9 oz.
Fine charcoal	0.11	x	16 oz.	=	1.75 oz.
Sulfur	0.04	x	16 oz.	=	0.65 oz.
Dextrin	0.02	x	16 oz.	=	0.3 oz.
Totals	1.01	x	16 oz.	=	16.1 oz.

Now do ya see how handy those decimals are? Of course, any final batch size can be plugged in instead of the 16 oz. A 32 oz. batch, or a 100 gram batch, can be calculated just as easily.

The charcoal can be all airfloat, or it can be half-and-half airfloat and 80 mesh, as mentioned above.

Zinc

What the heck is zinc, anyway? I don't know about you, but zinc is not one of those chemicals I'm all that familiar with. In the back of my head all I kinda knew about zinc was that it was coated onto the steel garbage cans of my youth to keep them from rusting. Galvanization they called it. Same stuff that's on the steel ductwork leading to and from my furnace. I actually had to look zinc up to verify that it is, indeed, an element like gold and copper. Shows ya how much of a chemist I am.

An interesting thing about the powdered zinc that we use in Granite Stars is that it doesn't stay powder for long. It forms clumps. Either at the supply house, or in our storage, zinc powder will become zinc clumps, because it oxidizes in moist air.

Unless these clumps have been allowed to harden for years, they can be broken up simply by rubbing them on a 100 mesh screen. I recently received a shipment of zinc dust which had formed these clumps, and I was quickly able to return the metal to a dust through my screen.

Screening Zinc Clumps

Note: Zinc is reportedly not toxic, but I can tell you from experience that it is irritating if it is inhaled during the above screening process, or during the manufacture of zinc stars. I mean Really Irritating in the nasal passages. I'm not saying this as some kind of CYA. Wear a good respirator when working with zinc dust. Really, no kidding.

I use a good, $25 respirator, from Home Depot which is rated for fine dusts as well as fumes.

Buy and Use a Good Respirator

Making Zinc Cut Stars

Zinc stars burn relatively slowly, and if they are made too large they will burn all the way to the ground, especially if used in a mine. Therefore, I like to make the stars a bit on the small side. For 4" shells and mines, I like to cut the stars 5/16" square, and once they are primed they end up being about 3/8" square. For a more dense spray of stars, they could even be cut 1/4" and this would work well for smaller shells as well.

I am working outdoors and away from any sources of ignition. I have screened 21 oz. of my BP prime through my 40 mesh screen and I have it in a closed container. I always keep every flammable composition in closed containers until they are actually being used. This minimizes the amount of exposed materials in case there is a stray spark or fire.

I have screened my 9.9 oz. of zinc through my 100 mesh screen. I weigh the rest of my chemicals into individual containers, add them all together with the zinc, and screen the complete composition 3 times through my 40 mesh screen to completely pulverize and mix the components.

Then I weigh the composition in a plastic bucket to make sure that it totals up to the 16.1 ounces of weight that it should, thereby insuring that I didn't make any mistakes when weighing the individual chemicals, or leave one out completely. This step can prevent a lot of mistakes and wasted chemicals.

I put a lid on the bucket and shake it to further mix the ingredients. Then, with rubber-gloved hands, I start to work water into the composition until workable putty is developed. It's OK to start adding water out of a jug a little at a time, until the composition starts to get dampened. But, the final increments of water ought to be added by spraying it out of a little, plastic spray bottle. This prevents the addition of too much water, which makes for a pain in the butt. It's always easier to add a bit more water than it is to remove a little.

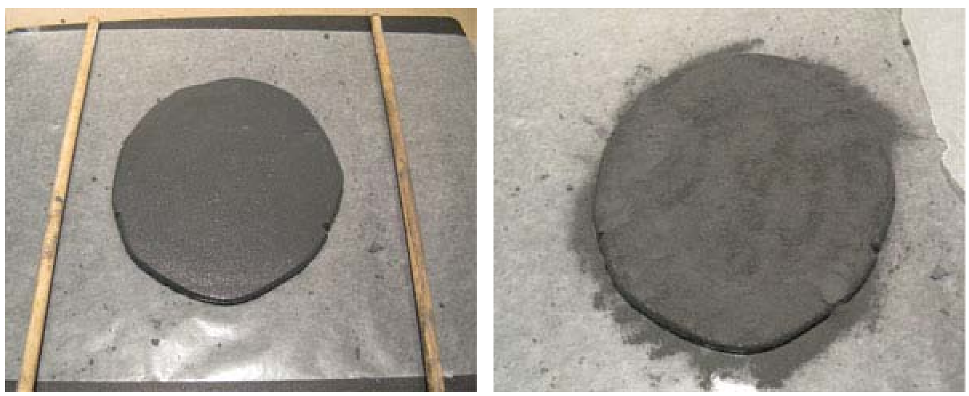
As I add the water, the comp will clump-up, form a hard ball, and finally, when enough water has been worked in, it forms a nice, workable ball of dough which will flatten out smoothly when patted with a hand. My one-pound batch of star-comp required 2.6 ounces of water to get to this point, which is about an additional 16% (0.16) by weight.

I have two, 14" x 17," 3/8" thick, black-plastic cutting boards from Kmart or Target that I use to cut stars on. I'll take one of the cutting boards, cover it with wax-paper, put the star dough-ball on it, and put 5/16" spacer dowels on either side of the comp.

Then I'll flatten the ball by hand a bit and cover it with another piece of wax paper. Then, using a rolling pin or a rocket tube, I'll further flatten the comp until it's just as thick as the spacer dowels, 5/16" in this case.

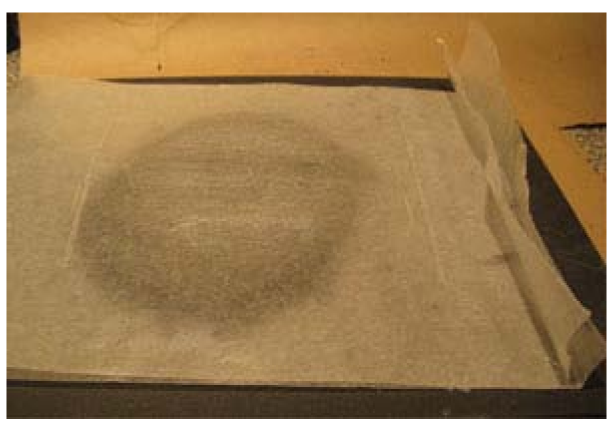
Star Comp Dough-Ball Being Flattened into a Pancake on Cutting Board

Now, the top piece of wax paper is removed and set aside, and the spacers are removed, too. The tub of star-prime is opened and some of it is evenly dusted onto the pancake using a small cup or a measuring spoon.



Pancake of Star Composition, Uncovered, and Dusted with Prime

The piece of wax paper is replaced on top of the pancake. Then fold the edges of the bottom and top pieces of paper together a couple of inches.



Folded Edges of Wax Paper

You'll see how helpful this step is in a minute. Then place the other cutting board on top of it all, press down a bit to compress the prime onto the pancake, and lift both cutting boards and flip them over, keeping the folded edges of the wax paper down so that the loose prime can't fall out from between the pieces of paper.

Remove the top cutting board and the top piece of wax paper. Now, dust the exposed side of the pancake with prime so that both sides have been coated in the prime.

Other Side Pancake, Now Primed

Now we're ready to do some star-cutting. I love the knife that a fellow pyro turned me onto years ago, that I use for cutting stars. It's a thin-bladed, very sharp, very straight edged, meat-slicing knife from McMaster-Carr. It costs $26 nowadays, and is part number 3851A11.

I cut and filed off the little plastic handle extension that hung down below the edge of the blade so that I could press the blade all the way down to the cutting board.

Great Knife for Cutting Stars

I start cutting the pancake of star comp into strips 5/16" wide, sliding the strips aside and flipping them over so that the primed edges are against each successive strip.

Note: The star comp can try to stick to the knife during this process. If a strip is clinging to the knife, it's easy to raise the knife a bit and rap its end on the cutting board, knocking the strip downward and off of it.

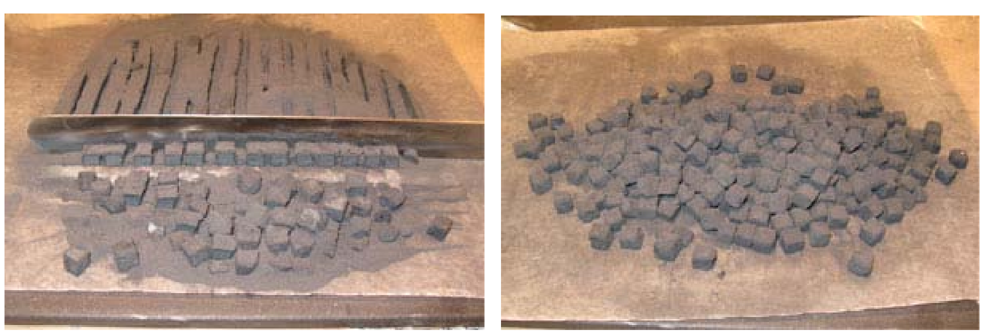
Cutting the Pancake into Strips, and Flipping Them Over

Then I sprinkle more prime on the strips, put the wax paper on the strips, fold over the edges of the two layers of paper again, put on the other cutting board, and flip the whole deal, keeping the folded paper edges down again. The top cutting board is removed as well as the top piece of paper, and that side of the strips is now dusted with prime.

Star prime is your friend in this process, and later on when you use the stars in a device. Don't use is sparingly. Use it liberally. Bam! Just like that cooking guy, what's his name? Emeril, yeah, that's it.

Strips of Star Comp Dusted on Both Sides with Black Powder Prime

The strips are now cut into 5/16" cubes, with the rows of cubes being flipped over as much as possible to keep primed edges touching each other.



Strips of Star Comp Cut into 5/16" Cubes

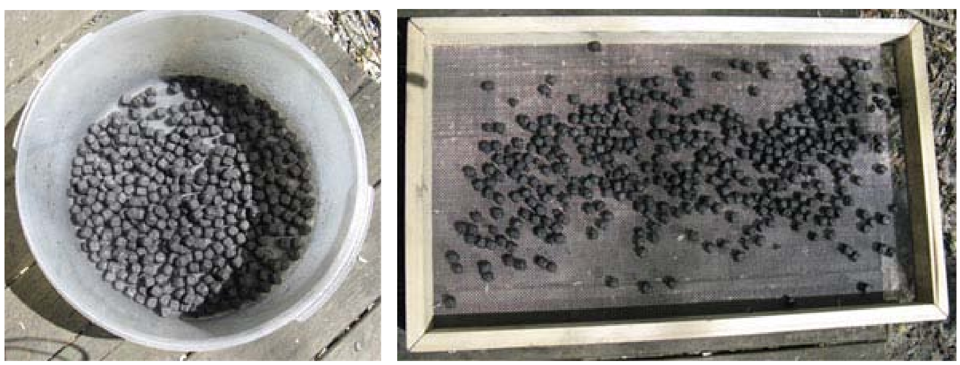
Now, it's easy to raise the edges of the wax paper and roll the stars onto each other, breaking up any that are clinging to each other, and fully coating all the cut sides with prime.

I like to dump the whole mess into a large plastic container, swirl them around a bit, and lightly spritz the stars with the water sprayer until they have fully gathered all of the star prime onto themselves. If I get them a little too wet, I add more prime, until a nice, thick, consolidated layer is on them.

In this instance, this one-pound batch of 5/16" stars used 6 ounces of the star prime.

Note: The above process is actually the beginnings of a simple, hand-rolled, round star production method. In a future article I'll use 1/8" zinc stars as the cores upon which to roll some round charcoal stars. These zinc stars make easy-to-handle, dense star cores for this procedure.

Then I spread the stars out onto a drying screen to dry in the warm air, or to be put into the drying chamber.



Fully Primed Stars in Plastic Bowl, and On Drying Screen

Testing the Zinc Stars

For purely scientific reasons, and not at all because I was impatient to see these babies in action, as soon as the stars were dry, which took about a week in the open air, or a few days in the drying chamber, I took a few of them out and fired them out of the star testing gun. Man, they are purty!

Testing Zinc Stars with the Star Testing Gun

Note: the 5/16" stars, which ended up being about 3/8" including the prime, worked well in the 1/2" star-gun tube, and required a flat 1/8 teaspoon-full of FFg sporting grade black powder to lift them. I also have some 1/2" stars which work well in the 5/8" tube, and require a heaping 1/8" teaspoon of the lift powder.

Since cut stars may not drop smoothly into the star-gun tubes because of their edges and corners, I use a thin dowel to push them down into the tube and to make sure they are seated against the lift powder.

How to Make Blinding Red Stars

Here is a formula for making red stars for aerial shells, mines, comets--anything where you need bright fireworks or stars.

Materials Needed

- Black powder
- Charcoal, airfloat (CH8068)
- Dextrin (CH8107)
- Magnesium aluminum, -200 mesh (CH2072, CH2073)
- Parlon (CH8210)
- Potassium perchlorate (CH5402)
- Red gum (CH8230)
- Strontium nitrate (CH5543)
- Superprime
- Sulfur (CH8315)

This was found on one of the internet mailing lists and described as "blinding red stars. Our thanks to "Gary" who furnished this. We haven't tried it, but since it smells similar to the legendary Independence Fireworks "Ruby" red stars, we thought you should have it. If you have ever seen Independence's Ruby red stars, you know how stunning these red stars can be. The writer rolls these red stars, primes with "superprime" (see Veline formula), and then black powder.

Parlon Red Stars Formula

Component	**Parts by Weight**
Strontium nitrate	50
Potassium perchlorate	8
Parlon	18
Magnesium/aluminum, -200 mesh	12
Charcoal, airfloat	5
Sulfur	5
Red gum	2
Dextrin	+5

How to Make Crackling (Dragon Eggs) Stars with Bismuth Subcarbonate

One man's experiments using bismuth subcarbonate to make crackling stars (commonly called Dragon Eggs) stars.

Materials Needed

- Bismuth subcarbonate (CH8039)
- Copper oxide, black (CH8096)
- Nitrocellulose lacquer (CH8198)
- Magnalium, 200 mesh (CH2072, CH2073)
- Screen, 10 mesh (TL2000)

Dragon Eggs: those popular crackle stars that so many people love and so many are tired of. Crackle stars or dragon eggs were traditionally made with formulas containing toxic lead tetraoxide. Later compounds were developed utilizing non-toxic, but expensive bismuth trioxide.

I am told that most Chinese dragon eggs use copper oxide. But somewhere in the dank recesses of my memory, I ran across bismuth subcarbonate dragon eggs. So, when I found some surplus bismuth subcarbonate a couple of years ago, I snatched some up, but never could find the formula for making dragon eggs stars with it.

But along comes an email from one of my customers, et voila! He sends me his bismuth subcarbonate star experiments. What follows is a strung together conversation he and I had over several emails. I'll leave it to you to extract from it what you need.

But at the bottom line, this is a relatively cheap, non-toxic way to make dragon eggs stars. And I promptly snagged a good supply of bismuth subcarbonate, which is about half the price of bismuth trioxide. Here's what he wrote, edited down slightly.

"That bismuth subcarbonate works pretty well to make crackle stars. I also like the fact that it's a lightweight powder as opposed to the dense powder that bismuth trioxide is. I've tried a formula of 90% bismuth subcarbonate, 10% magnalium (200 mesh) and 10% black copper oxide.

I'm going to try one of the formulas that use a lot less bismuth subcarbonate (75% bismuth subcarbonate, 15% magnalium, 10% black copper oxide). I'll let you know if it works better or worse."

I asked him to tell me more. He wrote: "As I mentioned earlier, I've tried a 90-10-10 mix of bismuth subcarbonate, MgAl 200 mesh, black copper oxide. I haven't primed anything yet, but I lit several of the little approximately 2mm stars on the ground with a torch-style butane lighter.

Boy do those things make a racket for such small chunks of star composition (about the size of the grains of soft pretzel salt, if even that big). I showed my brother the little stars before lighting, and he was absolutely amazed you could get that much sound out of such tiny stars.

These stars were just grated through regular aluminum window screen, which is about 10-mesh. When you take the thickness of the wires into account, you wind-up with almost exactly 2mm stars, though you'll probably wind up with a mix of sizes between 1.5 and 2mm.

I've now tried a mix of 75-15-10 and quite frankly, I don't see much, if any difference. Again, this is just lighting the stars on the ground. I've also made some 3mm stars with this composition. Some of them pop, break apart and each piece then pops, yielding a barrage of mini star bursts, but some go KABOOM in one fell swoop.

