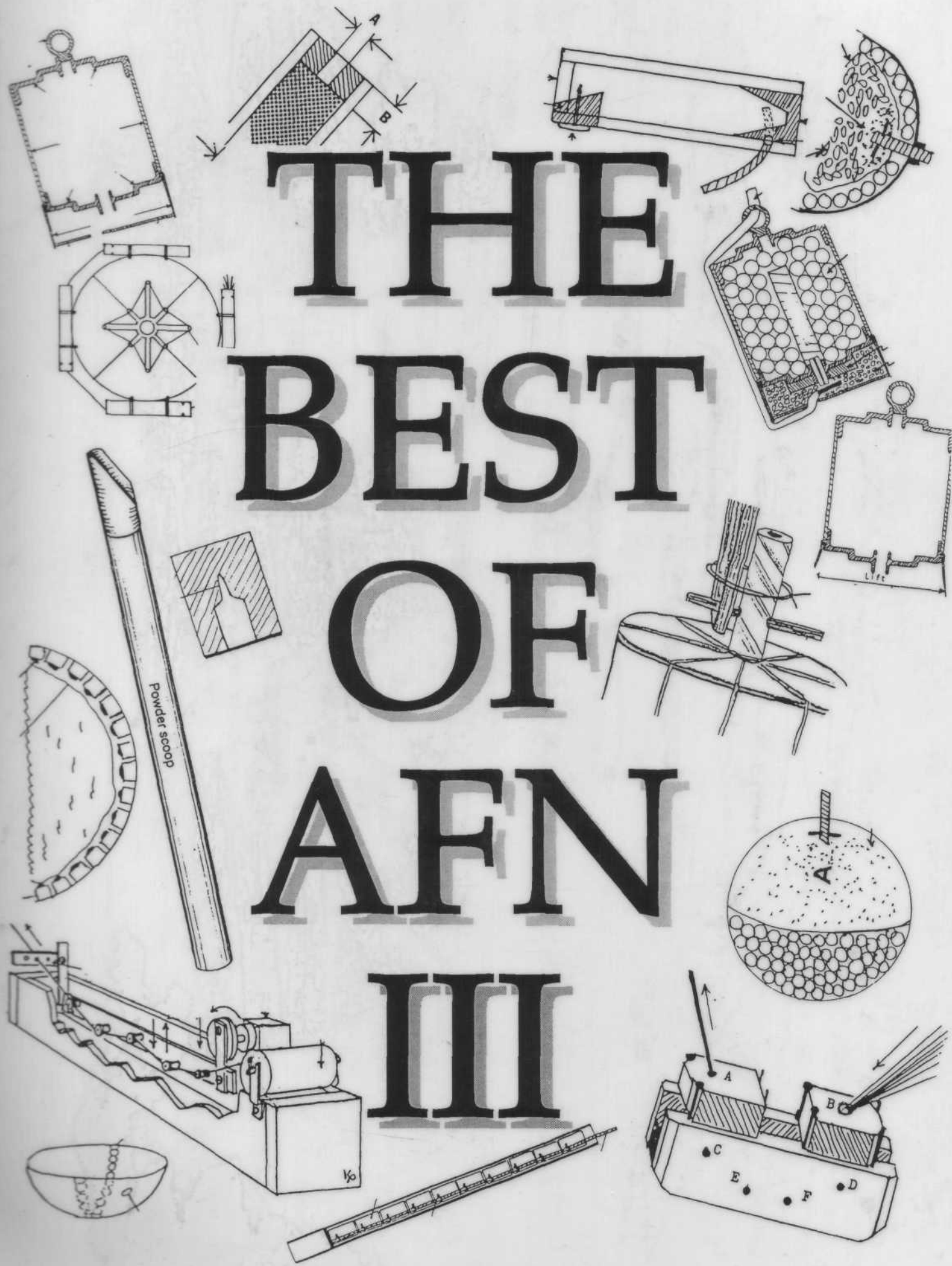


# THE BEST OF AFN III



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Edited by Jack & Dorothy Drewes



*American Fireworks News*



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***Warning:* This publication contains descriptions and pictures of fireworks. The information contained herein is based on the authors' experiences using specific tools and ingredients under specific conditions not necessarily described in the articles. No warranties are made, given or implied. Readers are cautioned that they must form their own opinion as to the application of any information contained herein.**

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## PREFACE TO THE THIRD VOLUME

Number Three of *The Best of AFN* series offers the reader all the how-it-is-done articles that appeared in *American Fireworks News* between May, 1990 and April, 1995. It also includes a few rocket articles from Max Vander Horck's old *American Pyrotechnist*. It gives us great personal satisfaction to be able to put these wonderful articles inside one set of covers and make the great mass of fine fireworks literature available to our many readers who have come onboard since 1990. Of course, very few of these articles would be available except for the willingness of our writers to share their hard work and fireworks insight with the rest of us. Over fifty writers contributed to this volume. Without their contributions, the fireworks hobby would still be stuck in the Weingart era.

In addition to those fifty writers, we are indebted to the newsletters of: Connecticut Pyrotechnics Association, New Hampshire Pyrotechnics Association, Florida Pyrotechnic Arts Guild, and Fred Olsen's *Lights in the Sky*; all first published some of the articles in this book.

It is necessary to say just a word or two about the fireworks hobby. Despite all the progress we've made since Van started all this in 1969, we still come across hobbyists who won't read the literature, who resist watching the videos, who don't belong to clubs or won't attend seminars at the PGI convention. You get the feeling that they treat the hobby as a kind of intuitive thing, and that they like to "fly by the seat of their pants". But as we pointed out in *Best II*, things happen fast in high energy reactions.

We are learning all the time -just look at some of Van's early *American Pyrotechnist* newsletters and you'll see how our body of knowledge has expanded so greatly. We must take advantage of the information that is available. In this hobby, the consequences of ignorance are profound.

Recently we received the following from Mr. Louis J. Semenza. Mr. Semenza was born to a fireworks family and worked in it all his life. We're sure you will enjoy his insight.

### HOBBY FIREWORKS MAKERS HAVE VALUE

There are many people in the U.S. who are unemployed and who need jobs to get the economy going. This brings me back to a few years before my retirement when I had an all-aerial fireworks display at a lake in Connecticut. There I had the pleasure of meeting many men and women who considered themselves hobby fireworks makers.

After the introductions, some of them asked if they could add their fireworks to those of mine that were to be fired in the show. After looking over their fireworks, I gave them the OK

My crew and I set up the display according to my plan. They set up theirs (after checking with me) according to their plan. There was one gentleman of Italian extraction who made rockets. He and his wife set them up on pieces of styrofoam sheets, from one end of the lake to the other. They were to be fired electrically, in series.

Just before it was time to start the display, I checked out all the shells, accompanied by a member of their crew. These young people fired the display along with my crew. I sat down and watched them do their thing. Every time they were ready to fire shells made by the hobby makers, they would pass the word as to whose shell it was. I was very surprised at their ability. However, the real payoff was when they fired the rockets on the lake. This had to be the most outstanding crowd pleaser of the whole display! After the display I asked the man who made the rockets if he would make rockets for me. His reply was that he did it only as a hobby.

Now this was a small group. Just think of all the people in the U.S. who can make shells and other fireworks that could be sold to the big displayers. This would put a lot of people to work. LJS

Remember, each reader bears the responsibility for his own interpretation of these articles. Development is on-going. Today's knowledge is the basis for tomorrow's improvements.

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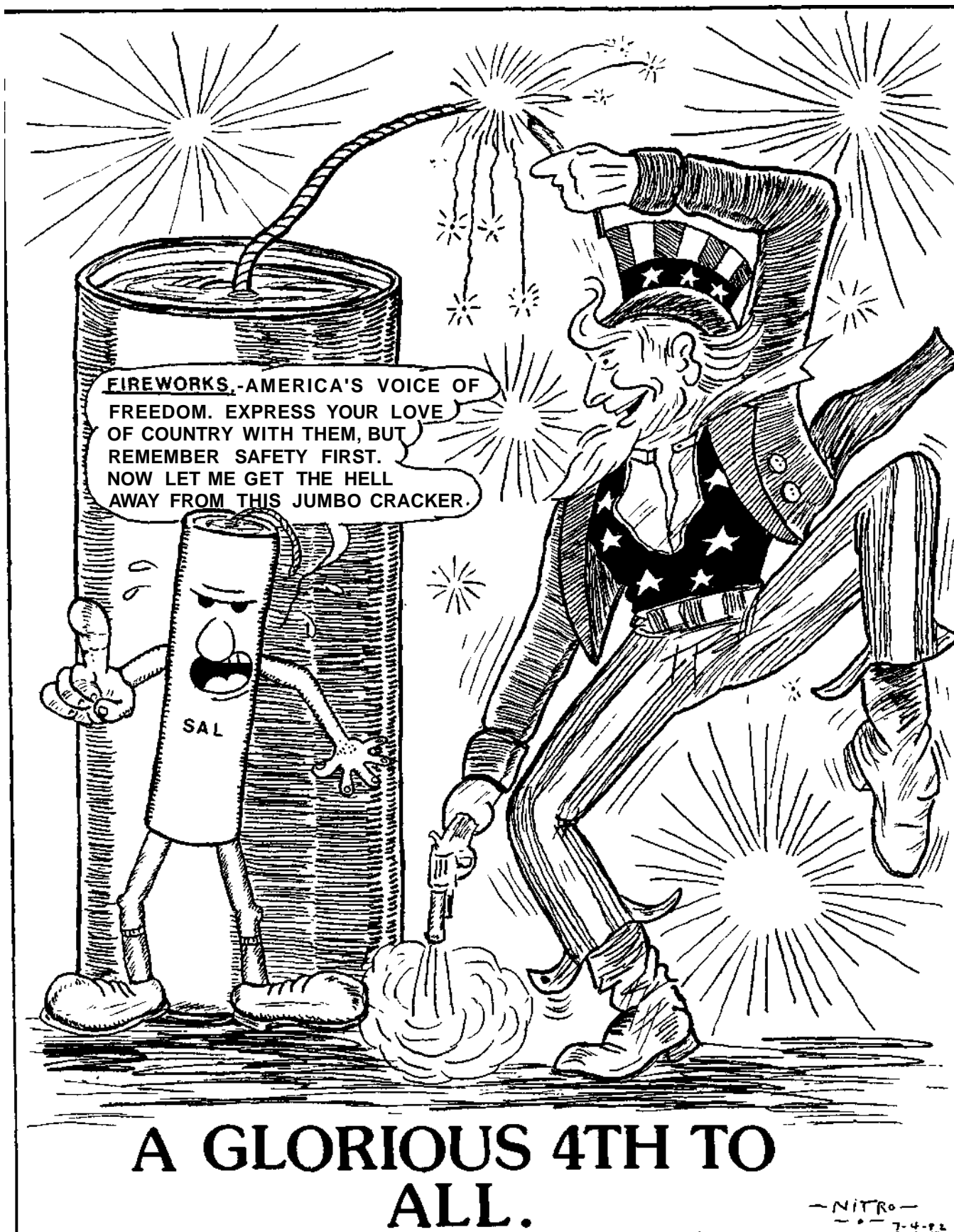
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Remember, each reader bears the responsibility for his own interpretation of these articles. Development is on-going. Today's knowledge is the basis for tomorrow's improvements.