I think all the stars probably all go KABOOM in a shell after priming where they get uniformly hot due to the speed of the inner prime. I believe the lighter I use doesn't evenly heat the star, so it sometimes breaks apart.

A few of these stars that went KABOOM have left my ears ringing for the better part of 10 minutes - almost as loud as a regular firecracker! Can't wait to get some of these stars primed and into an artillery shell, a cake, or maybe even a small mine to see what they do in the air - definitely an effect you want to do at as low an altitude as you feel safe with (like maybe 50-60 feet).

I'm actually using Skylighter nitrocellulose lacquer thinned to about 8% (1 part 25% NC to 2 parts dried acetone).

The only thing I have a problem with in making the dragon eggs right now is that you have to work really fast once you take a glob of the wetted star composition out of the closed Ziploc you've kneaded it in. The solvent evaporates so quickly that if you don't work damned fast, the surface gets crusty.

Then, when you try and roll out the star patty for cutting or pressing through window screen, it cracks and crazes on the surface and composition flakes off. Sure, you can just accumulate the broken bits, dust and misshapen stars, rewet with straight acetone and do it all over again, but that’s tedious.

And just to give you a heads-up on the volume of 1.5-2mm stars you get from 20g of mixed composition, they'll fill a 35mm film can about 1/3 the way up - literally hundreds of tiny stars.

I'm also thinking that granulating the composition through much thinner screen (20-30 mesh), where you wind up with stars closer to 1mm. This would allow them to be added directly to rocket compositions for what I bet would be a really "interesting" effect, especially if the prime you used on them was a color composition of sufficient thickness to allow them to exit the tail of the rocket before popping. Can't say I've ever seen a rocket that "back-fired" as it ascended.

The 75-15-10 star composition seems really good but as I said, that's only on the ground. These stars need to be tested in the air. I also want to judge the difference in sound in the air between the 2mm stars and the larger ones to see if the difference is as noticeable in the air as it is on the ground. I kind-of think it will be, but you and I both know that stars sometimes surprise you once you get them into the air."

I asked if he had tried dextrin as a binder instead of the NC lacquer. Gene replied: "Haven't tried dextrin as a binder for these--not sure it would work but it would be cheaper and much less troublesome. It wouldn't surprise me one bit if the NC lacquer not only works as a binder but also as a fuel of sorts and that it needs to be there to make the reaction work properly.

From my ground tests, it actually looks like the little stars heat up red-hot first and then blow. Maybe the NC is an intermediary fuel that sustains the precursor reaction. It's such a good binder; maybe it's what provides the confinement prior to bursting that allows the stars to pop so loudly. It's just speculation on my part.

I can't say I've ever seen a breakdown of the exact chemical reaction that causes the stars to pop so loudly so I don't know what the mechanism actually is. I have read that you never want nitrate to contact or leach into the stars as this will ruin the effect. Everything I've read suggests the use of a hot perchlorate inner prime with red gum, wetted with straight 70% isopropyl.

At 70%, the red gum is going to probably nearly completely dissolve, providing a pretty nitrate-proof barrier. Also, something tells me that, if dextrin or some other water-soluble binder works, someone would have published some info on it already. Still, it wouldn't be a big deal to mix up 5-10g of composition and try it."

Keep in mind that Gene's R&D is very much a work in progress. But I think it does provide an interesting, less-expensive, and less toxic starting point for anyone who wants to make dragon egg stars.

If you try his pyrotechnic formulas you may want to experiment with dextrin or Starpol water-soluble binders in place of NC. Using NC and acetone is a lot more problematic, as Gene mentions.

Cheap Barium Nitrate Emerald Stars

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Materials Needed

- Aluminum, Indian Blackhead (CH0144)
- Barium nitrate (CH5102)
- Boric acid (CH8042)
- Charcoal, airfloat (CH8068)
- Dextrin (CH8107)
- Parlon (CH8210)
- Potassium perchlorate (CH5402)
- Red gum, air milled (CH8230)

Here're some stars you can make with all that barium nitrate once you grind it fine. I know: "it's impossible to get a great green star using barium nitrate." But try this one and see if you don't become a believer yourself.

Component	Parts by Weight
Barium nitrate	65
Potassium perchlorate	15
Indian Blackhead aluminum	10
Parlon	16
Boric acid	2
Charcoal, airfloat	2
Red gum, air milled	5
Dextrin	5

Green Stars without Barium Nitrate or Chlorate

Pyrotechnic formula and notes for making green stars without using the toxic firework chemicals, barium nitrate or barium chlorate.

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Materials Needed

- Acetone
- Aluminum, dark pyro (CH0152, CH0144)
- Barium carbonate (CH8025)
- Parlon (CH8210)
- Potassium perchlorate (CH5400, CH5402)
- Saran (CH8248)
- Screen

Thanks to Norm for this one. We haven't tried it, but if the stars look good, they really do solve a big green star problem for a lot of folks who are not able to get barium nitrate or barium chlorate shipped to them.

"With all the shipping and health problems associated with barium nitrate or barium chlorate, I have come up with a fairly good green star using barium carbonate. This star has no apparent yellow and burns reasonably fast.

Radiant Green Star

Component	Parts by Weight
Potassium perchlorate	40%
Barium carbonate	30%
Dark pyro aluminum (or any -400 mesh or smaller flake aluminum)	15%
Parlon or Saran	15%

Make sure all ingredients are talcum-powder-fine. Keep the aluminum mesh size very fine to keep color depth. Screen the star composition and mix very well. For cut stars, mix with straight acetone. Then cut the stars and prime. If you want rolled stars, add an extra 5% dextrin to the composition and bind with water and 25% alcohol.

Substituting -200 mesh magnesium-aluminum for the aluminum gives the star deeper color and adds an interesting, slightly aqua appearance. Unique!"

HG's note: " Although I haven't tried it, I expect you could eliminate the acetone (and its problems) and make cut stars out of these by adding +5% dextrin and bind with water."

Charley Wilson's Notes: "Regarding substituting -200 mesh magnesium-aluminum (magnalium) for the aluminum...his is really similar to the Veline green--hard to light and blows blind a lot.

The use of magnalium is recommended. Magnesium would work also, and would give you a star closer to a go-getter result, but needs to use Parlon with MEK as the solvent. Good Saran does not dissolve in acetone or MEK except at high temperatures.

Regarding the magnesium-aluminum producing an aqua color... He may have some copper in there somewhere, probably in the magnalium as an alloy impurity. This is common in European versions of the alloy. I don't get an aqua color from magnalium.

Yes, it's an OK green, but not as deep as ammonium perchlorate-based greens or the old barium chlorate/shellac green. And, yes, I have made similar stars using Saran stars and bound with dextrin. My version (in %s) was:

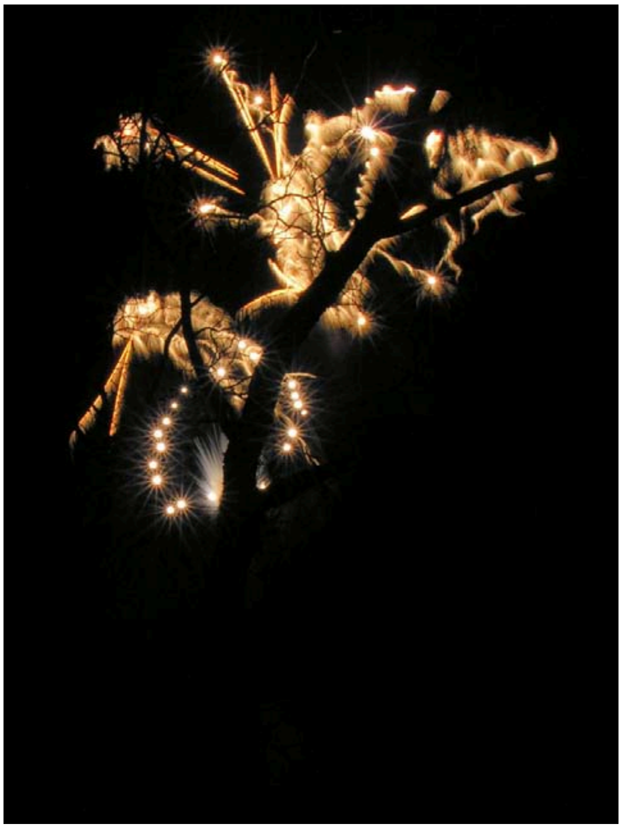
Potassium perchlorate	42
Barium carbonate	28
Saran	14

Sulfur	6
Magnalium	10
Dextrin	+5

Sulfur really helps the burn rate and seems to reduce cinder."

Making Pillbox Stars

By Lee Partin.



"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Learn how to make pillbox stars including rolling their paper tubes and their pyrotechnic formulas.

A fine article on making pillbox stars was written by Lee Partin, late of Homosassa Springs, Florida, for the best fireworks club and newsletter in the US, FPAG's "First Fire". She and the club have consented to its reprinting here. Thanks to the club and especially to Rich Ogden, editor of the First Fire, for compiling this article from three separate articles originally written by Lee, and for helping with questions and clarifications.

Materials Needed

- Alcohol
- Aluminum, flitter, fine (CH0140)
- Aluminum, bright (CH0142)
- Aluminum, flake, med/large
- Aluminum, flake, small
- Black match
- Charcoal
- Dextrin (CH8107)

- Kraft paper, 60-70 lb.
- Potassium perchlorate (CH5402)
- Red gum (CH8230)
- Shellac (CH8255)
- Sodium oxalate (CH8280)
- Strontium carbonate (CH8310)
- Strontium nitrate (CH5543)
- Water

Pillbox Stars Everywhere

Every time we turn around, we are making pillbox stars for PGI. Red ones, blue ones, green ones, gold ones, and the list goes on. I have even made them in my dreams - rolling tubes, mixing composition, loading and compressing them.

If you have never seen the effect of a pillbox star in the sky, you have missed one of the more spectacular pyro effects. It is essentially a tube of paper with black match extending at least a half-inch from each end and running the entire length inside of the tube.

This means that when you light the star it will burn from both ends and produce a larger flame envelope (visible burning area), and it will burn for several seconds. They are often loaded in rings in canister shells, break in beautiful rings and expand outwards while falling towards the earth. Absolutely beautiful!

We have probably made at least a couple of thousand pillbox stars. If you wish to try this effect, I will pass along the methods that I have learned.

Tubes: The pillbox star tubes are rolled from three turns of 60 or 70 lb. Kraft paper. The paper is cut 20 inches wide and 7-1/2 inches long, with the grain running in the 7-1/2 inch direction. They are rolled around a 3/4-inch wooden dowel or steel rod (the weight of the steel rod makes it easier to roll the tubes).

Paste is applied lengthwise to 2/3 of the width of the paper over the entire length. It is then rolled up, and then slipped off of the dowel. Some people paste the entire paper, including the area that touches the rod. This is also acceptable, but the rod can get tacky and needs to be cleaned. Allow the tubes to dry slowly.

Do not put in the sun (or oven), as this can cause the tubes to wrinkle or curve. Depending on the burning speed of the pillbox star composition, the dry tubes are then cut into sections from 1 inch to 1-1/2 inches long.

Filling Method: After the pillbox star tubes are rolled, dried and cut to the desired length, cut pieces of black match long enough to hang out both sides of the cut tubes by at least a half inch. Moisten the pillbox star composition only SLIGHTLY.

Insert the match into the tube along the inside wall, extending from each end of the tube. Bend or fold the black match over the ends of the pillbox star tube. Hold the tube with the black match in place and dip it into the bucket of dampened pillbox star composition.

Scoop the tube full of pillbox star composition and compress gently with the finger and thumb on each end of the pillbox star tube. If the pillbox star composition compresses too much, scoop more pillbox star composition into the ends of the tube to fill it. Press again on the ends with the thumb and finger. Place on the [optional] ramming tool and tap lightly. Do not consolidate too hard; this can cause the pillbox star to burn too long.

Set it aside to dry, and repeat the process. Let the pillbox stars dry a couple of weeks.

Compositions: Here's where I get confused. One source I trust says "Many regular pyrotechnic formulas will burn too long in the pillbox star tubes," which seems to imply that the pillbox star pyrotechnic formulas should be faster-burning than those used for other types of stars. But other sources (notably Hardt, 2001) claim that "pillbox star compositions...are often slower burning than compositions used for other types of stars," presumably because the black match will light the pillbox star along its entire length

Well, I'm going to let someone else tackle that question. I'll just finish with the pyrotechnic formulas our Dragon Lady gave in the three articles.

Pink and Silver Pillbox Star Formula

Component	Parts by Weight
Potassium perchlorate	68
Strontium carbonate	14
Strontium nitrate	2
Red gum	6
Aluminum, bright	4
Aluminum, flake, small	3
Aluminum, flake, med/large	3
Dextrin	+2

Moisten with no more than 8 to 9% moisture: 35:65 alcohol:water.

Red Electric Pillbox Star Formula

Component	Parts by Weight
Potassium perchlorate	70
Strontium carbonate	12
Red gum	6
Aluminum - bright	6
Aluminum - flitter fine	3
Charcoal	3

Moisten with water:alcohol 80:20 until the pillbox star composition is slightly damp, and composition clumps when compressed in the hand.

Red (from Lancaster)

Component	Parts by Weight
Potassium perchlorate	70
Strontium carbonate	15
Red gum	9
Charcoal 150 mesh	2
Dextrin	4

Yellow (Lancaster)

Component	Parts by Weight
Potassium perchlorate	70
Sodium oxalate	14
Red gum	6
Shellac 80 mesh	6
Dextrin	4

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Rich Ogden notes: "You just want to firm the pillbox star composition in the tubes, not pound it in. The paper case is only 2 layers of very thin Kraft and won't take any pounding and the pillbox star composition should not be pressed down too hard anyway - not like a pumped star. Some people don't use the tooling at all; just squeeze it between thumb and forefinger or middle finger. Guess it depends on the pillbox star composition, how moist and sticky, and so on.

But you don't want it too hard. These suckers are big (relatively speaking), and take advantage of the support provided by the paper to allow the pillbox star composition to be just a little softer than a similar-sized comet or pumped star; that results in a bigger flame envelope than a hard-pressed pillbox star composition"

He also notes that either Elmer's (white) glue or wheat paste can be used to make the tubes.

Making Comets: Formulas and Techniques

By John Werner.

Learn various methods and tools used for pressing comets including comet pumps and plates.

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Materials Needed

- Aluminum, granular, 50-150 mesh
- Antimony sulfide, 200 mesh Chinese needle (CH8010)
- Comet pumps or comet plates (TL3124)
- Charcoal, airfloat (CH8068)
- Dextrin (CH8107)
- Magnalium, -200 mesh (CH2072, CH2073)
- Potassium nitrate (CH5300)
- Sulfur (CH8315)

Comets are really nothing more than an oversize cylindrical star fired from a mortar to produce a single rising effect in the air. Like stars, comets can be made in numerous variations such as color, tailed, strobe and crackling, even sandwiched combinations thereof.

While many star formulas will work as-is for comets, some formulas, particularly color ones, need to be modified to burn faster if used for comets, in order to prevent the comet from coming back down to ground while still burning.

Comets are especially effective if fired in multiples, arranged in straight, fan shaped or angled setups and fired electrically. However, careful attention must be paid to the fabrication of the comet itself and to the loading of the mortar in order that all the comets burn out at the same time after rising to a consistent height.

Fabrication

Several methods can be used to shape the cylindrical comet pellet. While there is no standard dimension where a star becomes a comet, I like to think that anything 3/4" in diameter or larger is a comet, and anything under 3/4" is a star, although there is no clear distinction.

Using Comet Pumps

These are a great way for an individual to get started making comets. In their simplest form comet pumps consist of nothing more than a solid wood or metal rod, with a close, sliding fit in a short length of metal tubing. The rod is first slid part way into the tube so as to leave an empty cavity at the bottom of the metal tube. The rod should extend several inches above the top of the metal tube (or "sleeve," as it is sometimes called).

Firmly gripping both the rod and the tube at the same time, the two pieces are plunged as a unit into a dampened comet composition, filling the empty cavity in the metal tube. Next, the unit is set upright on a solid surface and a number of firm blows with a non-sparking mallet are delivered to the top of the rod to consolidate the comet mix.

Lifting the comet pump up, the rod is pushed further into the tube, thereby ejecting the comet out the bottom. Generally, the comet will stick to the end of the comet pump rod and will need a gentle twist to release it.

Advantages of Comet Pumps

- Inexpensive, low-tech way to make comets
- Easy to vary the thickness of the comet
- Possible to make very hard, strong comets
- Great for making small, experimental batches of comets

Disadvantage of Comet Pumps

Slow, not suitable for production runs

Using Comet Plates

Plates produce a number of comets simultaneously. They consist of a thick metal or plastic plate into which round holes have been bored the same size as the comet diameter. This is called the “hole plate.”

The thickness of the plate is about 10% greater than the height of the finished comet it produces. Another comet plate, called the “pin plate,” is machined with a series of round pins protruding down from the bottom of the comet plate. These pins are roughly 0.030" smaller in diameter than the holes in the hole plate.

The length of the pins is roughly .060" longer than the thickness of the hole plate. The pins are arranged so that they slide easily into the hole plate. A comet (or star) plate is nothing more than multiple comet pumps ganged together.

Comet plates can be used in hydraulic or pneumatic presses to consolidate the comet composition or they can be operated entirely by hand and do not require machinery of any kind. The exact procedure for operating the comet plates by hand is somewhat difficult to describe and is best learned by watching a demonstration, as available in Skylighter video #VD0166D.

Advantages of the Manual Comet Plate Method

This is a low-tech, fairly inexpensive method to quickly produce large quantities of comets. My favorite plate produces twenty-seven 1-1/2" diameter comets each time it is filled, and in one and a half hours can turn out 100 pounds of comets utilizing nothing more than muscle power. The comet plates are portable, can be set up anywhere, and are easy to clean.

Disadvantages of the Manual Comet Plate Method

- Comets are not as hard as when using a single comet pump or a press
- Height is limited to the thickness of the hole plate
- Large diameter comets tend to be "hockey puck" shaped due to limitations of trying to consolidate a large thickness of composition
- Comet compositions must be dampened very carefully; too dry, and the comets will not hold together when fired; too wet, and they will stick to the pins when they are ejected from the hole plate
- Not suitable for shock sensitive comet formulations
- Limited to 3" diameter or smaller comets

Mechanical Pressing

Comet pumps and plates are also used in conjunction with various types of presses to supply the force needed to consolidate the comet composition. Some presses such as arbor presses and bottle jacks (small hydraulic automotive jacks) merely amplify the human power supplied to them and are therefore limited to the amount of force they can apply. Large motorized hydraulic and pneumatic presses are employed when greater speed or production quantities are needed.

Advantages of Mechanical Pressing

- Very large diameter comets can be produced, from 3" to 6" diameter.
- Harder, more consistent comets can be produced when using comet plates.
- Shock sensitive comet compositions can be used more safely.

Disadvantages of Mechanical Pressing

- More expensive equipment required.
- Often requires a dedicated location for setup.
- Clean up is often more involved.

Silver Comet Formula

Here is an inexpensive, uncomplicated silver comet that is easy to mix and form into a nice hard comet pellet. It produces a kind of coarse, drippy tail due to the use of the granular aluminum.

Component	Parts by Weight
Potassium nitrate	54
Charcoal, airfloat	8
Sulfur	18
Granular aluminum	9
Magnesium/aluminum alloy	3
Antimony sulfide	3
Dextrin	5

Gilliam’s notes to the formula above: For the aluminum, try granular aluminum in about 50-150 mesh range, which is what Werner recommends. For mag-al alloy, use -200 mesh. For antimony sulfide, use 200 mesh, Chinese Needle.

Making Uniformly-Sized Round Stars

Learn how to make your round stars a uniform size using a star sizing screen for use in aerial artillery shells.

Materials Needed

- Stars
- Star sizing screen

If you have ever seen a really high quality color-changing spherical artillery shell, you may have noticed that the stars all seem to change colors at exactly the same time. The stars can actually look as if they are "blinking" on and off. The technique is to roll the stars up to a certain precise size before adding the dark changing relay or the next color. And to do this you must use some sort of star sizing screen.

Star sizing screens are not measured in mesh sizes, as with most screens, but rather by the size of each hole in the screen. They are more expensive than regular screens, because they are made of extremely heavy gauge stainless steel in order to be able to hold the heavy weights of the stars. If you are rolling stars or plan to, try sizing your stars and watch your artillery shells improve.

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Willow Star Formulas

By Gary Bergman & Kurt Medlin

Here are a few pyrotechnic formulas for making willow stars.

This was clipped from the Western Pyrotechnic Association's mailing list. It was a reply from Gary Bergman to Kurt Medlin regarding comets and stars Gary had made. It's a little choppy, but you can get the gist of it. Thanks Gary and Kurt.

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Materials Needed

- Aluminum, bright, 400 mesh
- Antimony sulfide, -325 mesh (CH8011)
- Black powder, 2FA
- Black powder, pulverone
- Charcoal, airfloat (CH8068)
- Comet pump (TL3124)
- Dextrin (CH8107)
- Kraft paper, 20 lb.
- Lampblack (CH8170)
- Potassium nitrate (CH5300)
- Sulfur (CH8315)
- Titanium powder
- Wheat paste

~~~~~~~~~~~~~ *[Gary replies to Kurt:]*

Hi, Kurt,

The 12-inch salami comets were pumped using a standard 1 3/4" Wolter comet pump. When the comets were dry they were wrapped with 2 turns of 1-inch wide 20 lb. Kraft (lightly wheat-pasted), which left 3/8" of comet composition exposed on either end.

This step was per your experience on the 8" Gold Willow you had made (I replaced your formula's 80 mesh airfloat charcoal with lampblack) and was to fulfill my desire to make sure that these made it to the ground - hopefully a little above ground level would be better. The basic pyrotechnic formula is (in parts by weight):
~~~~~~~~~~~~~

Berg’s Gold Willow Comet

Component	Parts by Weight
Potassium nitrate	36
Airfloat charcoal	29
Lampblack	14
Sulfur	9
Titanium sponge	7
Dextrin	5

For the titanium I mixed -10+20 mesh (64%) and -30+60 (36%). (If you can’t get sponge titanium, you can substitute any other form of titanium). This was all bound with 12% binder solution by weight (75% water and 25% alcohol).

~~~~~~~~~~~~~ *[Kurt further asked:]*

My "Mess-Kit Willow" stars are 1/2" grid stars using the plastic 1/2" X 1/2" light grid as a mold and mashing the star composition into the grid lying on a piece of PVC sheeting.

The formula was based on the "Bright Willow" pyrotechnic formula below (parts by weight).

Kurt's Bright Willow Stars

Component	Parts by Weight
Potassium nitrate	50
Charcoal, airfloat	15
Lampblack	15
Antimony sulfide, -325 mesh	9
Sulfur	6
Dextrin	5
Bright aluminum, 400 mesh	15

In the pyrotechnic formula that you use, you replaced 1/2 the recommended airfloat charcoal with lampblack for your version of "Bright Willow." My love of the willow star prompted me to ask about a long-hanging willow pyrotechnic formula.
~~~~~~~~~~~~~

If you will remember the "Bright Willow" pyrotechnic formula that you suggested to me, jokingly, was replacing all the airfloat with equal parts lampblack and bright aluminum, -400 mesh. This was after I first got to know you and I don't know if you wanted me to either "go away" or just see how dedicated a pyro I really was. I remember when you found out that I had actually made it you howled in laughter.

"You actually made that mess." And that is exactly what I named it - "Mess-Kit Willow."

Mess Kit Willow Stars

Component	Parts by Weight
Potassium nitrate	50
Lampblack	15
Bright aluminum	15
Antimony sulfide, -325 mesh	9
Sulfur	6
Dextrin	5

This is a pyrotechnic formula not to be undertaken by the faint of heart nor a clean freak. It goes EVERYWHERE and then some. But the results are a superior glitter star that hangs for along time.

Actually the "Mess Kit" willow pyrotechnic formula was only used to make the grid stars encasing the lone 1 3/4" comet. The comets were 1.75" diameter by 1.75" high cylindrical pumped comets (using a regular size Wolter comet pump) that were placed in concentric rings (16 to a ring) against the casing wall of the shell per Fulcanelli's great articles "Traditional Cylinder Shell Construction" in Pyrotechnica IX (Part 1) and Pyrotechnica XI (Part 2).

The smaller Mess Kit Willow stars were placed in with the pulverone (loose) surrounding the burst core.

Think of 3 rings radiating from the center (if looking down the inside of the shell from one end).

- Center ring: 2 1/4" diameter is burst (2FA)
- Middle ring: Pulverone/willow stars
- Outside ring: Large pumped comets

For anyone wanting to build cylindrical shells, the Pyrotechnica articles are very straightforward and a great reference. I have read them 20+ times and still refer back to them.

I pre-tested the stars and comets in 4-inch ball shells. The 4" ball shells were over lifted with extra long time fuse (2") to more closely simulate the breaking height of a 12" shell. It was for reference only to see what the burn time and characteristics were of the comet.

The Mess-Kit willow stars were an afterthought to help fill the shell and save valuable rice hull burst, of which I was running low. Glad I tried it. I tried the Mess Kit stars before. They did not light in a hard-breaking shell, and I was going to prime them. Lacking time, prime, and even less time I just threw them in there.

Hey were better in my shell as filler than filler for the burn pile. Anyway, the stars worked great in the light-breaking shell, which is how willow is supposed to be used.

By the way, I highly recommend Mess-Kit Willow stars for anyone manufacturing on a windy day so that you can "share it" with everyone downwind. You're sure to get responses, not all great ones, mind you.

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

The Blues, Part 1

A couple of years ago, I helped instigate a blue-star color contest at one of the Florida Pyrotechnic Arts Guild's spring shoots. The judges were looking for the color that most closely approximated a blue we described as "cop light blue." That is, a blue deep enough to be a good blue color, yet bright enough to be visible from normal viewing distances.

The results of that contest as well as other blue-related information are described in a single issue of the Florida club's newsletter, The First Fire, entirely devoted to the topic of "Blue." We are reproducing the articles that appeared in that issue over the next few Bulletins with some small editing on my part. I hope you will find them useful in trying to create this elusive color. Thanks to FPAG, Lin Collins, Mark Wilbur, Rich Ogden, Lee Partin and the cited authors for the use of this excellent material.

–Harry Gilliam

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Materials Needed

- Alcohol
- Copper oxide (CH8096)
- Dechlorane
- Dextrin (CH8107)

- Parlon (CH8210)
- Potassium perchlorate (CH5400, CH5402)
- Red gum (CH8230, CH8231)
- Water

Florida Pyrotechnic Arts Guild Spring Shoot, Blue Competition Results

By Lee Partin

Harry Gilliam and I were discussing this upcoming blue edition of our "First Fire" [newsletter], and he suggested a competition. It was a VERY informal competition. Everyone was to bring his or her favorite blue formulation and show it. We decided on Saturday night to give everyone a chance to get there. Just after the range opened we all agreed to get together at the left range at 8:30. I spent the next hour going around the field telling everyone I saw and asked them to spread the word, and I yelled it out at the ranges and in the viewing area, and still somehow missed Lin Collins. Boy did I feel bad after I found out. Sorry Lin. (Editor's note: Please contemplate Lin's contribution to this issue christened "Rhapsody in Blue").

There were shells of all sizes, both canister and round. We were looking for color, not shell break. We even had an incredible 12-inch round. We also had the seven separate personalities of Mark Wilbur, and incredible shells from Pete Leonardi.

I have asked the participants and the winners to share with us formulas and some of their insights on the blue color if they did any testing.

Place	Entrant (Shell #)	Score
1st	Mark Wilbur (Personality #3)	8.33
2nd	Pete Leonardi (Shell #1)	8.00
3rd	Fred & Lee Partin (Shell #1)	7.33
4th	Robert Stahl	7.00
5th	John Fuller	6.00
6th	Richard Ness	4.33

Wilbur's winning formula was potassium perchlorate (65%) with copper oxide (14%), red gum (7%), parlon (5%), dextrin (5%) and dechlorane (4%).

Partin's formula was a chlorate formula with Paris Green as the colorant.

Fuller's formula was a Veline Blue with magnalium and parlon.

We hope you enjoyed this, and we can do something like this again!

I Really Blue It This Time!

By Mark Wilbur

My evening shooting included seven blue star compositions for the blue star competition. I was quite surprised and greatly pleased to win 1st place with a blue star shell I shot. All the blues looked pretty much the same to me, with the exception of Veline's Magnalium Blue.

It was a brighter star, but it looked washed out compared to the other blue stars. In my pursuit for a deep blue star I searched the pyro literature for the many published blue pyrotechnic formulas and wrote the pyrotechnic formulas down side by side for comparison.

I grouped them by oxidizer first and by coloring agent second. The many pyrotechnic formulas were relatively close in ingredients and percentages. I narrowed the selection to two potassium chlorate ($KClO_3$) mixes, five potassium perchlorate ($KClO_4$) mixes, and two ammonium perchlorate mixes.

I wasn't able to make the ammonium perchlorate mixes in time, so I still have that on my list of "Try These" formulae. The blue stars I tried used copper oxide, copper carbonate, or copper oxychloride as the coloring agents.

Some of the published pyrotechnic formulas used copper metal, but I decided against trying them. It seemed that the potassium perchlorate mixes produced the deepest blue. It was one of these that won 1st place in the competition.

All of my potassium perchlorate mixtures outscored my potassium chlorate mixes. All of the stars were cut stars. I primed the potassium perchlorate mixes first with Bleser's #22 Igniter and second with ball-milled pulverone prime.

The potassium chlorate mixes were lightly primed with ball-milled pulverone prime. Ignition of each star mix seemed very good with these preparations. Priming of ammonium perchlorate stars is more involved, and that helped to postpone making these star compositions.

I enjoyed exploring and experimenting with these mixes. I find the chemistry of this hobby deeply fascinating. In my pyro reading I learned that the copper chloride ($CuCl$) molecular species is most desired in the flame envelope to emit the deep blue spectra. In order to achieve this, a good chlorine donor is needed. I have been using dechlorane with good success.

Blue must also keep a lower flame temperature than other colors. So a hot fuel like magnalium is not preferred. Some other factors peculiar to blue stars figured in my choices for mixes. As promised I will share the winning blue star formula.

Wilbur's Winning Blue Formula

Component	Parts
Potassium perchlorate	65%
Copper oxide	14%
Red gum	7%
Parlon	5%
Dextrin	5%
Dechlorane	4%

The mix was moistened with water/alcohol 75/25% and cut into stars that should have been put in a six inch shell instead of a four inch shell, since they burned all of the way to the ground. I suspect that 3/8 inch cut stars are large enough for a four-inch shell. The potassium perchlorate stars were easy to light with the two-step prime and did not seem to burn fiercely. A satisfyingly deep blue star was achieved.

The Blues, Part 2

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Materials Needed

- Alcohol
- Ammonium perchlorate (CH5005)
- Charcoal (CH8062)
- Copper carbonate (CH8087)
- Copper oxychloride (CH8098)
- Cupric chloride (CH8091)
- Cupric oxide (CH8096)
- Dextrin (CH8107)
- Hexachlorobenzene
- Lactose (CH8169)

- Magnalium 50:50, -200mesh (CH2072, CH2073)
- Paris green
- Parlon (CH8210)
- Potassium chlorate (CH5200)
- Potassium perchlorate (CH5400, CH5402)
- Red gum (CH8230, CH8231)
- Resin, Accroides
- Rice starch (CH8238)
- Shellac (CH8255)

Copper as a Colorant

By Lee Partin

Blue: one of the most elusive of colors.

"The production of a vividly-colored flame is a much more challenging problem than creating white light. A delicate balance of factors is required to obtain a satisfactory effect." (Conkling, 151)

Colored light has a visible band related to each individual color. In the electromagnetic spectrum, the emission of blue is perceived in the visible region of between 435 and 480 nanometers. This is a very narrow band. Certain elements when heated to a particular temperature range are unique in emitting visible blue light.

Blue should not be heated above 1200 degrees centigrade. Decomposition of the color occurs above this. It is then necessary to bring the copper to a high enough temperature to excite the electrons, but low enough to keep disassociation to a minimum.

Copper and copper salts produce blue color. In the following pages, I will cover the different colorants for blue stars.

Sources of Copper

COPPER POWDER: Cu. Appearance: A reddish powder with a pretty metallic luster (Shimizu 112). When added to an ammonium perchlorate composition, the result should be a nice blue star. 5% in the formula should be enough.

Copper powder reacts with ammonium perchlorate in the presence of H_2O. When decomposition occurs it can generate heat and ammonia gas. This composition should be protected from moisture.

COPPER ACETOARSENITE: $(CuO)_3\ As_2O_3\ Cu(C_2H_30_2)_2$, Paris Green. Also known as Spring Green, Imperial Green and Brilliant Green. Appearance: Shades of rich, mint green fine powder. Insoluble in water, and soluble in acid, ammonia solution, decomposes by alkali, not hygroscopic.