FIREWORKS.-AMERICA'S VOICE OF  
FREEDOM. EXPRESS YOUR LOVE  
OF COUNTRY WITH THEM, BUT  
REMEMBER SAFETY FIRST.  
NOW LET ME GET THE HELL  
AWAY FROM THIS JUMBO CRACKER.

SAL

A GLORIOUS 4TH TO  
ALL.

—NITRO—  
7-4-42



## GETTING A PYRO EDUCATION

One of the problems associated with having fireworks as an interest is the problem of finding good information in a modern format. As most pyrotechnists know there just is not massive amounts of good information easily available to those who are interested. This is improving with the advent of videos and desk top publishing. Still, there are few places for a person to be a student and try and learn as there are a very limited number of seminars, schools, and conventions.

This past summer I had the occasion to take advantage of two of these opportunities. I was able to attend the PGI convention (my first) and participate in all of the activities. The second time was the chance to attend the 2-day Chemistry of Fireworks class put on by the Kosanke's and their guest instructors. As a student of fireworks I enrolled in a local college course in chemistry to help in my fireworks knowledge. The class was great and it helped, but there is a big (I mean giant) void between college chemistry and the field of pyrotechnics with production and testing of pyrotechnic devices. It was a blessing to have the opportunity to fill this void with the Chemistry of Fireworks class, and then cement that knowledge with the "hands on and how-to" teachings in the convention seminars, demonstrations, and devices that were fired there.

The seminars taught at the convention dovetailed right into the learning curve which was established at the first of the week in the Chemistry class. It was interesting to tie the Chemistry of Fireworks class, the "how-to" convention seminars, and the shooters certification program into a great week of learning.

I was happy with the way the Chemistry of Fireworks class improved my understanding of the convention seminars. This was really brought home when I had the opportunity to talk to a friend and fellow pyro who is a chemical engineer by trade (who works with explosives, an area which I also work in) concerning the seminars we have attended. We were surprised to go through the Chemistry of Fireworks class notebook (over 300 pages) and rediscover concepts that had been learned the hard way. He

was impressed with the material and saddened that he was unable to take the class due to a commitment prior to the convention.

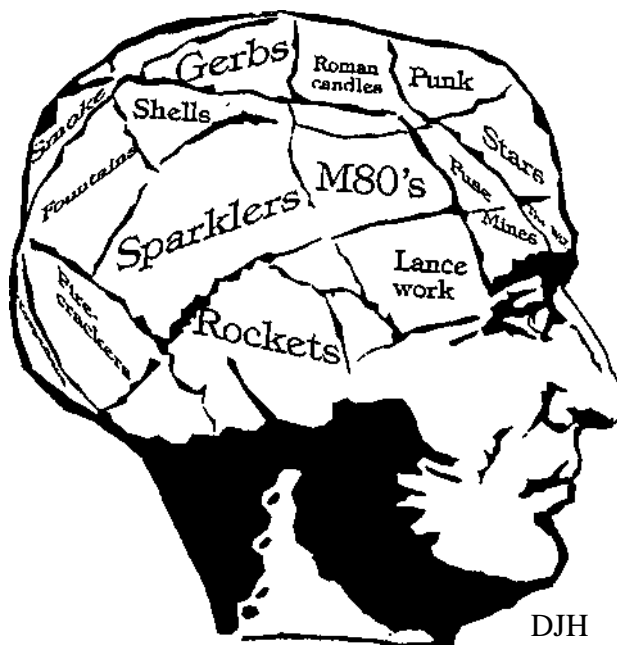
Judging the learning experience from the class and convention against other courses I have attended, I can only say that the whole experience was a bargain at twice the price and an educational experience.

If you are a pyro who cannot get:

- Enough knowledge about the field.
- A local mentor to walk you through problems.
- Sources to inspire your experimentation.
- A safe guide to performing your activities.
- Or are wanting to learn the fundamentals of fireworks and chemistry;

then I suggest that you attend the next PGI convention and take the Chemistry of Fireworks class offered before the convention. You'll come away with a great understanding of fireworks chemistry, an outstanding course manual, excellent handouts from the PGI seminars, a shooter certificate (if you take and pass the course), and one of the most exciting weeks of your life.

RPNM



DJH

## FIREWORKS AND ME

Of all the many pursuits in my life, none has been more fascinating, engaging, and at the same time, frustrating, as my long struggle to make bona-fide black powder. When I look back over the years at my earlier attempts, I can now pinpoint the critical parts of the process and eliminate most of the dead ends. I became very interested in the why's of the black powder process, and I gradually began to learn things.

I learned that moisture is important when milling black powder, not only from a safety standpoint, but also for proper consolidation. Pressure milling powder that has the right moisture content produces a plastic flow which serves to create a matrix of microscopic passageways that greatly enhanced the speed of flame progression across the powder grain surface. Clean, separate grains without fines or dust clogging the interstices between the grains is very important for burning speed.

Charcoal is extremely important and is the only true variable involved. Willow and alder wood have long been preferred for gunpowder making and has been since Roger Bacon's time, although in recent years maple wood has found favor with most commercial operations, and it appears to work fine. Personally, I have had great success using charcoal that I make from black willow, which is quite abundant here in Florida.

The charcoal is still most important, but now I have a small wheel mill, which I built. It makes a considerable difference. Pressing into cakes and densifying to a specific gravity of about 1.75 serves to intensify the energy per grain and gives the powder its characteristic power as compared to ball milled homemade meal, etc.

My interest in black powder started many years ago when I was twelve and living in my father's house with the mistaken notion that it actually was a powder mill; my father quickly set me straight on that matter. I was able, however, to experiment considerably, and with the aid of my mother's ancient set of encyclopedias, I had a

ball. Although the books gave a fairly comprehensive account of the black powder manufacture, the information was just general enough to require much trial and error to produce results. Oh well, that was a long time ago, and there's a whole world between.

When I was a kid, you could walk into a drug store and buy just about any chemical in stock with hardly so much as a raised eyebrow from the druggist. Pure-pac sold saltpeter, USP grade, in a four ounce pink tin for thirty-five cents. Charcoal, the activated kind, also sold for thirty-five cents, and flowers of sulfur was twenty cents. For less than a dollar, I was in business, so to speak. I also bought some aluminum bronzing powder which was used in paint. Once I even bought some iodine crystals, and as I recall, the only reaction from the druggist was a h-m-m-m. I have to smile today when I think of our Big Brother agencies and how they would be aghast at such goings on from a twelve-year-old.

I had a street sense, or something, in those days. It was an innate wariness that seemed to keep me out of harm's way. Some people just don't have it and they get hurt. There were accidents then, to be sure, but no more so than today, despite our stringent regulations. My biggest fear with fireworks is not explosions or accidental ignitions. It is starting grass fires! This really bugs me, which is why I always try to shoot over a lake, if at all possible. A really large field with closely cropped grass is OK, but anything else makes me paranoid. I carry a pressurized water fire extinguisher to handle unexpected fires, and even though I rarely use it, it's comforting to know that it's there.

I usually work alone, but it's a lot more fun with a couple of friends who know what they are doing. In a situation like this, accidents are minimized, as opposed to a factory scene where many people are involved and it's extremely difficult to know who's doing what every minute of the day. I try to be as safe as is practical. SW



# THE BEST OF AFN III



## LIGHTNING & THUNDER FOUNTAIN

Here is a two-effect fountain that begins with brightly flashing silver micro stars, then changes to the thunder effect of crackling micro stars. It's simple: I fill the tube half with silver micro star/fountain comp, and the other half with crackling micro star/fountain comp. I use a 1" i.d. tube choked to about 3/8". The comp is hand charged into the tube. I glue a disc into the bottom of the fountain and then attach the base. Let's start with the basic fountain comp.