When used in potassium chlorate pyrotechnic formulas, with a clean-burning fuel such as shellac, it produces the best blue stars next to the ammonium perchlorate blue stars. It equally is great in purple pyrotechnic formulas. This is not to be confused with copper arsenate (Schloss Green).

Paris Green does not decompose chlorates. Caution should be observed when using this copper salt; it is poisonous. When using Paris Green you should always use a respirator with good filters and wear rubber gloves. If reasonable care is observed it is worth the effort for the result.

COPPER ARSENATE: $CuHAsO_3$ Schloss or Schlees Green. Appearance: Lighter than Paris Green with a yellowish cast. It's a fine powder, insoluble in water, soluble in ammonia and slightly hygroscopic. This product was used in the pesticide industry, and many people have confused it with Paris Green. It produces a blue star, but it is not as intense as Paris Green. As it has the problem of being somewhat hygroscopic, this can present ignition problems in stars. Copper arsenate does not decompose chlorates.

COPPER CARBONATE. Basic copper carbonate occurs in two forms:

1. Malachite: $CuCO_3\ Cu(OH)_2$ Appearance: Dark greenish powder, consisting of monoclinic crystals. This is usually made by precipitation. It is considered the safest for use in ammonium perchlorate blue stars, or where the composition produces a high temperature and HCl is produced in the flame. (Shimizu) When used in perchlorate pyrotechnic formulas the addition of a chlorine donor will produce an acceptable blue star. Malachite does not decompose chlorates.

2. Azurite: $2CuCO_3\ Cu(OH)_2$ Appearance: Light to dark blue. This is not as a rule used in the fireworks trade. It is instead used in the paint industry. Azurite does not decompose chlorates.

COPPER CHLORIDE: $CuCl_2\ 2H_2O$ Appearance: Light yellowish green, small crystals like sugar that are very hygroscopic. An excess of chlorine has to be present to ensure color production, PVC, Alloprene (Parlon), Saran, etc. Stars made from this are very hard to dry, and if left out in the drying room after dark they will re-absorb the water that dried out. If the flame is in the presence of too much oxygen, it will burn above 1200C, in the 525 nanometer range and slip into the color green. The color produced from this is a better blue then copper carbonate. Copper chloride does decompose chlorates.

COPPER SULFATE: $CuS0_4$ $5H_20$ Appearance: Blue stone, dark blue crystals. This copper salt was used in older pyrotechnic formulas. It has a tendency to oxidize and produce sulfuric acid; care should be taken with chlorate mixtures. Separate screens should be used with compounds made with this. Stars or mixtures should not be stored, but be used immediately. It can be safely used with potassium perchlorate, but stars made with this can be hard to light. (Weingart, 7) Copper sulfate does decompose chlorates.

COPPER OXIDE: CuO Appearance: Black, fine powder. Black copper oxide has been used for many years to produce a pleasing blue in perchlorate pyrotechnic formulas. It is not hygroscopic, and it is relatively stable. "Copper oxide emits a series of bands in the red region, and this reddish emission is often seen at the top of the blue flame." (Conkling, 160). We have used copper oxide in potassium perchlorate mixtures with magnalium, and have had safe and reproducible blue stars that store well. This is easily available. Copper oxide does not decompose chlorates.

COPPER OXYCHLORIDE: This basic chloride appears to have variable composition and is possibly: 3CuO $CuCl_2$ $3H_2O$. Appearance: Pale mint green, fine powder, soluble in acids and ammonium hydroxide, but not in water. It is formed when cuprous chloride is exposed to air. It makes a nice blue star but not noticeably better than copper oxide. It was used in times past because it was cheaper than other coppers. This is no longer the case. Copper oxychloride can decompose chlorates.

Fuels

There are two types of fuels that I will cover, metal and organic.

Metal Fuels

I will cover this only briefly because we do not generally use metals in blue stars. It can bring the burning temperature up too high for one thing, and it can "wash out" or make the blue star appear paler. Metal fuels include magnesium, magnalium, aluminum, and several others.

Conkling stated, "A metal can be initially screened for pyrotechnic possibilities by an examination of its standard reduction potential. A readily oxidizable material will have a large, negative value, meaning it possesses little tendency to gain electrons and a significant tendency to loose them.

Good metallic fuels will also be reasonably light weight, producing high calories/gram values when oxidized." (65). The coolest burning of these is aluminum Al2O3, with the consumption of only 1.12 grams of fuel per gram of oxygen.

Magnalium alloy which is usually a Mg/Al ratio of 50/50 and MgO/As_2O_3 with only 1.32 grams consumed per gram of oxygen are also excellent fuels.

Metal fuels should only be used with potassium perchlorate composition mixtures. They will react unfavorably with ammonium perchlorate and potassium chlorate.

The Veline formulation is a great one if you like bright metal stars.

Organic Fuels

"The more highly oxidized or oxygen rich a fuel is, the smaller its heat output will be when combusted. The flame temperature will also be lower for compositions using the highly-oxidized fuel." (Conkling 76) This explains why we use such fuels such as lactose, shellac, red gum, and the like. I keep hearing the axiom, "Keep your blues cool", and with the knowledge we have of the temperature range of the blue light production, we understand why.

LACTOSE ($C_{12}H_{22}O_{11}$ H_2O): Lactose melts with decomposition at 200C. Used in compositions, which are required to react at low temperatures, it is of use in the manufactures of some blue stars. (Lancaster 50) Lactose is also less sensitive to chlorate than sucrose.

SHELLAC: Shellac is the refined form of lac, which is the secretion of the lac insect. It is usually marketed in flakes and comes primarily from Burma, India and Thailand. It is most useful in pyrotechnics as an orange-brown powder. It has become expensive and not as readily available or used as frequently today in pyrotechnics. It burns clean without the production of excess carbons that can muddy flames.

RED GUM (accroides resin): A reddish brown fine powder, originally from the Kangaroo Islands off the coast of Australia. It has [largely] replaced shellac in the pyrotechnic industry. It is [one of] the main non-metal fuel source[s] today. It has a low melting point to aid in ignition.

CHARCOAL: I have used charcoal as a fuel with ammonium perchlorate. A highly carbonized sample of charcoal showed a 91:3:6 ratio of C, H, and 0 atoms (Shimizu). Charcoal may vary greatly depending on type and hardness of wood used, and it can vary between batches of the same wood. Each batch should be tested before mixing a large amount of composition. Charcoal can produce great heat, which is why it is only used in cool burning ammonium perchlorate blues stars.

Pyrotechnic Formulas

Ammonium Perchlorate Blues

According to Weingart and many other sources, ammonium perchlorate and common copper salts produce the best blue stars. This is because ammonium perchlorate has a lower melting point and burns cooler than chlorate and potassium perchlorate. The safest copper to add to this kind of formulation is copper carbonate.

Care should be taken not to add finely divided metals, [such as] magnesium or aluminum to such compositions. "Corrosion of aluminum powder is accelerated by the presence of copper or mercury." (Weingart 59). In addition, it is always best to use distilled water for such star compositions when adding water as the solvent.

It should be noted that care should be taken when storing ammonium perchlorate stars. Moisture can cause decomposition.

Blue Pillbox Star, Lancaster

Component	Parts
Potassium perchlorate	39%
Ammonium perchlorate	29%
Basic copper carbonate	14%
Red gum	14%
Dextrin	4%

Bruce Snowden Blue Star, Pyrotechnica I

Component	Parts
Ammonium perchlorate	70%
Red gum	10%
Copper carbonate	10%
Dextrin	5%
Charcoal	10%
Moisten with alcohol	

Potassium Chlorate Blues

I personally prefer chlorate blue stars. The colors are clean, deep, and rich. Chlorate stars are easy to light, and require little heat for their ignition. Finely divided metals, or magnesium or aluminum should not be added to the star composition. When water is added it will attack the aluminum; the copper in the composition will aid this.

The decomposition of the aluminum is an alkaline reaction; this will produce heat and gas. A buffer of boric acid could be added. However, my question is, WHY add metal at all to the blue? It only weakens the color and will make it appear paler.

It can also raise the temperature of the blue star and cause it to go into the green range. Clean cooler burning fuels such as shellac and lactose also contribute to beautiful colors.

Chemical Formulary Blue Star

Component	Parts by Weight
Potassium chlorate	5
Paris green	3
Cupric chloride	1
Shellac	1

Bleser Blue Star

Component	Parts
Potassium chlorate	65%
Copper oxychloride	12%
Lactose	5%
HCB [hexachlorobenzene]	5%
Dextrin	5%

Potassium Perchlorate Blues

Considered the safest of the blue star compositions, it is also considered the weakest of them. Aluminum and magnalium is added to perchlorate star compositions to get blue electric stars. These metals are reasonably safe in perchlorate compositions. This is a good place for novice pyrotechnicians to start. The additions of flame enhancers will help with perchlorate stars. Perchlorate stars are harder to light.

Shimizu 216 Blue Star

Component	Parts
Potassium perchlorate	60.8%
Accroides resin	9.0%
Basic copper carbonate	12.3%
Parlon	13.1%
Rice starch [soluble glutinous]	4.8%

Robert Veline WCPB Blue

Component	Parts
Potassium perchlorate	55%
Cupric oxide	15%
Parlon	15%
Red gum	9%
Magnalium 50:50 -200mesh	6%
Dextrin	4+

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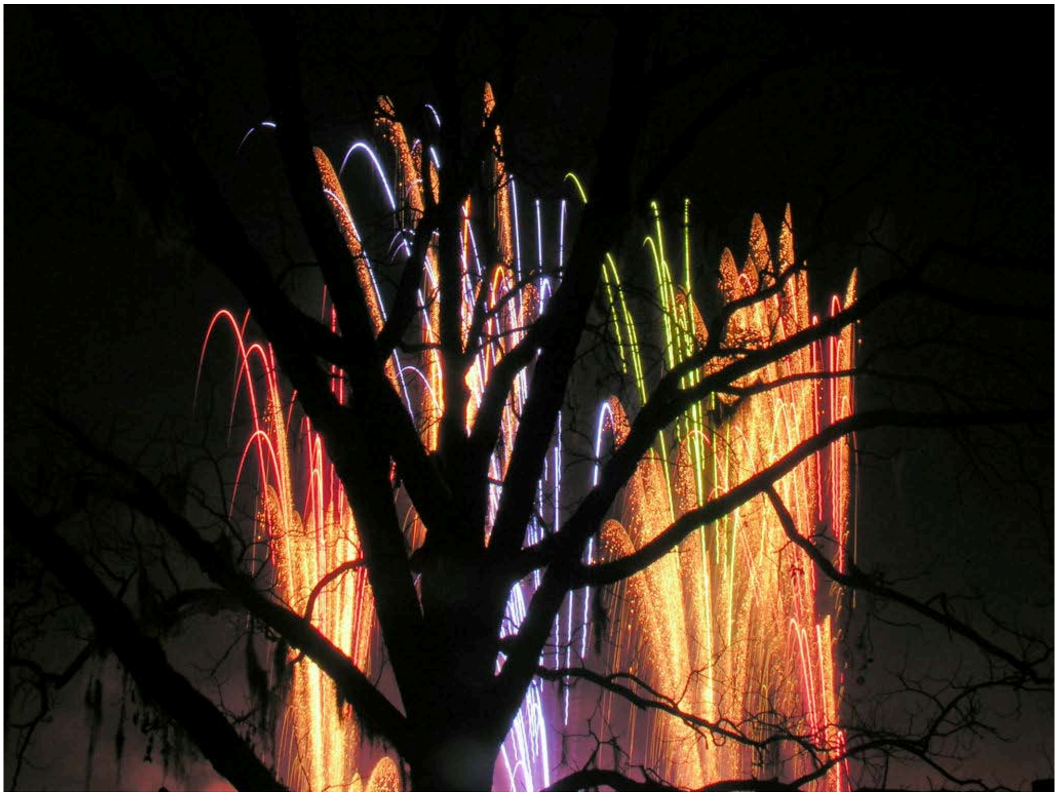
The Blues, Part 3



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Materials Needed

- Alcohol
- Ammonium perchlorate (CH5000)
- Barium chlorate(CH5505)
- Barium nitrate (CH5102)
- Chlorowax (CH8075)
- Copper benzoate (CH8085)
- Copper carbonate (CH8087)
- Copper gluconate
- Copper oxide, black (CH8096)
- Copper oxychloride (CH8098)

- Cupric chloride (CH8091)
- Dextrin (CH8107)
- Gum arabic (CH8131)
- HCB (hexachlorobenzene)
- Hexamine (CH8142)
- Lactose (CH8169)
- Magnalium 50/50, 200 mesh (CH2072, CH273)
- Paris green
- Parlon (CH8210)
- Potassium benzoate (CH8219)
- Potassium chlorate (CH5200)
- Potassium perchlorate (CH5402)
- Red gum (CH8230)
- Rosin
- Saran (CH8248)
- Shellac (CH8255)
- Stearic acid (CH8298)

"ee-roh ah-OH-ee"–Japanese for the Color Blue

By Lin Collins

In the endless pursuit for the very best blue star color available, we consumed a large quantity of time and firework chemicals. I have seen what I perceived to be very good blue color stars. But trying to make them is not easy. I will share the results with you. After hearing a great deal about Paris green as a blue firework chemical colorant, we decided to test this opinion.

#1, 2 Davis, Page 85

Component	Parts
Potassium chlorate	48
Barium nitrate	16
Paris green	18
Shellac	10
Dextrin	3

#3 Weingart

Component	Parts
Potassium chlorate	50
Paris green	25
Stearin (or stearic acid)	8
Dextrin	5

#4 Lancaster

Component	Parts
Potassium chlorate	70
Paris green	20
Shellac	10
Alcohol only	

#5 Paris Green and Copper Blue

Component	Parts
Potassium chlorate	50
Paris green	30
Cupric chloride	10
Shellac	10
Dextrin	5

#6 Box Star

Component	Parts
Potassium chlorate	4
Barium nitrate	4
Barium chlorate	8
Paris green	5
Stearin	1
Shellac	1
Dextrin	1

#7 Allen, Page 11

Component	Parts
Potassium chlorate	24
Paris green	16
Red gum	16
Dextrin	3

8 Allen

Component	Parts
Potassium chlorate	24
Paris green	16
Red gum	16
Dextrin	3

#9, Omitted

#10 Paris Green Blue

Component	Parts
Potassium chlorate	68
Paris green	22
Shellac	6
Dextrin	4

#11 AP Blue

Component	Parts
Ammonium perchlorate	82
Copper benzoate	18

Results

#1 Light blue star, medium burn speed and slight residue.

#2 Was Weingart's pg. 132, same as #1.

#3 Would not light; think the stearin is too high.

#4 Very nice blue star, fast burn, no residue.

#5 Nice blue star that has red at flame edge, with light carbon residue.

#6 Very nice turquoise star with medium speed, Parlon residue.

#7 Red flame no good, heavy carbon residue.

#8 Same as above.

#9 Omitted

#10 Very nice blue star, clean burning.

11 Very good blue star, medium speed, clean burning.

Note: #6 burned too hot and went into green but it could be cooled down with lactose.

Keep in mind if you choose to use these firework chemicals for your stars: Work in small quantities. Start with 10 gram batches. Always wear a respirator and gloves. Keep all tools clean. Never add finely divided aluminum to chlorate. Copper acetoarsenite (Paris green) was used in all of the tests. It does contain arsenic. Also you must see two blue stars together to judge the best color. Side by side, there is no better blue firework chemical than Paris green in my opinion.

Doc Barr's Blue Rocket

Doc posted a message to the PML concerning a good blue sky rocket pyrotechnic formula.

Component	Parts
Copper gluconate	40
Potassium perchlorate	55
Parlon	5

Doc's quoted source: Craig Villenueva

Pyroesoterica: "Rhapsody in Blue"
Observations of Some Published Blue Pyrotechnic Formulas

Producing a viable blue star with good depth of color has always been challenging for the firework builder and many pyrotechnic formulas have been published over the years. To compare the relative effectiveness of some of these recipes (as well as a few unpublished ones), 16 different, 500-gram samples were worked up and tested at FPAG shoots.

Data from these experiments along with subjective comments and source information follow herein, but the reader is asked to bear in mind that the focus was on producing stars for aerial artillery shell use only and consequently some of the mixtures regarded here as failures might still find useful application in other firework articles.

B1

Component	Parts
Potassium perchlorate	55
Black copper oxide	15
Parlon	15
Red gum	9
Magnalium 50/50, 200 mesh	6
Dextrin	+4

From R. Veline in J. Baechle's "Pyrocolor Harmony." Good ignition, a whitish, "washed out" blue characteristic of most metal fuel blues. A Useable pyrotechnic formula, but it’s clearly inferior in saturation to other pyrotechnic formulas.

B2

Component	Parts
Potassium perchlorate	60.8
Parlon	13.0
Copper carbonate	12.0
Red gum	9.0
Dextrin	4.8

"Morning Glory Blue", from R. Pimentel in J. Finckbone s "Green Notes," Vol. 1, Issue #3

Good ignition, another perchlorate-based star composition with better color than B1 that's probably cheaper also. Useable.

B3

A "sugar" blue star containing potassium chlorate, copper oxychloride, and lactose, plus some small amounts of chlorine-donor, resin fuel, and dextrin. This proprietary pyrotechnic formula was given to the author with the request that it remain unpublished so exact component percentages cannot be listed here. Readers can nevertheless glean enough information from the description for design evaluation.

Good ignition. A chlorate composition using the classic low-temperature carbohydrate fuel system. Superior in color saturation to both B1 and B2 and one of the three-best tested non-ammonium perchlorate star compositions.

B4

Component	Parts
Potassium perchlorate	67
Copper oxychloride	12
Stearin	12
Chlorowax	5
Dextrin	4

"Cyan Blue" From J. Baechle's "Pyrocolor Harmony." Poor ignition. Color saturation was mediocre at best. This is a substandard pyrotechnic formula.

B5

Component	Parts
Potassium chlorate	64
Copper oxychloride	18
Stearin	8
HCB (hexachlorobenzene)	6
Dextrin	4

This is from A. Anzalone and modified by J. Finckbone in "Green Notes" Vol. 1, Issue #2. Good ignition. This is a chlorate-based star composition. This takes advantage of HCB's higher fuel value and superior flame deoxidizing capacity. Color saturation was as good as B3...perhaps slightly better.

It is one of three-best tested non-ammonium perchlorate star compositions. Substitution of the now difficult-to-obtain HCB is possible but should be carefully done in order to avoid adversely affecting ignition and burn rate.

B6

A chlorate-based blue star containing black copper oxide, Parlon, red gum, and dextrin. This is another proprietary pyrotechnic formula "on loan" to the author that must remain unpublished. Good ignition. Somewhat brighter than the other non-metal blue stars. Color saturation was acceptable, but inferior to either B3 or B5.

B7

Component	Parts
Potassium chlorate	68
Copper oxychloride	12
HCB	10
Rosin	6
Dextrin	4

A blue candle star modified by J. Baechle in the old "American Pyrotechnist" publication, originally from Lancaster. Good ignition. This chlorate composition equaled or surpassed both B3 and B5 in color saturation and may have been the best non-ammonium perchlorate star pyrotechnic formula tested. Again, HCB can possibly be substituted for with a watchful eye toward ignition and burn rate.

B8

Component	Parts
Potassium chlorate	60.0
Copper carbonate	13.0
Lactose	17.5
HCB	5.0
Stearin	0.5
Dextrin	4.0

Another "sugar" blue star, this one comes from Dave Mayotte in PGI bulletin #47. Good ignition, color saturation from this chlorate/carbonate/carbohydrate mix was almost identical to B1 although it contained no metal fuels. This is an inferior color pyrotechnic formula.

B9

Component	Parts
Potassium perchlorate	66.1
Black copper oxide	13.4
Parlon	10.7
Red gum	9.8
Dextrin	5.0

T. Shimizu's B48 from Pyrotechnica #6. (With dextrin substituted for rice starch.) Good ignition. A perchlorate star composition with a long burn time in relation to other blues tested. Color saturation was inferior and deemed unacceptable.

B10

Component	Parts
Potassium perchlorate	38
Ammonium perchlorate	29
Copper carbonate	14
Red gum	14
Dextrin	5

This formula is from "Chemistry of the Elements" and reprinted in D. Haarmann's "Pyrotechnic Formulary" and the Aug. 1993 First Fire. Good ignition. This potassium-perchlorate augmented ammonium perchlorate star composition was in the minority of tested ammonium perchlorate pyrotechnic formulas in regards to ignition. Color saturation was very good and burn rate was acceptable. This is a good pyrotechnic formula.

B11

Component	Parts
Ammonium perchlorate	48
Hexamine	14
Copper oxychloride	12
Copper sulfate	6
Dextrin	6
Gum arabic	1

"Winokur Blue" from R. Winokur in APFN pg. 506 and reprinted in D. Haarmann's "Pyrotechnic Formulary." Poor ignition. This ammonium perchlorate-only/hexamine star composition was unique among tested ammonium perchlorate pyrotechnic formulas in that its color saturation was poor. Bad ignition and bad color make this star composition fairly useless.

B12

Component	Parts
Ammonium perchlorate	74.2
Copper dust	11.1
Stearin	11.1
Chlorowax	3.7
Dextrin	+5.0

H. Ellern's "Ashless Blue" #79 reprinted in Haarmann's "Pyrotechnic Formulary" and modified by the author by substituting Chlorowax for paraffin and adding dextrin. Good ignition and burn rate. This ammonium perchlorate-only star composition was also the only pyrotechnic formula tested using elemental copper. Color saturation was good.

B13

Component	Parts
Potassium perchlorate	40
Ammonium perchlorate	30
Copper carbonate	14
Red gum	7
Hexamine	6
Dextrin	4

This formula is from J. Baechle's "Pyrocolor Harmony" pg. 31. Poor ignition. This ammonium perchlorate-potassium perchlorate combination yielded good color saturation and OK burn rate, but its inability to take fire with standard priming techniques makes it an unacceptable star choice.

B14

Component	Parts
Ammonium perchlorate	68
Hexamine	17
Copper carbonate	11
Dextrin	4

From D. Bleser's "Round Stars and Shells." Poor ignition. Again, a formula with good color and OK burn rate that was unable to take fire from normal priming. This is an impractical pyrotechnic formula.

B15

Component	Parts
Ammonium perchlorate	40.0
Potassium perchlorate	20.0
Copper oxychloride	16.0
Red gum	8.0
Potassium benzoate	6.0
Hexamine	5.0
Parlon	2.5
Saran	2.5
Dextrin	+4.0

This formula is from S. Majdali in the Aug. 1993 First Fire. Poor ignition. This complicated star mix generated ammonia gas upon dampening but did not heat up. Burn rate was OK and color saturation was very good but as with most other ammonium perchlorate pyrotechnic formulas its inability to take fire from ordinary priming renders it impractical.

B16

Component	Parts
Ammonium perchlorate	82
Copper benzoate	18
Dextrin	+5

D. Bleser's blue from AFN #64, Jan. 1987 modified with dextrin binder. Good ignition. A simple, but effective, star composition employing a single entity fuel/color donor. Color saturation was very good, as was burn rate. One of only three useable ammonium perchlorate star compositions tested, its primary disadvantage may be the limited availability of copper(II) benzoate.

Since the goal of the experiment was to gain ground in the search for a better, practical blue star, all star compositions were dampened with water, cut, and tumbled in prime. No special solvents or multistage priming techniques were employed.

All potassium chlorate and potassium perchlorate were formed into 1/2" cubes and primed with mealed pulverone while ammonium perchlorate star compositions were formed into 3/8" cubes and primed with a potassium perchlorate-based meal to avoid chemical incompatibilities with the dampened ammonium salt. Copper acetoarsenite (Paris green) was omitted from testing due to its cost and limited availability.

When designing or selecting a blue pyrotechnic formula, careful consideration should be given to flame temperature and fuel/oxidizer primary systems. It is well known that reds, greens, and yellows benefit in both brilliance and saturation from hotter flames since SrCl(g), BaCl(g), and ionic Na (the respective spectral emitters) are stable at metal-fueled temperatures (while most of the interfering ions are not!). CuCl(g), however, is the preferred ionic blue emitter, is destroyed by such high temperatures and the flame is whitened.

Saturation is always sacrificed for brilliance and vice-versa when creating the pyrotechnic blue flame. Choosing a cooler burning fuel/oxidizer primary system will generally yield better color saturation, all other factors being equal. Below is a list of the most commonly used fuels and their relative temperature groupings:

Coolest

- Sulfur
- Stearin
- Charcoal
- Gilsonite
- All carbohydrates, (for example, lactose, sucrose)

Hotter

Hexamine

All organic gums, (for example, red gum, rosin colophony, shellac, Vinsol)

Hottest

The metals, (for example, magnesium, aluminum, magnalium, titanium, antimony, antimony salts)

The primary system must not be cooled (slowed) so far that the burn rate becomes inadequate, however.

These tests also showed that hexamine, while enlarging flame size with no apparent spectral interference, clearly inhibited ignition in ammonium perchlorate star compositions. Of seven such pyrotechnic formulas tested, all four containing hexamine exhibited very poor ignition while the three without it ignited well. No tests using hexamine with potassium chlorate or potassium perchlorate compositions were done, but future experiments are planned.

Only distilled water was used during this experiment, as should be the case with all aqueous processing systems. This avoids potential pH problems and undesirable ionic contamination. Copper and copper salts are prone to strange reactions in the wet state, and these reactions may be accelerated in the presence of metal fuels and extreme pH.

It must be remembered that copper, a component in many batteries, is multi-valent and capable of electrolytic reactions. Lancaster opined in the early 1970 s that copper salts should never be dampened in the presence of metal fuels. Experimental results and a recent accident with such a mix support this position.

The author feels that metal fuels have no place in blue pyrotechnic formulas since they invariably degrade color saturation while increasing the rise of composition heat-up and premature ignition. An exception might be where thrust is desired (as in the case of go-getters) but in this situation, a waterless system of organic solvents is used. Even here, however, unpleasant reactions have occurred and caution is advised.

One possible avenue of experimentation toward improving the safety of aqueous system blue star compositions might be to choose copper salts with the lowest relative solubility. The author knows of no such data currently available with respect to this concept, but a partial list of solubility of the most commonly used copper salts is presented here for the reader's evaluation. Available copper expressed as molecular percentage is also included.

Salt	**Solubility**	**% Copper**
Copper metal	Insoluble	100.00
Copper oxide	Insoluble	79.88
Copper oxychloride	Insoluble	59.51
Copper carbonate	Insoluble	57.47
Copper acetoarsenite	Insoluble	25.07
Copper(I) chloride	Very Slightly Sol.	64.18
Copper(II) fluoride	Slightly Soluble	62.58
Copper(II) benzoate dihydrate	Slightly Soluble	20.78
Copper sulfate pentahydrate	Very Soluble	39.81

The blue star designer is cautioned that lower solubility may make a star composition safer but not safe as surface electrolytic activity can occur with any copper entity in the wet state. Empirical research will surely continue in the never-ending quest for a better blue and it is hoped the experimental data and theories presented here will assist future color designers. -Lin Collins

Recommended Reading

To learn more about more pyrotechnic formulas for making blue stars read these:

- Shimizu, T. 1980. Studies on Blues and Purple Flame Compositions made with Potassium Perchlorate. Issue VI, Pyrotechnica: Occasional Papers in Pyrotechnics, Austin, Texas.
- Baechle, J. 1989. Pyrocolor Harmony, A Designer s Guide. Jamestown, North Dakota.
- Kosanke, K.L. 1981. The Physics, Chemistry, and Perception of Colored Flames. Issue VII, Pyrotechnica: Occasional Papers in Pyrotechnics, Austin, Texas.

Copper Benzoate Formulas for Stars

By Harry Gilliam

Two formulas for stars using the copper benzoate to make blue.

Materials Needed

- Ammonium perchlorate (CH5005)
- Copper benzoate (CH8085)
- Dextrin (CH8107)
- Hexamine (CH8142)
- Magnalium, 200-400 mesh
- Nitrocellulose lacquer (CH8198)
- Strontium carbonate (CH8310)

Copper benzoate is a great blue star coloring agent. Only problem is that copper benzoate is has not been produced commercially in the US. Consequently pyros who wanted to use it used to have to manufacture it themselves.

We have found a guy who produces a little of it and managed to snag a few pounds. It's probably a lot less hassle to buy a pound or two of copper benzoate than to mess with making it yourself, if all you need is a little bit or if you just want to experiment with it.

Here are a couple of copper benzoate color star formulas from Best of AFN II, from the articles "A New Blue" and "New Electric Purple". See the articles for in-depth discussions. All parts are by weight.

New Blue Formula

Component	Parts by Weight
Ammonium perchlorate	82%
Copper benzoate	18%
Bind with 1% nitrocellulose and make pumped or cut stars	

New Electric Purple

Component	Weight
Ammonium perchlorate	68
Copper benzoate	8
Strontium carbonate	12
Magnalium, 200-400 mesh	5
Hexamine	7
Dextrin	+4%

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Copper Powder Formulas for Green and Blue

By Harry Gilliam

Pyrotechnic formulas that use copper powder for various firework devices including stars and strobe pots.

Materials Needed

- Ammonium perchlorate (CH5005)
- Ammonium sulfate
- Barium nitrate (CH85102, CH85101)
- Calomel
- Charcoal, airfloat (CH8068)
- Copper, atomized, 40-100 mesh (CH8081)
- Copper oxide, black (CH8096)
- Copper oxychloride (CH8098)
- Dextrin (CH8107)
- Fimo [PVC "clay"]
- Gilsonite (CH8120)
- Guanidine nitrate (CH5515)
- Hexachlorobenzene
- Lead chloride
- Magnalium, -200 mesh (CH2072)
- Magnesium
- PVC (CH8216)
- Paraffin
- Paris green
- Parlon (CH8210)
- Potassium perchlorate (CH5400, CH5402)
- Red gum (CH8230, CH8231)

- Rice starch (CH8238)
- Saran (CH8248)
- Shellac (CH8255)
- Stearic acid (CH8298)
- Strontium carbonate (CH8310)
- Strontium nitrate (CH5543)
- Sulfur (CH8315)
- Tetramethylammonium nitrate

Here are some new angles on making blue, green, and other stars using copper powder. Through the years I've collect some interesting star pyrotechnic formulas, which you can see below. But even more interesting are the green star pyrotechnic formulas.

Particularly interesting to me were the blue fireworks star and strobe pot pyrotechnic formulas developed by Clive Jennings-White some years ago. According to Clive's article, it appears the atomized powder we sell is particularly well suited to the strobe applications. He reports that finer, or flake copper powders do not strobe as well in his pyrotechnic formulas.

A number of these pyrotechnic formulas listed below are dated. That is, they use ingredients you will not readily find today. But I am listing them anyway, because there are some pretty capable pyros who'll know how to make substitutions for the old ingredients, no longer manufactured or in widespread use in fireworks. And then, there are some older pyros still hoarding little stashes of Paris green, calomel, and so on.

So, in the interests of spreading copper powder into more mainstream use, here are a slew of copper powder-based recipes. One caveat: I have not tested or seen any of these, so you're on you're own. Don't bother writing to us and asking about missing information, like binder, solvent, and so on. We don't have any more info than what you see below.

Blue, Purple, Turquoise, and Black Star and Strobe Formulas

Unless otherwise stated, all parts are by weight. They may or may not total 100.

Blue Stars: Credited to Shimizu

Component	Parts by Weight
Potassium perchlorate	75.1%
Red gum	11.5%
Copper	9.6%
Parlon	3.8%
SGRS (rice starch)	+5%

Purple Stars: Credited to Shimizu

Component	Parts by Weight
Potassium perchlorate	70%
Red gum	5%
Copper	6%
PVC	10%
Strontium carbonate	9%
Starch (rice or dextrin)	+5%

Rolled Blue Stars from rec.pyro (in part)

Component	Parts by Weight
Potassium perchlorate	36
Sulfur	3
Red gum	3
Shellac	8
Copper	6
Parlon	4

Blue Strobe Pot Formula No. 1 (Clive Jennings-White, Pyrotechnica XIV)

Component	Parts by Weight
Ammonium perchlorate	50
Ammonium sulfate	25
Magnalium, 100-200 mesh	20
Copper, atomized, 40-100 mesh	5

Blue Strobe Pot Formula No. 4 (Clive Jennings-White, Pyrotechnica XIV)

Component	Parts by Weight
Ammonium perchlorate	25
Guanidine nitrate	55
Copper, atomized, -100 mesh	20

Blue Strobe Star Formula No. 2 (Clive Jennings-White, Pyrotechnica XIV)

Component	Parts by Weight
Ammonium perchlorate	40
Ammonium sulfate	10
Guanidine nitrate	25
Magnalium, 100-200 mesh	15
Copper, atomized, -100 mesh	10

Blue Strobe Star Formula No. 5 (Clive Jennings-White, Pyrotechnica XIV)

Component	Parts by Weight
Ammonium perchlorate	55
Tetramethylammonium nitrate	30
Copper, atomized, 40-100 mesh	15

Turquoise Strobe Formula (Clive Jennings-White, Pyrotechnica XIV)

Component	Parts by Weight
Ammonium perchlorate	25
Barium nitrate	25
Guanidine nitrate	25
Magnalium, 100-200 mesh	20
Copper, atomized, -100 mesh	5

Purple Strobe Formula (Clive Jennings-White, Pyrotechnica XIV)

Component	Parts by Weight
Ammonium perchlorate	55
Strontium nitrate	5
Tetramethylammonium nitrate	28
Copper, atomized, -100 mesh	5

"Black" Strobe Formula (Clive Jennings-White, Pyrotechnica XIV)

Component	Parts by Weight
Ammonium perchlorate	30
Tetramethylammonium nitrate	40
Copper, atomized, -100 mesh	30

There is a great deal more information about Clive's pyrotechnic formulas above in Pyrotechnica XIV (BK0114), Blue Strobe Light Compositions. Russ X derived the next pyrotechnic formula from Jennings-White's.