### FOUNTAIN COMPOSITION

Potassium nitrate	
Charcoal, air float	37.5
Sulfur	12.5

### SILVER MICRO STARS

Magnalium 50/50, -200 mesh	30%
Barium nitrate	40
Sulfur	30
Binder (10% N/C)	<i>ad lib</i>

For this portion of the fountain, I use a ratio of silver micro stars to fountain comp of 1:4. If the micro star ratio is increased, they merely burn up in the tube.

Some people dislike using lead chemicals, so for the thunder part I will give two crackling micro star formulas. One uses bismuth trioxide and the other uses lead tetraoxide.

### CRACKLING MICRO STAR #1

Bismuth trioxide	75%
Magnalium 50/50 -200 mesh	15
Copper oxide (black)	10
Aluminum 200 mesh atomized	+5
Binder (10% N/C)	<i>ad lib</i>

### CRACKLING MICRO STAR #2

Lead tetraoxide	70%
Copper oxide (black)	12.5
Magnalium 50/50 -200 mesh	17.5
Aluminum 200 mesh atomized	+5
Binder (10% N/C)	<i>ad lib</i>

For this portion of the fountain I use a ratio of stars to fountain comp of 1:1.

In case you are wondering about that binder, it is a 10% solution of nitrocellulose lacquer. I did not give a stated amount because it depends on the skill of the star maker.

Several techniques have been described for making micro stars. I like to take the easy way and use a food grater.

The micro stars described in this article must be primed. I have found that if I use the crackling micro stars for dragon eggs, etc., and they have not been coated with wax first, the potassium nitrate will leach into the micro stars and render them ineffective.

My technique for coating the stars with wax is, first, to buy some cheap paraffin wax at the local supermarket. The brand I get is called Parowax. I put a few stars in a heated double boiler, add a small amount of wax and mix the stars around until they are coated. Then I dump them on a piece of kraft paper to cool and separate them.

The wax coated stars are ready for priming. I use the standard round star making technique. I put a couple of tablespoons of stars in a bowl, spray them with a 50/50 water/alcohol mix with an atomizer, then add prime comp and roll them until they are coated.

### PRIME FORMULA

Potassium nitrate	57.2
Sulfur	11.4
Charcoal (air float)	11.4
Silicon	11.4
Aluminum, dark pyro	5.7
Dextrin	2.9

BJV



## CONSTRUCTION TECHNIQUES OF 3/4" ROMAN CANDLE USING ROUND STARS

*This article was prepared from a seminar given at the Western Winter Blast HI in February, and has been reprinted from the Connecticut Pyrotechnics Association News.*

### MATERIALS NEEDED

- 1) Parallel wound tube 18" long, 13/16" i.d. with 1/4" wall
- 2) 3/4" x 22" rod
- 3) 3/4" x 3/4" nipple on base
- 4) 1 1/2 lb. dead blow mallet
- 5) Tablespoon measure
- 6) 1/4 teaspoon measure
- 7) Funnel for charging tube with clay and lift powder
- 8) 3/4" star pump to pump star 3/4 x 3/4"
- 9) Fine powdered clay
- 10) FFG black powder
- 11) Delay mix: (Ball milled meal powder):

Potassium nitrate	75%
Charcoal air float	15%
Sulfur	10%
Dextrin, additional	5%

I ball milled these for 12 hours then mixed it with the following to form the delay mix powder:

Ball milled meal powder	71%
Charcoal air float	18%
Red gum	4%
Alcohol	10%

(Added when delay mix is charged)

- 12) Alcohol to dampen delay mix before being charged
- 13) Eight 3/4" round stars
- 14) Window screen to screen delay mix
- 15) Kraft paper for under screen

### STAGES OF CONSTRUCTION

- 1) I screen the delay mix ingredients together through the window screen four times.
- 2) I incorporate the alcohol into delay mix so little dust is present then I pass mix through window screen twice to further incorporate the alcohol evenly.

3) I pump out eight 3/4" x 3/4" delay units by charging the star pump with damp delay mix and ramming lightly (using the wrist as the pivot for the mallet) six times with mallet. I extrude excess composition from the pump and cut off the excess back into the damp mix. I extract the delay unit and set it aside for later use in charging the candle. I repeat until eight delay units have been made.

4) I place the candle base with nipple on a hard firm surface. I place the candle tube on the nipple and charge in one tablespoon of clay through the funnel into the tube. I remove the funnel, insert the rammer into the tube, and ram the clay eight times with a mallet (using the elbow as the pivot point for the mallet). I pull the rammer up 4", turning one full turn to allow the loose clay to settle back to the bottom of tube. I push the rammer back to the bottom of tube and ram it four times using the elbow as the pivot for the mallet). I remove the rammer.

5) Next I place 1/4 teaspoon FFG black powder into the tube.

6) Then I put 1 star into the tube, making sure the star is seated all the way to the bottom of the tube, on top of the lift powder.

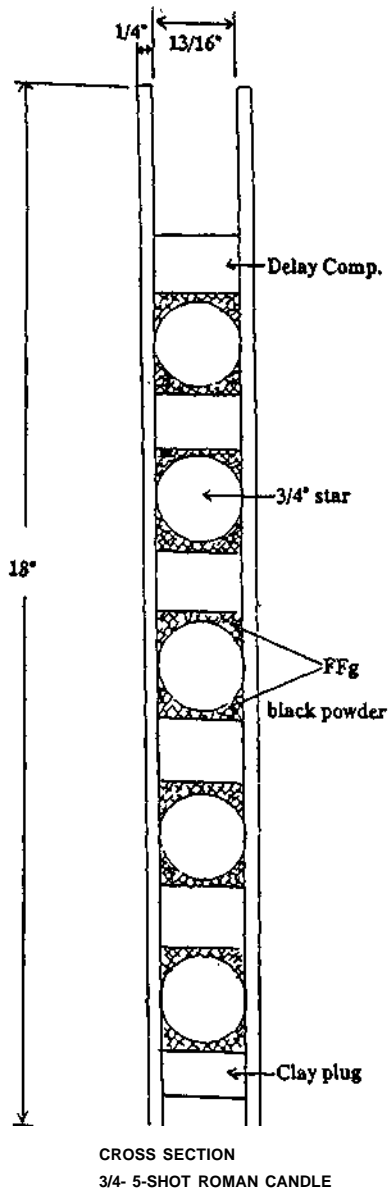
7) Then I put 1/4 teaspoon FFG black powder into the tube.

8) I carefully pick up one delay unit and place in the tube. It should slide down the tube with ease.

9) I insert the rammer into the tube and ram eight times (using the wrist as the pivot for the mallet). I raise the rammer 4" and turn one full turn, letting loose powder fall to the bottom of the tube, and then ram eight more times (using the wrist as the pivot for the mallet). I remove the rammer from the tube.

10) I carefully repeat stages 5 - 9 until the tube is charged with eight stars and delay units.

## BIGGER & BETTER BREAKS WITH SMALL BALL SHELLS



I was watching a video I'd taken of some rockets I shot two years ago, to pick out some good ones to make for the Western Winter Blast V. One particular break of red stars caught my attention. My description on the tape was "Red parlon - taped". That seemed curious because for the past two years I had been unable to get that star to ignite in a 3-inch ball shell with a hard break. Then I recalled that when assembling one of those shells the plastic hemi cracked so I had placed four strips of 1/2" fiberglass reinforced strapping tape longitudinally on the shell to hold it together. Could that be why the stars ignited?

To make a short story even shorter, I made up another shell with those red stars and taped it. 100% ignition! I started to tape all my plastic ball shells with fiberglass tape, and ignition on all stars was improved. In addition, the breaks are about 50% larger. There were comments to that effect at the Winter Blast.

By coincidence, I attended an excellent seminar at WWB-V, in which was mentioned the successful use of fiberglass tape on cylindrical multi-break shells.

I have been sealing these shells with methylene chloride. Perhaps if I used the plastic shell fragment/xylene glue, the tape wouldn't be necessary. This remains to be tested.

Evidently the stars were not being retained in the shell long enough to have sufficient exposure to fire, and were getting out ahead of the flame front, as suggested in *Round Stars & Shells*.

WCB

11) I remove the loaded candle from the base and tap both ends on a hard surface to remove excess clay and delay mix. I allow the finished candle to dry.

12) After the candle has dried for one week it can be fused and tested. AK

*[During pre-publication discussion of this article, the author emphasized the value of videotaping one's experiments, a view that we heartily endorse. Videotaping offers a permanent record.]*

## DESIGNING PORTFIRES

Although I have been an amateur for more than ten years I never have tried to make portfires - until very recently. Until a slow burning comp is achieved I think it is best to not hold them in my hand after ignition. As a precaution I fill the bottom of the portfire with some inert material, i.e. flour, clay, etc. to avoid burning my fingertips in a moment of excitement watching a beautiful shell ascending.

The problem was to find the correct formula. I did some thinking before experimenting and made up these guidelines: to find a slow burning and cheap composition without concern for smoke or dross. Still, it has to be able to consume the paper tube while burning and emit enough light so a flashlight is not needed to find the fuse in the dark!

### CHOICE OF FUEL

First I tried a comp I once made trying to copy a comp for smoking out rodents. It contained sulfur, a lot of sulfur. The gas produced while burning, sulfur dioxide, is not pleasant to inhale so I excluded sulfur from my portfire experiments.

Another cheap fuel crossing my mind was charcoal. But if you have ever tried to press a charcoal composition in a snugly fitted paper tube you know why I excluded charcoal. Besides, charcoal lowers the density of most mixes, thus making them burn faster.

In order to get light, a high temperature (fuel) is necessary. Metals are extremely hot burning but not cheap and, since I wanted to ram the comps hard to increase the density, it could be dangerous since I didn't yet know what oxidizer to use. Instead I chose red gum that also burns at a high temperature.

To slow down the burning of the red gum I tried lactose. It didn't work in my formulas so I added dextrin. This is a slow burning fuel that I knew would work from experience. The only drawback is its tendency to destroy the light output from the white flame produced by the red gum. This means that dextrin can only be added to some ex-

tent and still keep the white flame. Somewhere I have read that because of its hygroscopic nature, dextrin should not exceed 5% in a comp, unless in exception.

Now I had two fuels. One that burned with a high temperature and giving off light but no irritating smoke, and another that burned slowly and diluting the more expensive and sometimes hard-to-find red gum. It was time to consider the oxidizer. Of course, I already had used several oxidizers to thoroughly test the different fuels, but for this reason alone.

### CHOICE OF OXIDIZER

During the previous tests I had an idea of what I could use as an oxidizer. Potassium nitrate is the cheapest and it burns slowly. Unfortunately all nitrates in my country are coarse powders and vigorous shaking of a lit portfire would make it go out. It was obvious after watching all the dross coming off and NOT coming off the paper tube that an additional oxidizer was necessary. Barium nitrate is not recommended due to the toxic gases produced by burning, and strontium nitrate didn't smell too good. Once again I considered the risk of ignition that may occur from (hard) ramming and excluded potassium chlorate. This left only potassium perchlorate, as I thought ammonium perchlorate would be too expensive. However, potassium perchlorate is not a bad choice, because it contributes to a high flame temperature and good burning, and without much dross.

After some tests it was found that the percentage of potassium perchlorate was better kept high in order to obtain stable burning without dross. By excluding all of the potassium nitrate there is no dross, but the paper tube is not consumed either. There is a balance between dross production and consuming of the paper tube in formulae #1. It might be possible, however, to use more potassium nitrate if it's a fine mesh powder. But with the coarse powder I used, not even one extra percentage was added to formulae #2 in order to avoid hot dross falling on my feet, as this formulae is optimized to have the highest percent-

age of potassium nitrate possible in order to lower the price.

## PORTFIRE FORMULA #1

Potassium perchlorate	58
Potassium nitrate, coarse pwd	20
Red Gum	17
Dextrin	5

Approx. burning time(mm/sec.):1.50

## PORTFIRE FORMULA #2

Potassium perchlorate	55
Potassium nitrate, coarse pwd	25
Red gum	16
Dextrin	4

Approx. burning time (mm/sea): 1.25

The burning speed depends on how hard the comp is rammed and in how many increments. After I have rammed in increments of 12 mm I noticed that a 175 mm paper tube weighed 14 grams including the tube. This makes 0.8 grams per centimeter.

The problem that I actually set about first was how to make my own paper tubes. They had to be thin walled yet stiff enough to ram in. I made them as follows:

I take a roll of gummed paper (48 mm wide) and cut pieces of desired length, about 170 mm because it is difficult to ram an extremely long tube. I place a billet of wood or a never-sharpened pencil 7 mm in diameter on the gummed side of the paper and roll breadthwise, but not too hard if I use the same size of pencil to ram the comp later on, until about 10 mm remains. I moisten the gummed side and fold it down around the pencil and press. Now I have a thickness of two turns of paper. I move the end of the pencil inside the paper tube close to one end (about 5 mm) and fold down the end four times. Now I add a strip of gummed paper to force the folded end to stay put. When dry they can be used for several applications. They are easily and quickly assembled, and cheap.

When filling the tubes I take some clay and ram. I personally do not use inert filling since it is hard to know where the comp ends in the dark. A

trick I use would be to ram a comp of a different color next to the clay giving you time to light another portfire before the first one is going out. Then, I fill and ram the comp every 12 mm to obtain a stable and slow burning rate. I always remember that it is better to ram several times with less force than a few real heavy blows. When I have rammed the comp almost to the top (12 mm) I then set the portfire aside. After all the portfires have been rammed the last step remains. I am always sure to have saved a little comp which I damp with water (I have not tried alcohol) and I press it in the open end of the portfire with my fingers until it's full. Sometimes I use Meal A with additional charcoal and dextrin. I then set it aside to dry. Now I have a complete portfire with a starting fire at one end, also making sure that the dry comp stays inside the paper tube. I do not make these items possible to strike against a striking surface, as they often are stored and carried together with matchboxes. It is a bad thing to risk. They are easy to light anyway by holding the tip of a match tight to the starting fire and rubbing the striking surface to the match tip. Portfires are nice to use when the wind is strong or it is raining. I point the flame (approx. 50 mm long) at a 90° angle towards the fuse, at the end, and NOT lengthwise to prevent sparks from getting into the item I want to ignite!

I have presented how I make portfires. Of course, there are other ways, e.g., using damp comps, other chemicals, etc. My formulas may be considered too expensive for commercial use, but they correspond to my high demands and make indeed a good product compared to some commercial stuff I have tested. As an amateur making a few per year using approximately 14 grams per each, the price is of no concern compared to the usefulness. The smoke production is strong but even if inhaled, I don't find it bothersome. The dross is no problem and the paper tube is consumed while burning. Unfortunately, the comp burns a little too fast to be optimal. However, this and maybe the price are the only drawbacks.

One final tip: If the light output is of no concern and the fuses are easy to light, I'd buy some punk [joss] sticks. They smolder for a long time, smell good and are cheap. AP





## FUN WITH JUMPING JACKS

I must admit that the first time I purchased a Chinese Class C "Jumping Jack", it was with some reservations. I felt I wasn't getting the real thing; the Jumping Jacks I was used to were something quite different. To me, a "Jumping Jack" was what Weingart describes as an English Cracker or Grasshopper. And, as a boy, I just loved them.

The Chinese Jumping Jacks didn't even jump but they did do some other exciting things. So I soon forgave the makers of these devices for misnaming them. Total forgiveness came when I discovered that the Chinese did make the real thing (which jumps and bangs) under the name "Jumping Frogs".

The Chinese Jumping Jack looks like a string of firecrackers. Close inspection reveals what looks like a firecracker with a small hole pierced in the side of its case. Herein lies the secret of this device. The hole is a jet hole which allows the device to be propelled like a chaser-cum-spinner. Light a Jumping Jack and you are treated to a string of devices that scoot and spin along the ground. Great fun - and in color too!

As a boy I often felt that lighting a whole string of firecrackers at once was a waste. I would thus laboriously unwind strings of firecrackers and set off each cracker individually. As an adult I sometimes (not always) follow the same practice. I tried this with Jumping Jacks and made a few discoveries.

Just like with firecrackers, the fun can be prolonged with Jumping Jacks by firing the devices one-by-one, i.e., with the string unwound. And they perform just great in the air. Throw one into the air just before the fuse sets off the device, and one is treated to a little hummer which behaves in a similar way to the "Bees" in "Happy Bees" candles.

For safety's sake, I throw them quite far because their movement in the air is rather unpredictable. But why throw something if you can get a

little bit of BP to do the job for you? I dug out some tubes from a used Class C device which were just the right thickness for the job, i.e., their internal diameters were slightly wider than the Jumping Jack cases. I then drilled small fuse holes near the base of each tube. For fuses, I cut the fuses off the Jumping Jacks, leaving about a quarter-inch fuse on each device.

Taking six tubes, I glued them to a half-inch diameter tube with hot glue. I then glued on the main fuse of the device, making sure it came into contact with the fuse in each tube. Each tube was then charged with a small amount of homemade BP and the Jumping Jack tube with its fuse pointing downwards. The final product fired each tube in quick succession, creating an aerial Jumping Jack. It was far more impressive than just shooting off a Jumping Jack string on the ground.

Another way I tried to make Jumping Jacks airborne was to try and use them as drivers for miniature helicopters. Alas, after many attempts, my best helicopter got no higher than one foot off the ground.

Jumping Jacks are quite effective in mines. Here I discovered two distinct possibilities. A weak charge in the mine will merely drop the Jumping Jacks onto the ground, causing them to move along the ground in their usual way. A strong charge will blow them into the air, giving a low aerial display. The weak charge option is an improvement on just lighting a Jumping Jack string in that the individual devices can be dispersed over a wider area.

It should be worthwhile trying Jumping Jacks in shells and rockets. They can also be made to behave like firecrackers if their jet holes are blocked.

I'm sure that I haven't exhausted the possibilities with this device and would be interested to hear of any other ideas. IvM

## TISCHFEUERWERK

Tischfeuerwerk, or "table fireworks", long popular party items in Germany, are designed and intended for use in indoor celebrations. My 1929 Johnson-Smith mail order novelty catalog shows several kinds of German made Tischfeuerwerk among its fireworks selections. For some reason, the use of this kind of firework has waned in the U.S., while in Germany they remain popular. My 1987 catalog from the Moog-Nico Pyrotechnik firm in Germany devotes five entire pages (out of 67 pp. total) to a total of forty different Tischfeuerwerk and Tischfeuerwerk assortments.