Blue Strobe Cut Stars, from Russ X

Component	Parts by Weight
Ammonium perchlorate	25
Guanidine nitrate	55
Copper, atomized, -100 mesh	7.5
Copper oxide, black	5
PVC, suspension grade	7.5

Russ's notes: "Bind with nitrocellulose lacquer, enough to bind them together, but not enough for them to be tacky. Copper powder is used in the best blue strobe pyrotechnic formula in Pyrotechnica XIV (BK0114).

Playing with this as a base, I have lifted shells that contained blue strobe stars. I cut them into 1/4 - 3/8" cubes, then 'roll' them in a bowl to consolidate them. As you roll them in the bowl, they become denser and take on a round profile.

A light misting of 1:1 MEK/lacquer thinner is sometimes needed to keep the surface from drying out too fast. You have to be gentle when you start rolling these stars so that they don't crumble. For some reason, the crumbs don't like to reconsolidate into stars that will strobe.

I prime them with a thermitic perchlorate prime (superprime) after they have dried for a couple of days. The issue with making this on a regular basis is the guanidine nitrate availability and the pain of cutting the stars and then rolling them to consolidate them."

Copper Powder Blue #2

Component	Parts by Weight
Ammonium perchlorate	74.2%
Copper dust	11.1%
Stearin [stearic acid?]	11.1%
Paraffin	3.7%

Blue Torch, Allen

Component	Parts by Weight
Potassium perchlorate	50
Barium nitrate	30
Charcoal	5
Paris green	4
Copper dust	6
Copper oxychloride	1
Lead chloride	8
Calomel	4

John Driver's Blue (from a PGI Bulletin)

Component	Parts by Weight
Potassium perchlorate	50%
Copper powder	30%
Parlon	16%
Saran	4%

From Christian Brechbuehler - June 15 1993

Component	Parts by Weight
Potassium perchlorate	70
Fimo [PVC "clay"]	20
Copper	10

Green

Component	Parts by Weight
Potassium nitrate	15
Sulfur	2
Airfloat charcoal	1
Copper powder	1
Red gum	1
Dextrin	1

Copper Formulas from the Pyrotechnic Formulary

Finally, here are several of the more useable pyrotechnic formulas from Donald Haarmann’s Pyrotechnic Formulary (BK0078). This incidentally is what the Formulary is great for: finding pyrotechnic formulas to match a set of ingredients.

Green Stars (from Experiments in Developing Green Star Formulas)

Component	Parts by Weight
Magnesium	1.8 pts
Barium nitrate	5.8 pts
Copper	0.5 pts
Parlon	1.5 pts

Component	Parts by Weight
Magnesium	1.0 pts
Barium nitrate	5.8 pts
Copper	1.3 pts
Parlon	1.7 pts

Component	Parts by Weight
Magnesium	1.8 pts
Barium nitrate	5.8 pts
Copper	0.5 pts
Parlon	1.5 pts
Gilsonite	0.2 pts

Flare Green, MC241

Component	Parts
Magnesium	23%
Barium nitrate	53%
Copper	2%
Hexachlorobenzene	20%
Gilsonite	2%

“Tom’s Tree” Series: 11/7/2009, Florida Fall Fireworks Festival

Large Reloadable Glitter Comets

By Ned Gorski

Introduction

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

In Fireworks Tips #111, How to Make Gold Glitter Comets I described the process of making relatively small, single-shot gold-glitter comets. These were designed to be fired out of a star gun or a small mortar, with the black powder lift charge preloaded into the bottom of the mortar, and a piece of visco fuse inserted into the bottom of the gun.

In this article I want to take that process one step further, and show how to make reloadable comets, similar in construction to festival-ball and aerial fireworks shells. This construction technique allows the comets to be easily and quickly loaded and fired, and reloaded as desired.

I'll show you how to construct 1.5-inch, 3-inch, and 4-inch comets. The smaller ones can be fired out of a typical 1.75-inch festival-ball shell mortar PL3170. The 3-inchers can be fired out of a 3-inch mortar PL3183, and the 4-inchers out of a 4-inch gun PL3184.

Warning: Fireworks devices such as comets and standard aerial shells are only safely fired out of mortars constructed of paper, fiberglass, or HDPE plastic. Never fire these devices out of improvised and unsafe mortars constructed of PVC pipe or materials other than those listed above.

The 3-inch comets actually measure 2.5 inches OD, and the 4-inch ones measure 3.5 inches OD. The 1.5-inch comets do measure 1.5 inches OD, and are to be fired out of a mortar between 1.75 and 2 inches ID.

There is perhaps no simpler a device than a comet, but a beautiful gold-glitter one never fails to catch the crowd's attention and impress them. The smaller ones described here are perfect for that backyard, consumer-type fireworks display, and the larger ones can fill the sky during any large, professional-type show.

There are also simple, fast-burning charcoal compositions, which can be used for this type of comet. They leave a bushy, orange spark trail while ascending into the sky.

Gold Glitter Comet Composition

In this particular project, I'll be using the D1 Gold-Glitter composition that was demonstrated in the article cited above. If you've been following along with the articles this year, the procedure for mixing up a comp like this will sound very familiar.

To determine how much of this composition to mix up, I need to plan the comets that I am about to make. Each size comet, if it is pressed with the hydraulic press, uses the following amount of the dampened composition:

Size of Comet vs. Amount of Composition

1.5-inch diameter, 1.5 inches long	2.75 ounces
2.5-inch diameter, 2.5 inches long	12 ounces
3.5-inch diameter, 3.5 inches long	32 ounces

Note: The 2.5 and 3.5-inch comets have to be pressed with a hydraulic press in order to achieve dense consolidation of the composition. The 1.5-inch comets can be hand rammed using a pounding-post and mallet, or they can be pressed hydraulically.

If they are hand rammed though, only 2.25 ounces of composition will be able to be consolidated into a 1.5-inch long comet. Hand ramming simply will not achieve quite the density that a press can.

I plan on making four of the 1.5 inchers, and one each of the larger ones. So, I need to make 55 ounces of the damp composition. I will be adding 5% (2.75 ounces) of water to the comp to dampen it, so I'll actually end up with 57.75 ounces of the damp composition. This is 2.75 ounces more than I need for my planned comets, so I think I'll simply press one extra of the 1.5 inchers rather than complicate the math involved. It never hurts to have an extra comet.

In the small glitter comet article I described starting with a black powder meal base. This time I'll start with the individual raw chemicals, which works just about as well.

D1 Gold Glitter Formula

Component	Percentage	55 ounce batch
Potassium nitrate	0.53	29.15 ounces
Sulfur	0.18	9.9 ounces
Charcoal, airfloat	0.11	6.05 ounces
Aluminum, atomized, 325 mesh	0.07	3.85 ounces
Sodium bicarbonate	0.07	3.85 ounces
Dextrin	0.04	2.2 ounces

I weigh each chemical out individually, and make sure each one, except the metal, will pass through the 100-mesh screen. If it won't, I'll grind it in the coffee grinder until it will all pass through the screen. I never put metals through the fine screens.

A coffee grinder is used to mill individual chemicals only, and once it has been used for an oxidizer such as the potassium nitrate, it is never used for a fuel such as the charcoal. A separate grinder is used for fuels.

The chemicals are all added to a plastic tub and shaken to mix them. Then the mix is passed three times through a 20-mesh kitchen colander and mixed once again in the tub.

At this point, I weigh the mixed composition to make sure its weight comes up to the desired 55 ounces. This step ensures that I weighed each component correctly, and that I didn't leave anything out. I can't tell you how many mistakes, and the resulting poorly-performing devices, this step can avoid. In actuality the total composition weight is typically a tenth ounce or so lighter than the total I was shooting for, due to some loss to airborne dust from the lighter components like charcoal.

2.75 ounces of water is added to the mix and it is all shaken in the tub again. Then it is passed through the colander again to completely integrate the water. One final shaking in the pail completes the preparation of the composition.

Pressing Comets

As I said, the 1.5-inch comets can be either hand-rammed or pressed in a small hydraulic press. I weigh out either 2.25 ounces of the composition, for hand-ramming, or 2.75 ounces for pressing. The comp is poured into the comet pump sleeve and the comet is either rammed or pressed.

Hand-Ramming and Hydraulic Pressing 1.5-Inch Glitter Comets

The same is done for the 2.5-inch and 3.5-inch comets; comets of these sizes must be pressed hydraulically.

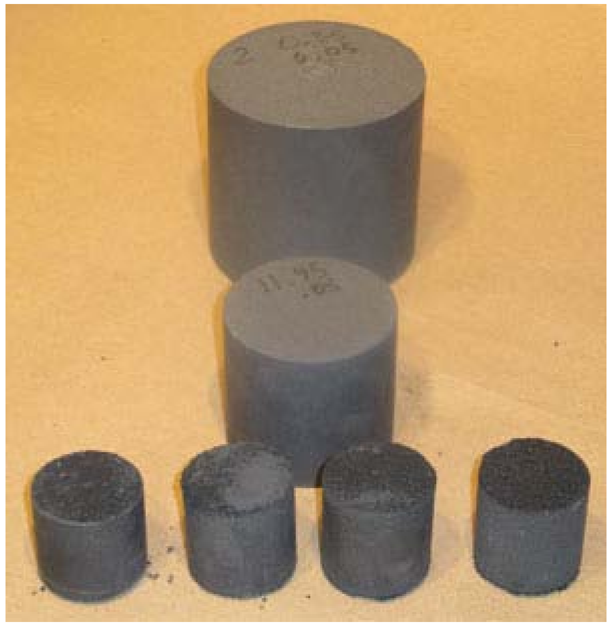
Pressing 2.5-Inch and 3.5-Inch Glitter Comets

When using the press, I apply about 5000 pounds of force on the1.5-inch comet pump, which amounts to about 3000 psi on the composition.

With the larger pumps, I'll apply about 10,000 pounds of force, which applies about 2000 psi on the comp in the 2.5-inch pump, and about 1000 psi on the comp in the 3.5-inch one. This is enough pressure if I allow the press to "dwell" for a minute or two on the pump, slowly compressing the comet, while I regularly pump the pressure back up.

One of the things I really love about this glitter composition is that once it has been pressed, it forms a rock-solid comet. This also makes the comets a bit difficult to extract from the pumps once they have been pressed (no problem extracting a hand-rammed comet, though). A comet extraction-sleeve can make this final process much easier. The sleeve is simply a hollow cylinder that the pump sits in the top of, and into which the comet is pushed with the press.

Using an Extraction-Sleeve to Push a Comet Out of the Pump



1.5-Inch, 2.5-Inch, and 3.5-Inch Gold Glitter Comets

Drying the Comets

Since these comets only contain 5% water, they come out of the pump relatively dry, and pieces of them can actually be lit and tossed even before they are dried.

But, because they contain potassium nitrate, fine aluminum, and sodium bicarbonate, there can be unwanted chemical reactions if they are allowed to get too hot before they dry a bit. So, I air dry them in the shade for a few days before they are put into the drying chamber for a few more days to complete the drying process.

You can notice on the tops of the two large comets in the photo above that I've written their weights with a Sharpie marker. I did this immediately after pressing them, and then once a day as they dry. Once their weight equals 0.95 of the original weight, I know all the water is gone and they are completely dry.

Priming the Comets

You can also see in the photo that the 1.5-inch comets have been primed, per the instructions in Fireworks Tips #111. I do prime both ends of these comets, rather than only one end, which I did in the original article because the comets could be used as rising tails on shells. Priming both ends ensures that the flame propagates quickly to the whole comet's surface when it is ignited.

Priming Comets

Finishing the Comets

In Fireworks Tips #114, Making Mines, I illustrated a simple "piston" which is used to propel all the mine-stars out of the mortar at one time and straight up into the sky.

I'll use a similar piston under each of these comets.

"Why," you might ask.

Often, when you see a large comet shot out of a mortar you'll see some small, lit fragments come out of the mouth of the gun with the main comet, or else you might see the whole comet split into two or three pieces, ruining its effect.

I envision these defects to be the result of the impact of the initial blast from the black powder lift hitting the bottom of the comet, possibly chipping the bottom edges off of it, combined with the comet twisting as it is propelled up the mortar. In that case, the comet is wedged in the mortar, and suffers damage due to those stresses. All of this, of course, occurs in a matter of milliseconds.

To prevent such damage, and to get the comet out of the gun in one piece, I employ the piston. This is made out of two cardboard discs, with a hole in the center of each, and a length of cardboard tube glued between them. The discs and tube are the same OD as the comet, and the tube is about that same distance long.

None of these dimensions is extremely critical, though. While I like to have the discs the same diameter as the comet, the tube can be a bit smaller or larger and the tube can be a bit shorter than the comet's OD. This ain't rocket science. It's comet science!

Unlike the pistons I showed in the article on making mines, with these comet pistons I only put one hole in the center of each disc to allow fire to get to the comet easily. I also only use the one, large tube, instead of the two tubes used in the mine pistons.

Cardboard Pistons Sized to Be Used Under Each Size Comet

I prepare black powder lift bags, and insert quick match leaders, once again as described in the mines article. The amount of lift for each comet size is as follows:

- 1.5-inch comet 0.3 ounce of FFg or FFFg sporting black powder
- 3-inch comet 0.75 ounce 2FA black powder
- 4-inch comet 1.5 ounces 2FA black powder

Black Powder Lift Charge, Baggie, and Quick Match Fuse Leader

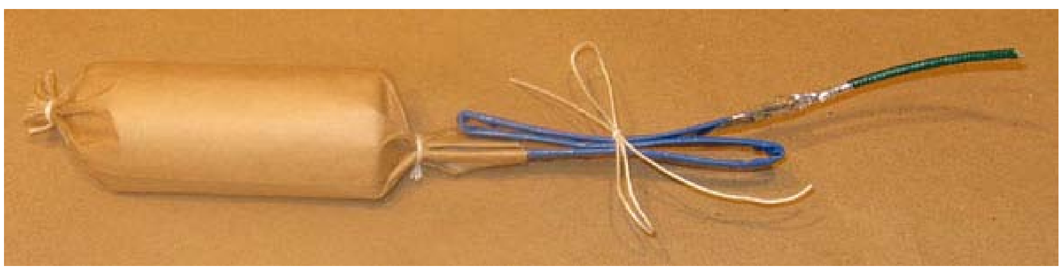
For the quick match fuse leader, commercial quick match, homemade quick match, or fast-fuse wrapped with aluminum foil duct tape may be used.

The lift charge and leader, the piston, and the comet are then wrapped up in two turns of kraft paper, which is glued to itself. The ends of this wrapper are then tied closed with clove hitches, and the excess paper is trimmed from the bottom. The size of paper for each size comet is:

- 1.5-inch 8x11
- 3-inch 11x18
- 4-inch 16x25

Kraft Paper Wrapping the Comet, Piston, and Lift Charge

Visco fuse is installed into the quick match leader and taped in place. The leader is then S-folded and tied to keep it neat until the comet is loaded into a mortar.



Finished 1.5-Inch Gold Glitter Comet

Results

Here's a photo of one of the 1.5-inch comets in flight. If you click on it you can see a video of it in action.

1.5-Inch Gold Glitter Comet Ascending

(Click Image to Play Video)

The second comet in the video is made with a slightly different formula I came up with by modifying and combining a couple of other formulae. It burns a bit more slowly (yes, the comet did burn out before it hit the ground) and the tail is a longer, slightly more delayed glitter, which sparks like a Senko Hanabi sparkler. I've labeled this glitter formula N1.