The concept of these Tischfeuerwerk, or Tischbomben, is simple. A relatively large, usually cylindrical tube contains some sort of appropriate party novelty - perhaps candy, small toys, streamers, or other party favors. A small firecracker or other explosive charge lies inside the tube beneath the other contents. When fired, the contents of the tube are ejected and rain down upon the party. These table fireworks are especially popular at Christmas and New Year's time which, as here in the U.S., are festive days in the old country.

The wrappers on the items suggest the social contexts of their intended use: "Prosit Neujahr" reads one label, accompanied by an illustration of well-dressed party revelers. Others are, shall we say, less inhibited? "Argentina O-O Sex" reads one wrapper, and the accompanying illustrations of many are reminiscent of Playboy centerfolds.

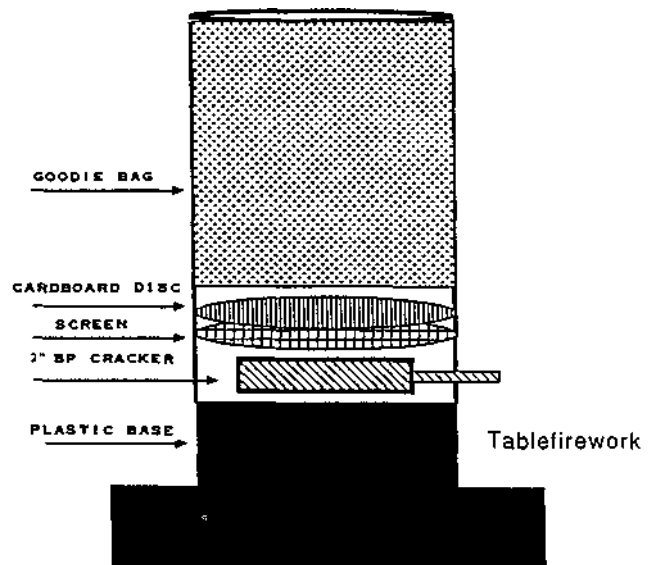
Since I can't simply run down to the local party store as the holidays approach and buy one of Moog's fine assortments, it occurred to me that I might make for myself a very acceptable substitute from scraps of this and that out of the workshop. This is what I came up with.

At a local store that specializes in recycled arts & crafts supplies, I bought a thick walled, spiral wound tube 3" i.d. x 6" long. I wrapped the tube with a layer of decorative paper, then plugged one end with a plastic base, as one might do for an aerial bomb or mine. Next, I drilled a 1/8" hole for the fuse through one side of the tube, just

above the top of the plug. I reinforced the top of the plastic plug with a heavy kraft disc dropped on top of the plug, and then cemented a 2" black powder-type cracker, glued to the center of the kraft disc. This I fused with a piece of good, American visco inserted through the prepared hole. Over the cracker I placed a piece of coarse metal screening (about 4 mesh) cut to fit snugly into the tube. This traps smoldering debris from the cracker inside the tube, reducing the risk of fire. Next I placed a 2-7/8" disc of corrugated cardboard in the center of a larger sheet (about a 10" square) of flame resistant crepe paper and then pressed this gently into the tube. I then placed two more sheets of this crepe paper over the disc and the first sheet. I filled this bag to the top of the tube with assorted, small, wrapped candies. After folding the corners of the bag toward the center of the top of the tube, I glued on a disc of colored crepe paper over the top, to keep things in place.

Then it was ready to fire. A match to the fuse, and seconds later the kitchen was covered with candy! Needless to say, the crowd loved it.

I might also add a word to the wise - I clear the immediate area of all flammable materials before using my *Tischfeuerwerk*, make sure the crowd stands a few feet back, and have a fire extinguisher ready, just in case. Prosit Neujahr! WK





## BIKE WHEEL PYRO

I like to put together various consumer items on a bike wheel and let it spin! Now it's time to double your pleasure, double your fun, with two, two...two bike wheels in one!

26-inch bicycle wheels are easy to obtain. Just watch the curbs for dead bikes being throw away. Or visit a bike shop and ask for cast off wheels that aren't too badly trashed. Getting two identical wheels is great, but unnecessary.

I remove the axles from the wheels, and since I rarely can find the correct wrench, it's back to the bike shop to buy one, or spend the same money having them remove the axles for me. The bearings must remain in the wheel hub. This takes care to prevent the bearings from falling out until the wheels are bolted together.

At the hardware shop I get a foot or so of "ALL-THREAD", which is just a shaft that's all thread. I'll pick up some nuts, wingnuts and large washers too.

Now I put the ALL-THREAD through the wheel hubs, and using the nuts and washers, fasten the wheels to the shaft, as shown in the illustration.

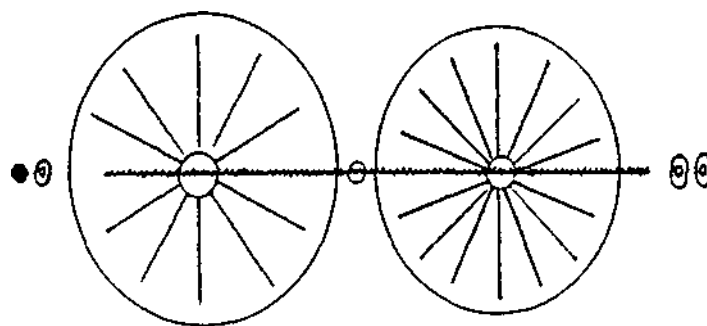
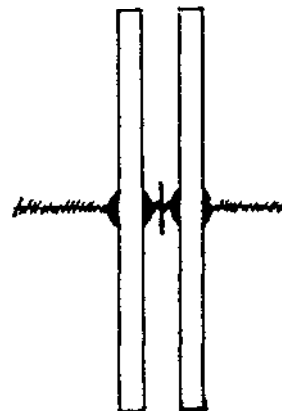
I attach drivers and other garniture with wire and/or nylon filament strapping tape. A good brand of fountain for this is one called "Font", although the cone shape makes them a little difficult to attach.

It's vital to remember to drive the wheels in opposite directions. Or I'll drive them at two different speeds in the same direction, with some extensions on the rearward, slower moving wheel.

A 26" and 20" wheel may be successfully paired.

To mount it, I put the long end of the shaft through a post, 2x4, or through a bracket on a 2" diameter PVC pipe, then attach with washers and a wingnut.

Finally I erect it in a safe place and ignite it at the appropriate time. FMO<sup>3</sup>



## GROUND BLOOM FLOWER WHEEL

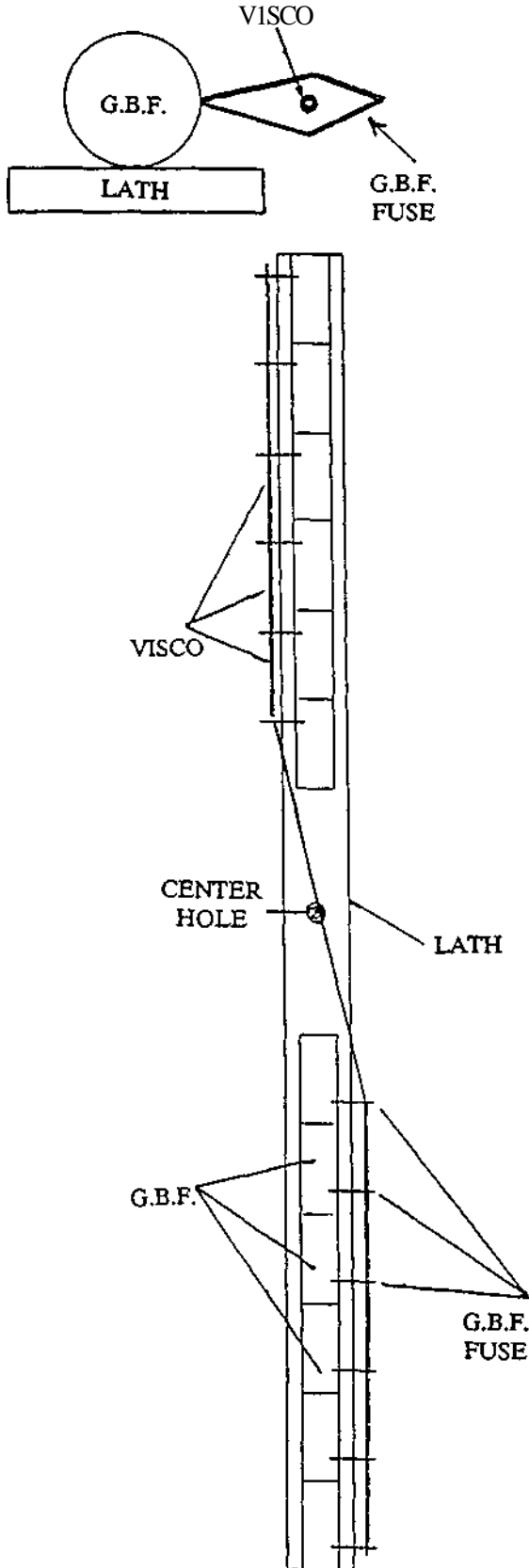
One of the favorite devices at our Independence Day Celebration is a Ground Bloom Flower Wheel. This device is assembled using Class C Ground Bloom Flowers (G.B.F.) for drivers. A G.B.F. is classified as a ground spinner in most catalogues and is manufactured by Red Lantern. When lit on the ground they spin around forming a lotus pattern in fire, changing colors from green to red to yellow. The sound they make when spinning is a low pitched hum.

To construct this wheel three wood laths 1"x1/4"x30" will be required. Also needed are six packages or 36 G.B.F.'s, along with some white glue, masking tape, 9 feet of visco fuse, a finishing nail, some string, and a 2" #12 or #14 round head wood screw with washers. A festive wrapping paper is optional.

I start by laying down a bead of glue 12 1/2" long on the end of a lath, then lay a G.B.F. on the glue bead starting from the end of the lath, and making sure the nozzle is pointing off to the side so that it thrusts in the right direction. Then a



# THE BEST OF AFN III



wrap of masking tape is placed on the G.B.F. to keep it in place while the glue is drying. I continue laying G.B.F.'s end to end in the glue bead, keeping the nozzles in alignment. When six drivers are on one end, the lath is turned around and the process repeated on the other end, making sure the thrust will be going in the same direction. Then these steps are repeated on the other two laths, so that I end up with three identical pieces.

The next step is to find the center of balance. When the glue is dry, each lath is balanced on the tip of an awl or nail. When properly balanced the lath will be horizontal, looking at the end and edge. I mark the balance spot then drill a hole the same size as the finishing nail, then glue the centers of the laths together, using the nail as a temporary axle. I try to get the ends as equidistant as possible. I clamp or tie the centers until the glue is dry, then the nail is removed and the hole is drilled out to take the screw. The whole assembly should turn freely but not sloppy.

The G.B.F.'s are fused together by threading a 36" piece of visco through the twisted loop of fuse on each driver. One piece of visco should tie together all 12 drivers on one lath, and should be threaded under the masking tape. It may be easier to pull back the masking tape while connecting the fuses. When finished there should be a few inches of slack in the center of the wheel. I find the middles of the three fuses and cut them, then take the six ends and tie them together with a piece of string. Fused in this manner, the wheel will burn from the center out to the ends.

The appearance of the wheel will be much improved by wrapping each end with some bright wrapping paper. This will also ensure that the visco doesn't go flying off because of the centrifugal force, which is considerable.

I think it is best to mount the wheel to an arm or some sort of stand-off from the post to make sure that the wheel ends don't strike anything. This wheel will have a lot of power and can be further embellished with whistles or fountains. For ignition a string of firecrackers or a loud whistle attached to the center fuses makes an exciting starter. CV

## EASY SUN

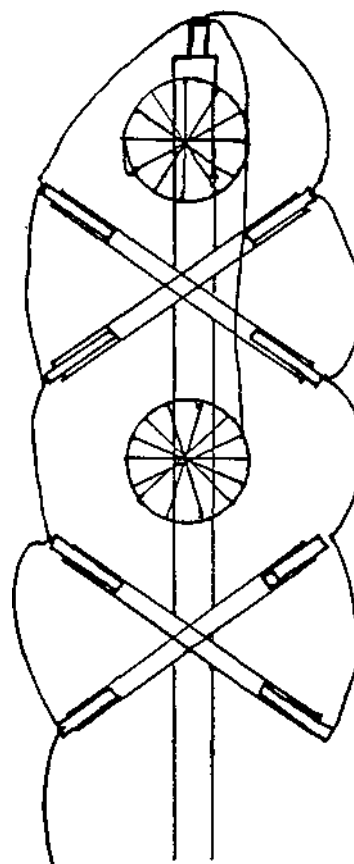
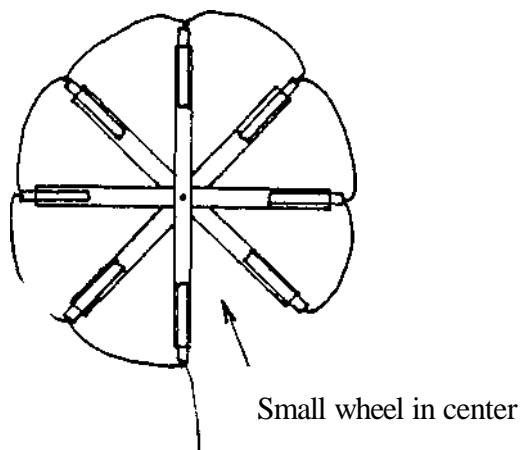
Here comes the sun! To make the sun come out at night:

- Four (4) 2-ft. lengths of lath or light scrap wood
- 8 Cuckoo fountains
- Tri-Rotating Wheel
- 10-ft. quickmatch
- 3" visco fuse
- Strapping (filament) tape

First I securely tape the fountains to the laths, then put a nail through the center of the laths and arrange the fountains into an eight-pointed star. Next I attach it to a post or pole, then fasten the Tri-Rotating Wheel at the center of the fountains. Then the whole thing is matched. I put on the 3" length of visco as the initiating fuse. Sometimes I'll put a 3 - 4" piece of visco in to delay the fountains, so that the wheel goes for a bit before the fountains kick in.

If I'm concerned about the next door folks, I'll remove the whistles from the Cuckoos, and remove any whistles on the wheel. This takes a little thinking because if I just rip the whistle fuse out, the whistles may take fire anyway, so I'll remove the entire whistle.

For best effect, I keep my audience back at least 30 feet. This one is a crowd pleaser, and it's made with consumer items, with a cost under \$7.00. I think the sun will be coming out at night more often! See illustration.



### VARIATIONS ARE EASY

It's easy to think of variations. For a "square wheel", I take four 2-ft. pieces of lath and make a square frame, then drill holes in the lath for lances or Morning Glories. I attach the lath square to a bike wheel with twisted wires. Then I add some drivers, match it, and away we go! Fountains (Cuckoo or other long lasting fountains) are a good additional garniture at the corners of the square. Starting the lances or Morning Glories first and using some visco to delay the drivers for 10 - 12 seconds is a nice touch.

### LATTICES TOO

Lattices are shown in Ron Lancaster's book and can be put together easily from consumer fireworks items, like Tri-Rotating Wheels and Cuckoo fountains. Naturally, non-commercial items will dress up any piece, and there's a lot of consumer items to choose from if the shooter doesn't have time to bang out his own gerbs.  
FMO<sup>3</sup>

## CLASS C REPEATERS

### Things needed:

- 1) 1/2" i.d. x 3" long casings
- 2) 1/2" caps or plugs
- 3) 1/2" Easy Capper
- 4) Visco fuse
- 5) End glue or wood putty
- 6) Fg black powder
- 7) 1/2-teaspoon measure
- 8) Small funnel
- 9) 14-20 mesh Titanium sponge (optional)
- 10) Small stars, Jumping Jacks, Lady Fingers, etc.
- 11) Tissue paper or cotton

**Step 1:** First I determine how long to cut the visco because the fuse is what makes the project work. I take the desired number of casings and multiply by 3/4", then add 6". Then I measure the fuse to that length and cut it as a 45 degree angle.

**Step 2:** I make a hole through both sides of the casing, 1/2" from the end, punching all the casings at once. Then I feed some casings onto the visco fuse. Using my Easy Capper, I cap the end that has the visco through it. Then I push the tubes to the far end of the fuse, leaving about 2" on the end. It is important to thread the casings onto the visco before capping. All casings are now on the visco.

**Step 3:** Now I take the string of casings and place them end up in a row. I mix up some wood putty (or end glue if I have it), making the mix fairly runny. Then I fill each cap and put the assembly away to dry.

**Step 4:** When dry, I lay the string of casings on the bench, muzzle end toward me. I stand the casings up one at a time for loading. I place the funnel in the end and measure 1/2-teaspoon of black powder into the scoop. Then I measure 1/4-tspn of titanium fines and mix with the black powder. Then I dump this into the casing. Now I add small stars or whatever I wish to produce the

desired effect. I have found that 5 or 6 stars from a festival ball works great.

**Step 5:** Wadding is needed to complete the task. I have found that toilet paper is a cheap, easy to get wadding. I tear a piece in half and start folding it until it forms a 1" square. I tamp this wadding down lightly onto the stars. When all the casings are filled, I roll the string of casings into a bundle and wrap with heavy twine. That finishes the repeater. JMcN

## EXPLODING INSIGHT

Knowledge is sometimes hard to obtain. I would like to share something that happened to me last 4th that added a lot to my fireworks knowledge.

I was preparing to shoot a three-incher out of a steel mortar which was buried about a foot in the ground. As I carried the shell toward the pipe, I noticed that the piece of visco delay fuse was missing from the top of the quickmatch. This I didn't like, so I took the shell back and stuck in another piece.

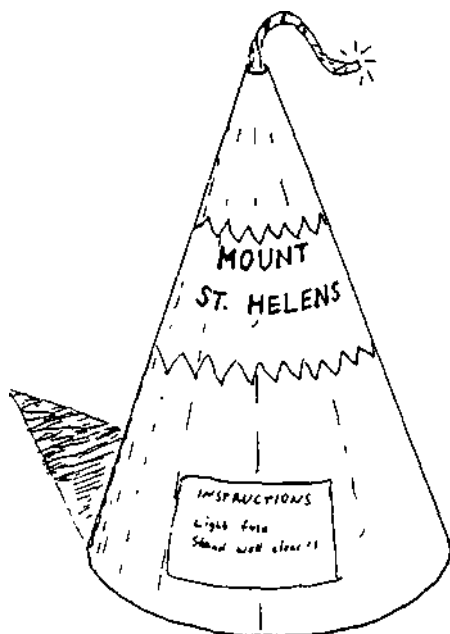
Back at the mortar, I inserted the shell, lit the visco, did the pyro twist and headed for distance. Then BOOM, the damn thing went off in the pipe!