You can see that one of the advantages of this formula is that with a longer burn time, comets made with it can be pumped about 2/3 as long as their diameter (The comet in the video was 1.5 inches long, which I'd shorten to 1 inch next time). So, it's a bit more economical to make and use.

N1 Gold Glitter Formula

Component	Percentage	55 ounce batch
Potassium nitrate	0.51	28.05 ounces
Sulfur	0.15	8.25 ounces
Charcoal, airfloat	0.10	5.5 ounces
Aluminum, atomized, 325 mesh	0.08	4.4 ounces
Sodium bicarbonate	0.12	6.6 ounces
Dextrin	0.04	2.2 ounces

Try both formulas and see what you think. I will say that when one of the two-pound, 4-inch D1 babies is fired, it's hard to take your eyes off of it. Very impressive, indeed!

So, you have your homework. Two formulas to play with and three different sizes to make.

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Gold Glitter Comets for Standalone Comets or Rising Tails on Shells

By Ned Gorski

Materials List

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

- Comet Pump or Plate
- Black Powder Meal
- Aluminum, atomized (CH0105)
- Antimony Trisulfide (CH8010 or CH8011)
- Sodium Oxalate (CH8280)
- Dextrin (CH8107)
- Sulfur (CH8315)
- Sodium Bicarbonate (CH8275)
- Potassium Nitrate (CH5301)
- Charcoal, airfloat (CH8068)Screen, 100 mesh
- Rawhide Mallet (TL4100)
- Star Gun (TL4030)
- Titanium, spherical

Introduction

One of my favorite effects is a nice gold glitter comet. This is also one of the easiest and most impressive beginner pyro projects. Make some homemade black powder and one of these simple projectiles, and you are ready to impress the folks around you. And you made it all yourself!

This is also the simplest and most effective rising effect to put on my aerial fireworks shells. The shell is launched out of the mortar and leaves a beautiful glittering gold tail as it ascends skyward. Just as the comet tail burns out, the shell bursts. The rising effect effectively doubles the display time of the shell, and fills the sky all the way from the ground to the starburst. A tail also helps to point the spectators' eyes at the exact spot where the shell is about to break.

Some master rocketeers put these comets on top of their rocket headings. The comet is ignited at the same time as the rocket, and leaves a beautiful glitter tail as the rocket ascends. I'll be detailing this method in a future newsletter article.

It is also very easy to pop a bunch of these little comets out using a half-inch star-plate, and put them into a small ball shell like the 4-inch plastic shells we built in Fireworks Tips #99. The combination of some color stars and these glitter comets makes a beautiful starburst.

Note: The difference between stars and comets is a subtle one. Typically comets are fired individually, and stars are shot out of a device in a cluster.

I have a favorite gold glitter formula which I have been using for years in both stand-alone comets and as shell tails. Anytime I fire something made with this formula someone is sure to ask me what it was and how they can make it, too. This glitter is a slightly modified version of the Gold Twinklers found in Ofca's Mastering Cut Stars, and in Weingart's Pyrotechnics.

This formula is relatively expensive though because of the chemicals it uses. There is a much less expensive gold glitter formulation which does not use chemicals which cost as much, but which also produces a beautiful effect. This glitter is a slightly modified version of one called D1.

I'll be using both of these formulae in this project.

The Comet Pump

Besides the formulated glitter compound, one tool is essential for pumping comets: the comet pump.

Star Plate and a Variety of Comet Pumps

The black individual comet pump and star plate shown in the photo are treated aluminum. The other pumps shown are aluminum, brass, and homemade, PVC-pipe-and-wood pumps.

It's simple and inexpensive to make a 3/4-inch or 1-inch homemade comet pump as shown above. Start by going to Home Depot and getting the correct size oak dowel, a length of the corresponding size of PVC plumbing pipe, and 3 hose clamps which fit the outside of the pipe. (You can buy ready-made comet pumps from Skylighter. Skylighter pumps are rugged brass or aluminum and will typically last a lifetime. They are faster and easier to use than homemade comet pumps.)

Then cut a 6-inch length of the dowel, and a 5-inch length of the pipe, preferably with either a hand miter box or a power one to insure good, square cuts.

Using a hacksaw, slice about halfway up one side of the pipe, and remove enough of that slice of pipe so that it fits the dowel snugly at the sliced end when the gap is closed.

Sand the rough edges of the pipe and dowel, and make sure one end of the dowel is nice and square and smooth. Either seal this end with polyurethane, or cover it with a disc of aluminum-foil duct tape.

Making a Homemade Comet Pump

Mixing the Comet Composition

The Gold Twinkler formula is as follows:

Component	Percentage	Ounces
Black powder meal	0.68	5 ounces
Atomized aluminum	0.08	0.6 ounces (I'm using Skylighter #CH0103)
Antimony trisulfide	0.08	0.6 ounces (either dark-pyro or chinese-needle)
Sodium oxalate	0.11	0.8 ounces
Dextrin	0.05	0.4 ounces
Total batch weight:		7.4 ounces

The D1 formula is:

Component	Percentage	Ounces
Black powder meal	0.71	5 ounces
Sulfur	0.11	0.8 ounces
Atomized aluminum	0.07	0.5 ounces
Sodium bicarbonate	0.07	0.5 ounces
Dextrin	0.04	0.3 ounces
Total batch weight:		7.1 ounces

I'm planning on making one batch of each formula to compare with each other. Therefore I need a total of 10 ounces of the homemade, black powder meal. This will include:

- 7.5 ounces of potassium nitrate
- 1.5 ounces of airfloat charcoal
- 1 ounce of sulfur

To make the BP meal, I screen the potassium nitrate through a 100 mesh screen, and then screen all the chemicals together twice through the same screen to thoroughly mix them together.

Then I add 1/2 cup of denatured alcohol to the dry chemicals to form a damp ball of putty, which I screen through my 1/4-inch screen onto kraft paper to dry overnight.

Note: Alcohol fumes are combustible. I dry these granules outdoors to prevent the fumes from collecting and igniting.

Mixing Black Powder Chemicals through 100 Mesh Screen, and Granulating Dampened Composition through 4 Mesh Screen

When the black powder granules are dry, I screen them again through a 12 mesh screen or a wire-mesh kitchen colander. I then have a black powder meal which ranges from fine dust up through 12 mesh granules.

To complete the compositions, I split my meal powder batch into two, 5 ounce halves. I then weigh out the rest of my individual ingredients. I don't screen the aluminum or antimony trisulfide, but I do screen the rest of the ingredients for each batch through my 100 mesh screen.

Then I put all the ingredients for each batch into a plastic tub, attach the lid, and shake vigorously to thoroughly mix the ingredients.

Using a small, trigger-operated garden spray-bottle, I add just enough water to knock the dust down and start to make the composition not quite as free-flowing. I work the water into the powder with gloved hands and by capping the plastic tub and shaking it. Each batch took 0.35 ounces of the water, which is about 5% by weight.

Note: It is a good idea to used bottled, distilled water to dampen compositions containing aluminum and potassium nitrate. This helps to prevent reactions between the two chemicals. One person's tap water might be fine to use, and another's might cause problems.

Ramming Glitter Comets

Now it's time to make some comets. I place my comet pump sleeve on my aluminum ramming puck after making sure that the hose clamps are tightened. I place a funnel in the mouth of the sleeve and introduce a weighed amount of the glitter composition into the sleeve.

Then I put the comet pump ram into the sleeve, place the whole shebang on my 6x6x36 ramming post, and I whack the ram with 8-12 blows with my rawhide mallet. At a certain point, the comet will start to feel solidly consolidated.

It's just a matter of slightly loosening the hose clamps, and gently ejecting the comets from the pump sleeve with the ram. I then dry them for a couple of days in a well ventilated, warm area, or overnight in my drying chamber.

Ramming a Glitter Comet

One of the things I want to record is how much composition it takes to form different length comets with the 3/4-inch and the 1-inch pumps. Those results are as follows for both formulae:

1-inch Comets

Weight	Length
0.4 ounce	1/2-inch long
0.5 ounce	5/8-inch long
0.6 ounce	3/4-inch long
0.7 ounce	1-inch long

3/4-inch comets

Weight	Length
0.2 ounce	7/16-inch long
0.3 ounce	5/8-inch long
0.35 ounce	3/4-inch long
0.4 ounce	13/16-inch long

3/4-inch and 1-inch Diameter Comets of Various Lengths

For stand alone comets, I'll press them as long as they are in diameter. For rising shell tails, I'll press them long enough so that they burn out just as the shell breaks (duration of shell timing fuse). I'll be determining the burn time of each length comet in a minute.

Priming the Comets

Many folks would say that these comets do not need any priming because they are mostly made of BP meal, which ignites very well all on its own. But, often pumped stars and comets have a very smooth surface, and I've learned the hard way to avoid assuming they'll light without priming. They might, and they might not. So I prime everything.

Scratch Mix BP Prime Formula

Component	Percentage	Ounces
Potassium nitrate	0.75	7.5 ounces
Airfloat charcoal	0.15	1.5 ounces
Sulfur	0.10	1 ounce
Dextrin	+0.05	0.5 ounce
Total batch weight:		10.5 ounces

I screen the potassium nitrate through the 100 mesh screen, and then screen all the chemicals together through the 100 mesh screen twice to thoroughly incorporate them. Then I put them into a plastic tub, with a lid, and shake them a bit to really mix them well.

Depending on how many comets I plan on priming, I'll take a few tablespoons-full of the dry prime comp, put it in a paper cup, and add enough water to make a thick syrup, like honey. After stirring this a bit with a wooden stick, I use a brush to coat one end of each comet. Then I dunk that end into some FFg sporting grade black powder, or some more of the homemade black powder meal. What I want is a rough, granular surface that will more easily take fire.

I allow the primed comets to dry overnight outdoors, or for a couple of hours in the drying box.

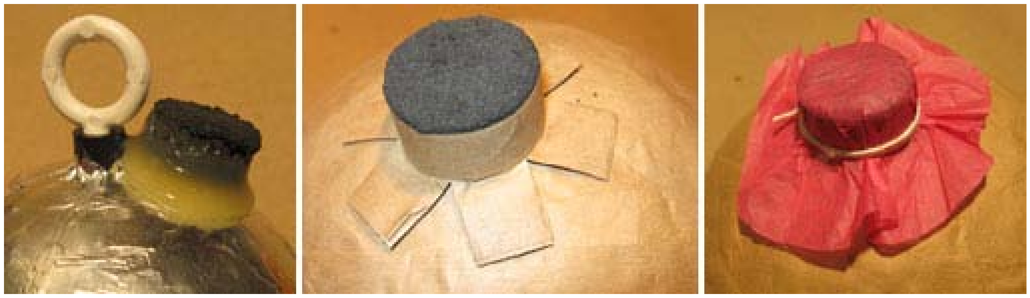
Priming Glitter Comets

Installing the Comets on an Aerial Shell or Rocket Header

It is easy to hot-glue one of these comets onto a plastic or paper shell or header. Just put a healthy blob of the glue onto the bottom of the comet, and press it onto the device. Then apply more glue which laps up onto the side of the comet, and helps hold it in place during lift.

A more traditional way of installing rising tails on paper ball shells is to wrap the comet with a couple of turns of thin pasted kraft paper or moistened gummed tape. Have half of the strip lap onto the side of the comet, and half hanging off the bottom of it. Slice the overhang paper with scissors about every half inch and fold out the tabs. Apply Elmer's or wood glue to the bottom of the comet and to the tabs, and press in place on the top of the shell.

I like to cover the shell's rising tail with a disc of tissue paper, tied on with a bit of string. This dresses the shell up, and keeps the comet's prime layer from rubbing against anything during transport. These comet tails will ignite when the shell's lift gasses flow around them before the shell leaves the mortar.



Attaching Comet to a Aerial Shell for Rising Tail Effect

Test Firing the Two Different Gold Glitter Comets

To test fire the 3/4-inch and 1-inch comets made with the two different formulae, I shot them out of a star gun which has 7/8-inch and 1-1/8-inch tubes. I also tested some of the 1-inch comets out of a small paper mortar made with base #PL3002 and tube #TU2123.

Mortar and Star Gun Used to Test-Fire Glitter Comets

Using commercial FFFg black powder, I had to use a flat 1/4 teaspoonful for the 3/4-inch comets, and a flat 1/2 teaspoonful for the one-inchers.

With my homemade red-gum granulated BP, I had to use a heaping 1/4 teaspoonful, and a heaping 1/2 teaspoonful respectively.

I installed 3-inches of visco fuse, the BP lift powder, and then dropped the comets in. If I was making these babies for a display, and they were going to be boxed and transported, I'd use a layer of tissue paper between the comet and the BP, and a layer of tissue pressed in above the comet to hold everything in place until firing.

Test Results

Both of the formulae resulted in beautiful comets, and the one-inchers would make a very nice addition to any display. I have to say I like the Gold Twinkler a bit better than the D1. The Gold Twinkler creates very golden, long hanging, large glitter, whereas the D1's glitter is a bit paler, and does not hang quite as long.

But either one is very beautiful and the economics of the D1 formula make it quite attractive to produce.

In order to have a rising tail on a shell that lasts as long as the shell's ascent before burst, I measured the burn times of various lengths of comets with the star gun and a stopwatch. I wrapped the comets with aluminum foil duct tape to simulate the amount of the comet surface that would be exposed and burning if it was attached to a shell.

Foil-Tape-Wrapped Comet Ready to be Fired and Timed

The burn times were as follows, along with the size of the shell to use them on:

Shell Size	Timing	Length
3-inch to 6-inch shells	2.5 to 3 seconds	1/2-inch long
8-inch to 10-inch shells	4.3 seconds	5/8-inch long
8-inch to 10-inch shells	4.5 seconds	3/4-inch long
10-inch shells	5 seconds	1-inch long

For tails on 12-inch shells, I'd use 1.25-inch to 1.5-inch long comets. Shell rising comet tails can vary from 3/4-inch to 2.5-inch in diameter or larger, depending on the size of the shell.

Conclusion

The one thing I'd add about these beautiful gold glitter comets is that my wife, Molly, who is not passionate about fireworks--especially really loud ones--has always loved gold glitter effects. That's reason enough for me to use a lot of gold glitter in my fireworking.

Bonus Round

It is easy to make a brilliant silver titanium spark comet using the methods described above.

Component	Percentage	Ounces
Black powder meal	0.68	5 ounces
Spherical titanium	0.27	2 ounces
Dextrin	0.05	0.4 ounces
Total batch weight:		7.4 ounces

Fine Ti will give a short, bushy tail. Coarse Ti will produce a longer tail filled with larger sparks. These titanium comets produce an effect which contrasts nicely with the glitter ones.

How to Make Yellow Glitter Stars

Materials Needed

- Airfloat charcoal
- Aluminum (12-20 micron, atomized)
- Antimony trisulfide, Chinese Needle
- Dextrin
- Potassium nitrate (CH5300)
- Sodium bicarbonate or Sodium oxalate
- Sulfur (CH8315)

Glitter is that Silver Part at the Bottom of the Brochade Shells
Photo Courtesy of Tom Handel

This is a gold brocade shell. Glitter is hard to depict in slow-shutter-speed fireworks photographs, but you can get an idea of what silver glitter might look like in the sky if you enlarged the picture above.

Here's a good recipe from Bob Winokur for making yellow glitter. Bob wrote the greatest treatise on making glitter stars and comets in Pyrotechnica 2. It's probably the most complete study of glitter stars ever done. This article ran in the August 1992 issue of the First Fire, the Florida Pyrotechnic Arts Guild's excellent newsletter. Thanks to FPAG for letting us use this, and Chris Miller, wherever you are, for writing it.

Yellow Glitter

By Chris Miller-WPA

I originally got this formula from Dr. Winokur a few years ago as a universal (good for all occasions), "state of the art" yellow glitter. It has a long delay and can be used in any sized star, from 1/4" t o 3." Stars 5/8" and smaller tend towards the "glitter cloud" effect and are great in shells by themselves or mixed with color stars in a volume ratio of 3:1 or 4:1 (color:glitter). Stars 3/4" and larger leave long, beautiful tails and are particularly suitable as either regular comets or crossettes.

Assuming the ingredients are lump-free, sieve the mix three times through a 20-mesh screen (window screen works fine) and bind with 8% water. This isn't a lot of water so one should knead it for several minutes to insure that the water is well incorporated. Because of the antimony sulfide, I wear a respirator when mixing the dry ingredients and latex gloves when adding the water (I'm told antimony poisoning is akin to lead or barium poisoning-very unpleasant and I don't want to find this out first hand!)