It flattened the pipe like a piece of paper, which then struck the heel of my shoe, ripping it open.

I got to thinking that if I had been a step back, the metal would have hit my leg; two steps back and it would have lodged in my back, more than likely killing me.

The moral of this story is to avoid using iron mortars, and if they must be used, they should be buried flush with the ground, and/or sandbagged. I was very lucky this time. DH

## THOSE CAPTIVATING CONES



### Background and Theory

Ever since I was a kid I have been fascinated by those differently-shaped fireworks known simply as cones, or, in some parts of the world, volcanoes. I remember them having such exotic names such as Mount Vesuvius and Dragon's Teeth. My allowance would only stretch as far as the smaller ones on the market but I still remember my dad and uncle buying some really big cones. I think they also tried their hand at making them.

This bit of nostalgia drove me to trying my hand at producing my own. An added incentive was the fact that lately I couldn't find any authentic cones on our local fireworks market. I once did buy a cone which turned out to be a pseudo-cone, a small choked fountain inside a thin cardboard cone; another pyrotechnic rip-off!

Nostalgia is often a good enough reason on its own to attempt anything pyrotechnic. Cones

aren't, however, easy beasts to manufacture properly and after making a few I doubt if nostalgia alone would have motivated me to attempt any more. But cones, I was happy to discover, had a few advantages over the ordinary fountains and gerbs. One such advantage is that a cone can stand on any flat surface without additional support, as opposed to other devices which have to be pressed into the ground or be supported by other means. An even more important advantage offered by cones is their characteristic way of burning.

Fountains and gerbs have an almost consistent burning rate. Cones, on the other hand, have a burning rate which progressively increases. This means that a cone starts off producing a small shower of sparks which progressively gets larger and larger until the cone burns out. This increase in burning rate is very marked and cannot be compared with other devices which are made with tubes. To understand this phenomenon it is a good idea to compare cones with other devices.

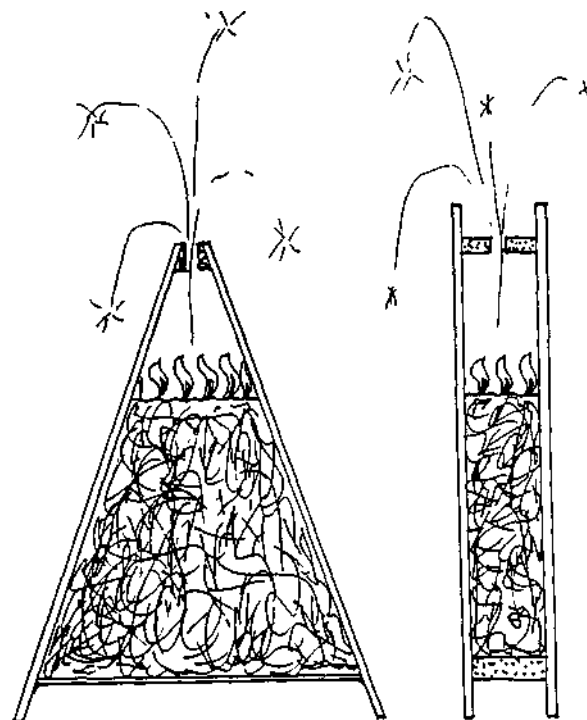


Figure 1

# THE BEST OF AFN III

Here I am going into a bit of a theoretical explanation. I myself do not like to get bogged down in theory but this little bit is valuable when one gets to tackling the "how to" part.

Figure 1 shows how a cone compares with an ordinary fountain made with a standard cylindrical tube. The cross-sectional area of each is shown related to a time period after ignition has started. Note that this area remains unchanged in the fountain while progressively increasing in the cone. This cross-sectional area relates to the amount of material actually burning at any one time. In the cone this area increases exponentially; for example, the area after two time intervals is four times the area then after one.

All this means that properly functioning cones need to be made to specifications not necessarily found in other devices. Cones which are not made to these specifications are prone to certain problems which can severely degrade performance. These are:

- The nozzle or tip of the cone burns away, resulting in a loss of pressure.
- The wall of the cone burns away, resulting in burning material spewing out sideways.
- The bottom of the cone is blown out, resulting in the complete failure of the device.

This last problem is perhaps the most serious as it results in a large mass of material suddenly being ignited in a totally uncontrollable and unpredictable manner. Another problem when this happens is that the casing can take off for the wild blue yonder carrying with it burning residue.

Yes, these problems can also affect fountains and gerbs but to a far lesser extent. The higher pressure found inside a burning cone means that its nozzle has to withstand greater forces than choke in a fountain or gerb. This means that a nozzle made from materials such as clay or Plaster of Paris is often recommended. Such a nozzle is mandatory in larger cones containing hotter mixes. Can you imagine a large fountain with only a cardboard washer for a choke?

Cone walls burn away more quickly than those of comparable devices. This is because burning materials inside a cone actually strike the cone wall at an angle rather than merely flowing parallel to it, as in a tube. If you doubt that this makes a difference try holding a blowtorch to a piece of wood and vary the angle at which the flame strikes the wood.

Another problem unique to cones is the problem of plugging the case at the bottom. Cones cannot be plugged as easily as tube devices because:

- The cone base has a large surface area.
- The walls taper outwards, meaning that the plug is easily dislodged.

Looking at all these problems I have concluded that cones require:

- A good nozzle which will not burn away.
- Thick walls which will not burst or burn away.
- A strong bottom which has been firmly glued in place.

The larger the cone, the more important it is to give attention to these requirements. And talking about cone sizes, here is probably the best place to discuss how sizing affects the amount of composition needed.

If one rams a tube with material which fills two inches of the tube, filling four inches requires twice the amount of material. Do the same with a cone and you will find that you need approximately eight times the material to double up the filling depth! This is probably the reason why some manufacturers don't fill their cone cases with mix. One can calculate the volume of the cone to a given depth by using the formula:

$$1.047 \text{ hr}^2$$

where:  $h$  = depth of fill  
 $r$  = radius of the bottom plug



Alternatively the formula can be represented as:  
 $0.333 h \times \text{area of bottom plug.}$

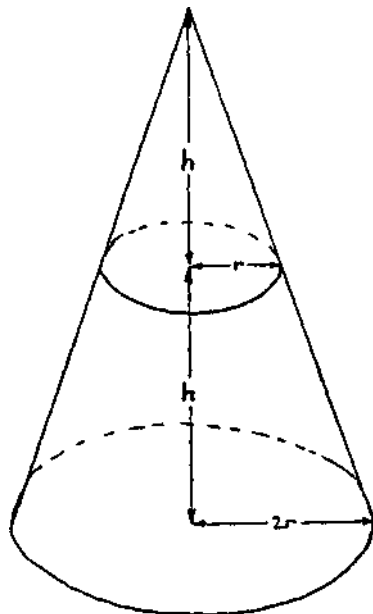


Figure 2

This is the standard formula for the volume of a cone. This formula can be derived from first principles using integral calculus, but I think we'll give that a miss. Just as a matter of interest the second representation of the formula also holds for pyramid-shaped devices. If we throw in a bit of geometry we note that two things stand out in the formula if we increase the filling depth. First, if we double the depth we increase  $h$  to  $2h$ . Our geometry (illustrated in figure 2) tells us that by doing this we change  $r$  to  $2r$  and the final result is:

$$1.047 (2h) (2r)$$

which calculates out to

$$8 \times 1.047hr^2$$

or eight times the original volume.

I said approximately eight times earlier on. In practice it is never exactly eight because the formula assumes that the cone tapers to a dimensionless point, which it does not. So doubling the filling depth actually requires, in practice, slightly more than eight times the material.

Something else which is apparent from the formula is the rate at which the burning rate changes. The burning rate is proportional to the surface area of the material which is proportional to the radius squared. Thus the burning rate at a depth of  $2h$  will be four times that at a depth of  $h$ . Other factors such as the nozzle being burnt away or plugged up with dross would obviously have an effect as well. The base to height ratio of the cone should theoretically also affect its performance. The lower this ratio the closer the cone approaches an ordinary cylindrical tube. Personally I have not yet made any meaningful comparisons in this regard, but will possibly do so at a later date.

So much for the theory. We now move on to the second part of this discussion on cones: how to make the cases.

## How to Make the Cases

In making my own firework cones I have explored two options for obtaining the necessary cone-shaped cases. The first option was to make my own, the second was to obtain some ready-made paper cones. This first option has been the more difficult and time-consuming. Obtaining ready-made paper cones has also not been easy as they are not nearly as much used as paper tubes. However, there is one industry which uses paper cones extensively. This is the textile industry.

Various types of textile yarns are wound onto paper cones. This applies both to yarns used in textile factories and those supplied to home users. So the person one might trouble for these could be one's wife, mother or someone in a textile factory. I finally got some textile cones from my sister who works in a textile factory.

Ready-made cones should have certain features for firework use. First of all they should be made of paper (not plastic). Secondly they should be as tough as possible, i.e., they should not be too thin. They should also preferably taper to a narrow point. I have seen some which taper to a point about an inch wide. Ideally the point should be narrower than this.