Priming is not required although some people like to prime them when going for the cloud effect. It is also a good idea to lightly prime the exposed face of crossettes made with this formula because there is a lot less exposed ignition area on a crossette compared to a regular comet of the same size. Priming is cheap insurance against one or two of them being blown blind and diminishing the symmetry of the break (not to mention wasting all that labor that goes into making each crossette that didn't work).

Yellow Glitter Formula

Component	Parts by Weight
Potassium perchlorate	48
Airfloat charcoal	9
Sulfur	11
Aluminum (12-20 micron, atomized)	9
Antimony trisulfide, Chinese needle	10
Sodium bicarbonate or sodium oxalate	9
Dextrin	4

How to Roll Better Round Stars

By John Vico

Learn a technique for rolling round stars in a large bowl. This is another wonderful jewel, which I lifted right out of the Pyrotechnic Mailing List. John Vico wrote it and graciously gave us permission to reprint it here. If you're just learning to make fireworks, and/or you're new to rolling stars, read this. It is a huge help.

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Materials Needed

- Star composition
- Large bowl
- Lead shot
- Mister
- Needle
- Plastic gloves

- Powder can
- Spatula

I would like to offer a few tips for starting round stars:

Many of you are using small amounts of material which does in fact make it more difficult.

So be it, but adapt accordingly. My best "bowls"... an aluminum wok and/or its cover.

Use tiny heavy star cores i.e. #7 lead shot. (I never found the initial clay coating to help. It's just an extra step.) Millet, rape seed, acini di pepe (pasta) are all good second choices but save them until you've got the technique a little practiced.

Never thought of using the silver candy toppings but they seem a little big. You'd be better off researching how they are made and adapt the technique to star cores for those bright little color flashes at the center of a nice charcoal star.

A small spray mister is essential. The best one is the small cosmetic type that fits easily in the palm of one hand and sprays a minimal amount of perfume (in our case solvent) from a single downward pump of the button. Aim well; hit the star cores not the pan, roll fast in a small area of the pan.

Shake the star composition in from a baby powder can or the like. Again aim well, small amounts. Some of the plastic cans that allow you to squeeze out a "puff" of powder are ideal.

A minimal build up of powder on the bottom of the bowl is okay especially if your bowl is very smooth which causes the stars to slide more than roll especially when you are first starting the cores. Add small amounts of dry star composition until no more cores pick up star composition when working in a small area of the pan then shift the star cores to another area of the pan and keep them rolling.

If everything is right you should be able to stop briefly without the star cores sticking together badly, otherwise add a little more star composition. Roll fast and add another spritz on the star cores from the mister. Keep going fast for equal coating and to keep them from sticking together.

Don't be in a hurry to add star composition: it encourages the raspberries. Too much moisture? Then work a larger area of the pan to get rid of some but when your are ready to add star composition try and stay in a small area then move out as things get coated.

"Toro paste" is available on the bottom of your bowl in one of the areas where star composition has stuck to it. Work the stars out to an area where everything is good and they are not sticking to each other. Stop and with good aim spray the stuck star composition.

Work it with your gloved fingertip into syrup, especially around the edges of the stuck star composition. Roll fast again and pass the stars through this area. They should pick up the syrup nicely and be ready for a little dusting of dry star composition. If they are sticking together roll and bump really fast and add a little more star composition on a "virgin" area of your bowl.

In general roll fast and hard when stars are wet and sticky. Bump if needed. If you really get too much star composition stuck to the bowl, scrape with a spatula and use it to make cut stars.

Size the stars frequently on hardware cloth returning the ones that pass through to the bowl. If you get a clump of stars that you really want to save, the best way to separate them is with the point of a needle. Good luck.

These tips are for starting small amounts of small star cores. As things grow, so does the technique and tools. That's when the machines are most helpful.

Firefly Stars

Learn what the firefly aluminum star effect is and how to make it using several different pyrotechnic formulas.

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Materials Needed

- Charcoal, 36 mesh (CH8064)
- Charcoal, 80 mesh (CH8066)
- Charcoal, airfloat (CH8068)
- Dextrin (CH8107)
- Firefly aluminum (CH0150, CH0148)
- Potassium nitrate (CH5300)
- Red gum (CH8230, CH8231)
- Sulfur (CH8315)

What is the firefly aluminum effect? Firefly is an interesting effect. It is also called a "transformation star." It is generally a star or a comet whose effect consists of variations of charcoal orange (even red) mixed with twinkling silver flashes.

The description "transformation" comes from the tendency of some firefly aluminum stars to begin as one color (orange from charcoal) and then to "transform" into twinkling silver. This delayed action ignition of the firefly aluminum powder is caused by the firefly aluminum powder particles being so large that it takes them awhile to get going.

Here is a typical firefly aluminum star formula, the one you get in each container of firefly aluminum powder from Skylighter. This one originally came to us from Steve Majdali, and has since been slightly modified a couple of times, after input from Bill Sharpe and others.

By the way, it was also Steve who initially "discovered" the Transmet K102 firefly aluminum powder and introduced it to others and us in the pyro community. K102 firefly aluminum powder is so coarse that when several experienced pyros first looked at it, they opined it was too coarse to be useful in stars. But, of course, it is this large particle size that actually does make it work. All parts by weight:

Basic Firefly Star Composition

By Bill Kimbrough, as told to Harry Gilliam

Component	**Parts**
Potassium nitrate	49
Airfloat charcoal	29
80 mesh charcoal	11
Sulfur	9
Firefly aluminum	5
Dextrin	To taste
Dampen with water or water and alcohol.	

Solving one firefly problem: There are many, many different firefly star formulas and differing visual effects, but my personal favorite is the one invented by Bill Kimbrough, which everyone now calls "Flaming Shit." Bill shined a light on a problem he was having making these stars. Let me share it with you all.

Here's an edited version of his recent emails to me. He had made 50 lbs. of firefly stars recently and they had eventually crumbled apart, making them useless. He had also heard of others having similar problems making firefly. (I have only lightly edited Bill's scratchings, as I wish to preserve forever the historical import of what he wrote for posterity.) –HG

Bill wrote:

"On the subject of the pH of potassium nitrate, I found that my (locally bought) technical crystal nitrate has a pH of 5. Due to the logarithmic scale of pH, that means that it is 10 times more acidic than 6 and of course 10 times more acidic than 7.

I measured the pH of what is the normal nitrate I use, and it came out to be right on the dot 7 (good news). I tried to neutralize the acidic nitrate, and added 1% potassium bicarbonate, which turned out to be a little too much, as the resulting pH ended at 8, but a good start. Now if I can only figure out what logarithmic means.

I have had a lot of discussion in years past about reacting compositions, mostly centered around flaming shit stars. I thought then, and now I believe that I have the direct evidence that the problem was and is the nitrate. Litmus paper is really not adequate, and a good broad range paper is needed. --WAK"

Now the implication of this is clear: if the potassium nitrate you are using in your firefly stars is too acidic, over time (sometimes a very SHORT time) your nitrate is probably going to attack the aluminum powder and cause it to oxidize. Your stars will kind of fluff up, and come apart, and get crumbly. So, if you are using potassium nitrate other than Skylighter CH5300, you may want to check its pH. This goes for any the off-spec stuff you get from us and agricultural grades you may have acquired.

But I suspect using acidic potassium nitrate may not be a problem if you’re just using it to make plain ole black powder. Not to worry.

Here's another firefly recipe. Back in 1996, when Skylighter first started peddling firefly-aluminum, some folks were experimenting with it and having problems. In October 1996, LN published this recipe for firefly stars on the Pyrotechnic Mailing List (PML). He writes:

"I have used the following firefly star composition (all parts by weight) and obtained excellent results in mines.

Firefly Cut Stars

Component	Parts
Potassium nitrate	49
Airfloat charcoal	29
Sulfur	9
Dextrin	10
36 mesh charcoal	11
Firefly aluminum	5

I ball mill the potassium nitrate, air float charcoal, sulfur and dextrin together for 1 hour. I then add the 36 mesh charcoal and firefly aluminum powder and mix with a spoon. I add water to make a dough-like mix and cut with a knife into 3/8-inch cut stars. I separate the stars and dry for 3-4 days.

The effect is a long tiger tail going up and firefly aluminum sparkles coming down. The original formula made stars that were too brittle. The extra dextrin in this mix makes stars that are nice little bricks. If you make larger stars it takes longer to dry. A damp star produces very little firefly aluminum effect."

LN also elaborated in a note to me later, explaining that his formula was an adaptation of the Majdali formula and telling why he uses so much dextrin in his formula:

"I also use your (Majdali) formula with your 36 mesh charcoal and I use 10 parts dextrin instead of 5. This makes a much harder star that can hold up to a hard lift charge. I roll into 0.480-inch round stars for 1/2-inch Roman Candles. The effect is super."

But some folks were not able to make their formulas work–the firefly effect wasn't happening. So Mike S. wrote this message to the PML:

"The firefly effect results from the synthesis of aluminum carbide and its combustion in the air. A simple test is to use your firefly aluminum powder in a mix like the following. Burn a loose heap on a tile - and while it's still glowing, but not flaming, flick some into the air with a piece of flat metal. You will see those pesky little fireflies come to life.

Component	Parts
Potassium nitrate, 200 mesh	65
Red gum, 100 mesh	30
Firefly aluminum	5

Sieve the nitrate and red gum well before blending in the firefly aluminum powder. If Harry's firefly aluminum powder still has problems, then use a bright-waxed fine flake of known identity. Please tell us your source and batch number or other identifying information. Thanks..."

Flaming Shit Firefly Star

By Bill Kimbrough

Learn how to make stars using a firefly aluminum powder pyrotechnic formula.

Materials Needed

- Barium carbonate (CH8025)
- Magnalium, 30 mesh (CH2060, CH2061)
- Pine Charcoal
- Potassium nitrate (CH5300)
- Starpol (CH8297)
- Sulfur (CH8315)

Bill Kimbrough developed the recipe for this firefly aluminum star a few years ago. The effect is sort of like a rich silver twinkling kind of like a firefly, but surrounded by really red glowing embers. Not charcoal orange, but more red than that. The silver and red together are incredible. This is truly a noble star.

If all goes well, and everything burns up where it's supposed to, this effect is called "Fireflies on Cocaine." If not the star is accurately called "Flaming Shit Falls on You."

Here are a couple of notes. All parts below are parts by weight; it doesn't matter what they add up to. The pine charcoal is critical. Without it, you don't get the true Flaming Shit firefly aluminum star.

Kimbrough's Fireflies on Cocaine (or Flaming Shit Falls on You)

Component	Parts by Weight
Potassium perchlorate	46
Pine charcoal	44
Sulfur	6
Magnalium, 30 mesh	10
Barium carbonate	6
Starpol	4.5

I like to take the pine charcoal as it comes out of the yard grinder, and put it in the ball mill for 10 minutes. Sift out (remove) what doesn't fall through a window screen, and just use the mixed granulation of the charcoal--Better charcoal effect. I mostly roll mine with Starpol as a binder, but I have made the formula into comets, stars, and even tried it in lances. Pump, cut or rolled stars, worked good for me, but never use Starpol as the binder if it is to be the outside of a color change star, as it will surely cause a moisture problem.

How to Make Break Mix for Crossette Comets

By Harry Gilliam

Learn how to combine black powder and flash powder to make the break charge for your crossette comets.

Materials Needed

- Black powder
- Crossette comet
- Flash powder

I recently came by some fine-grained Goex black powder, around FFg or finer. A pyro friend and I were hashing over what the stuff could be used for, and he told me about a great crossette comet break mix which uses fine-grained black powder and flash powder. If you're unfamiliar with crossette comets, they are comets that, after rising or igniting, are seen to split into several pieces in the sky.

They can be constructed so that they split into either a precise number of pieces or into a random number of pieces. The comets are made with a cavity in their center. The cavity is then filled or partially filled with an explosive charge (the "break"). As the comets burn, the fire eventually reaches this center charge and splits the comets into their pieces, creating the crossette effect.

My friend uses a break charge that is a mix of flash powder and fine black powder, 10 parts flash to 8 parts fine grained black powder (7FA or FFFFg or something in between). The reason for the black powder in the charge is to add some "fluff" to the flash powder. I have heard of people adding bran, sawdust, rice hulls, Cab-O-Sil, and other such agents to flash powder to aerate it, and thus speed up the burn/explosion, but this is the first time I had ever heard of black powder being used. Makes sense when you think about it. Back powder will burn quickly, the other agents won't.

My friend told me that this break mix works so well in his 1-1/4 inch crossette comets that he only uses about half of the volume of a .22-short caliber shell casing! The cavity in the comet is perhaps 3/8-inch diameter by 1/2 inch deep. (The best instructions I have seen for making crossettes can be found in the Fulcanelli article in Pyrotechnica IX, (BK0111)).

Veline Color Stars System

Learn a basic color system used to make various stars using a number of different firework chemicals.

Robert Veline developed this color stars formula system years ago. This very efficient star color system uses magnesium-aluminum throughout. These are bright stars, though not as bright as magnesium-based electric stars.

"Tom's Tree" Series: 11/7/2009, Florida Fall Fireworks Festival

Materials Needed

- Barium carbonate (CH8025)
- Barium nitrate(CH5101, CH5102)
- Calcium carbonate (CH8052)
- Charcoal, airfloat (CH8068)
- Copper oxide, black(CH8096)
- Dextrin (CH8107)
- Iron oxide, red (CH8168)

- Magnalium (50/50 -200 mesh) (CH2072, CH2073)
- Parlon (CH8210)
- Potassium dichromate (CH5525)
- Potassium perchlorate (CH5400, CH5402)
- Red gum (CH8230 CH231)
- Strontium carbonate (CH8310)
- Wood meal (CH8335)

Robert Veline created this fireworks star system and intentionally put it in the public domain. When you look at it, you can see that it uses very similar firework chemical ingredients and proportions for many of the different fireworks star colors, making this an extremely versatile fireworks star color set; you can create any color you want using only ten firework chemicals!

When you look at the part called "Now the Fun Stuff" you can even see how to mix an almost limitless palette of fireworks star colors by mixing the different primary fireworks star colors shown in the table. A word to the wise: These fireworks star colors are well balanced in terms of color brightness and intensity. So, Veline's fireworks star colors seem to appear most pleasing when they are used with each other in any given device (artillery shell, mine, etc.). Here's the original paper published by Veline, but formatted slightly differently.

A Compatible Fireworks Star Formula System for Color Mixing

By Robert Veline

Component	Red	Orange	Green	Blue	Super Prime
Strontium carbonate	15				
Calcium carbonate		15			
Barium carbonate			15		
Copper oxide, black				15	
Barium nitrate			24		
Potassium perchlorate	55	55	30	55	55
Parlon	15	15	15	15	
Red gum	9	9	5	9	
Magnalium (50/50, -200 mesh)	6	6	11	6	5
Dextrin	+4	+4	+4	+4	+4
Charcoal, airfloat					20
Wood meal, -70 mesh					6
Iron oxide, red					5
Potassium dichromate					5

A Few Notes about These Fireworks Star Formulas

The numbers are in percent by weight. The potassium perchlorate is a fine powder. The Parlon was Hercules brand, but Superchlon brand from Ishihara Co. Ltd. also works. Nothing special about the red gum, just fine powder. The best barium and strontium carbonates are obtained from Barium and Chemicals of Steubenville Ohio.

The calcium carbonate was -200 mesh 'Whiting'. Copper carbonate may be used rather than black copper oxide without much change in performance. I have tried finer more pure forms and found they have slowed the burn rate, and degraded the fireworks star color... Note that all of the proportions are the same for the different fireworks star colors, the exception being the green.

The idea is to have as many characteristics - burn rate, brightness, flame size, color purity, and density of powder - common between the different powders as is possible. While these formulas do not excel in any one characteristic, they are all part of a matched set. The green: I was unable to get a suitable green fireworks star for this family without using barium nitrate. So, in order to compensate for the reduced oxidizing ability of the nitrate, a more energetic fuel mixture was used.

Now the Fun Stuff

Color	Red	Orange	Green	Blue
Yellow		45	55	
Chartreuse		20	80	
Aqua			80	20
Turquoise			55	45
Magenta	50			50
Maroon	85			15
Peach	25	60		15
Purple	15	5		80

Well, that's it! These stars are the results of a couple of years of hard work, they are offered as some form of repayment to the many people who published information which I have feasted on all these years. THANK YOU!!!!

–Robert Veline II