Ready-made cone cases are certainly a nice-to-

have, but suffer from certain disadvantages. Availability might be limited and subject to the goodwill of the suppliers. They also do not offer much versatility when it comes to size and shape. One does have more freedom if one opts to "roll one's own". Personally I have chosen to use both ready-made and homemade cone cases, and thus have the best of both worlds.

The first challenge in making one's own cone cases is to find a suitable former. Yes, it can be turned out of metal on a large lathe, but this works out to be expensive. My first cone former was a small plastic cone borrowed from my daughter's set of sandcastle shape formers. This worked fine for small cones. Subsequently I have discovered a few other potential formers, including a plastic rain gauge (for the really big ones). One can always make his own formers from inexpensive materials and without specialized equipment. A third option is to make a type of cone which does not need a former at all. This is a subject in itself and I'll deal with that in a separate article. What follows is a description of the second option.

### **Making Cone Formers**

I use good old plaster of Paris to make cone formers. The plaster I have experimented with is a good dental grade but other grades might work equally well. One needs to, of course, find a cone-shaped former to pour the plaster into. I opted for some cone-shaped paper drinking cups.

First of all I found a glass bottle which had an opening just slightly smaller than the diameter of the mouth of the cup. I then suspended the cup in the bottle and poured in the plaster. Then I tapped the bottle vigorously to remove any trapped air bubbles in the plaster. After drying thoroughly and removing the paper cup from the plaster I gave the plaster a couple of good coats of stone floor sealer. This is essential to prevent the plaster getting wet when making the cases. It also effectively hardens the surface of the plaster. This process does not produce a perfectly formed cone as the paper cup tends to bulge slightly. The cone also has some indentations where the paper cup comes into contact with the bottle. But it is good enough for the purpose and I have made

some good cases from these less-than-perfect formers.

Note that a glass bottle might be ideal for making the cone former but is a definite no-no for holding the former when filling it with mix. I used to use bottles this way but had a serious rethink after making a cone which detonated!

### **Making the Cases**

The first step is to determine the actual size of the cone former by measuring the distance from the former's tip to its base. I then cut circles from some kraft paper with radii about half an inch smaller than the size of the former (from tip to base). I then make a straight-line cut in each circle from somewhere on its circumference to its center. I then cut a small hole with a radius of about quarter of an inch in the middle of the circle. The next step in my process is to liberally apply some flour paste to the former. Lots of paste here ensures that the case will separate easily from the former. Paste is applied to one of the kraft paper circles which is then wrapped around the cone. I have found that a bit of practice is needed to ensure that the paper lines up properly. I try to get the outer edge of the circle to follow itself around the cone without spiraling towards the tip. In practice a little bit of spiraling is hard to avoid and I just aim to keep it within limits of about an eighth of an inch deviation from the base of the case. Sometimes I find that I need to unwrap and rewrap the paper circle a couple of times before I get it to line up properly. I then repeat the process with one or two more circles depending on the paper thickness and the actual base to height ratio of the former. I tend to vary to final thickness of the case according to the size of the cone and the mix used to fill it.

When I have finished wrapping the paper circles around the former I remove the case by grasping the bottom of the former in one hand and twisting it off the former with the other. If I have applied enough paste to the former the case comes off without any trouble. I then let the case dry for a couple of days. My cone cases are thus dried off their formers. I find that very little distortion occurs in the cases if they are dried reasonably

slowly. One could possibly get slightly better results if the cones are left to dry on the formers. Here one might also be able to dry them more quickly, i.e., in the sun or in a drying oven.

When the cone cases are dry I then make a 1/8" to 3/8" hole in the tip of the cone. The size of hole depends on the size of the cone and the mix it is filled with. I make this hole by slicing off the tip of the cone with a modeling knife. The cone cases can be used as is but will be subject to the problem of their tips burning away. There are several ways of getting around this problem.

### **Strengthening the Tips**

A simple method to strengthen the tip of the cone is to dip it in a saturated solution of sodium silicate. This should not be confused with sodium salicylate which is used in whistle comps. The common name for sodium silicate is water glass. I find that this method is often adequate for small cones which contain mixes which burn at relatively low temperatures.

Another method I have tried is to stick extra layers of paper/cardboard over the tip. Here I effectively wind another smaller cone over the tip of the larger one.

The third method is to make a nozzle out of clay or similar material. I have opted for plaster of Paris.

To make the required hole in the nozzle I use a golf tee. I have experimented with two different methods and will describe both. In the first method I coat the tee with a thin film of Vaseline and insert the tee in the tip of the cone from the tip end. The tee is pressed in as far as it will go, ensuring a tight fit. I then make up a mix of plaster of Paris and water, and spoon some of it into the tip of the cone. The second method is the reverse of the first. Here I first spoon in the plaster of Paris and then insert the tee from the base end of the cone. This method is a bit more difficult than the first method and thus a detailed description is in order.

This second method does not plug the tip of the cone before the plaster is put into it. To stop the

plaster running out I simply place the tip of my forefinger over the tip and insert the golf tee with my other hand. This is actually the tricky part. Some of the larger, more narrow cones don't have enough room to get one's hand or even one's fingers into them properly. Here I use a short stick to press the tee into the plaster until its tip protrudes from the tip of the cone and fits tightly. Spooning in just the right amount of plaster of Paris also requires a bit of practice before getting it right.

I now (with either method) tap the end of the cone and wiggle the golf tee around slightly to get rid of air bubbles. This is particularly critical in the second method.

After the plaster of Paris has solidified I gently twist the tee and then remove it. The plaster is now allowed to dry thoroughly. The resulting hole may or may not be wide enough. If it isn't, one can carefully drill it out to the required hole size.

Why use the second method one might ask? It is certainly more of a pain-in-the-neck than the first! It does, however, have a big advantage in that it creates a tapering hole which has its largest end on the inside of the cone. This allows burning material to flow more freely and helps to prevent the hole being plugged up with dross.

Once the tip has been prepared the cone is ready for filling.

### **Filling the Cases**

Before filling the cone with comp I usually put in the fuse. My preferred method is to insert the fuse and then stick it in place with about a teaspoon full of damped comp. I allow this comp to dry before putting in the rest of the comp. I now have a fuse which will not easily fall out and which rarely fails to ignite the comp.

I now place the cone, tip downwards, in a short paper tube which is strong and sturdy enough to hold it. Note again I do not use a glass bottle for this purpose just in case the comp ignites while filling. Certain plastic bottles or tubes could also be used for this purpose. I fill my cones to a

# THE BEST OF AFN III

predetermined depth which is determined by the size of bottom plug which I am using. I take care not to put in too much comp because this results in the bottom plug not fitting tightly. It's not possible to ram cones like one does with tube devices and I simply press the comp down firmly with a one-inch brass former or dowel stick.

## Plugging the Bottom

Plugging the bottom properly is very important. Failure to do so can result in the bottom being blown off very soon after the comp has started to burn. Small cones, with relatively thin walls, are more easily plugged than the larger cones. Here I just firmly wedge in a thick cardboard disk and then fold the ends of the cone base over the disk. The larger cones require a different technique.

I cut four cardboard disks for the larger cones, two from thick cardboard and two from thin. The thick disks are cut to the required base diameter and the thin disks to a diameter about an inch wider. I press one of the thick disks into the bottom of the cone. My preferred method here is to press the disk into place with the bottom of a plastic tumbler. I then smear a generous amount of Elmer's glue over the area where the disk comes into contact with the wall of the cone.

After the first disk has been glued into place I take the second thick disk and glue it to one of the thin disks, positioning it in the center of the thin disk. I then cover the other side of the disk with glue and press in into the base of the cone so that the thin disk is sandwiched between the two thick disks. Finally I glue the second thin disk in place and let the glue dry. Figure 3 shows a cross section of the completed cone with the disks glued in place.

Some of the procedures I have described might be an overkill, depending on the size of the cone and the comp used in it. The larger the cone, the more critical it is to pay attention to the method

of construction. Different compositions, and how they affect cone performance, will be the subject of a future article. IvM

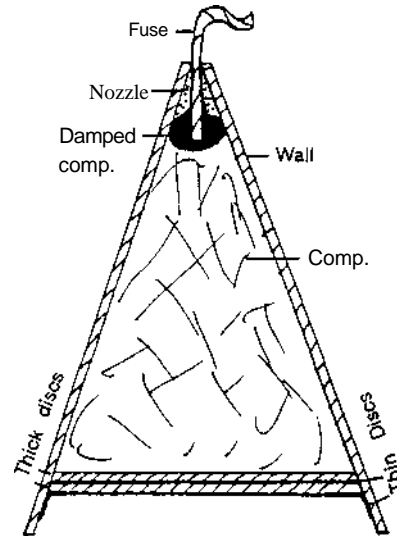


Figure 3

## TIP OF THE MONTH

In my endeavors dealing with experimental shells, I may have a novel idea pertaining to caps for piped quickmatch leaders. I purchase 1/4" plastic soda straws and cut them 3" in length. Then I take a candle and hold one end of the straw near the flame to melt the end. Then I press the end closed against a formica tabletop using a small steel bar approximately 1/2" x 4". These straws can then be fitted to the bare end of the piped match for a tight form fit. This does away with paper caps, if they are not available. PG

## PYROTECHNIC SERPENTS

Pyrotechnic serpents employed in aerial shells are an interesting addition to nearly any type of star effect. They can be easily made and cost very little. The only drawback is that they are somewhat tedious to construct. Like many pyrotechnic devices, the builder needs to find ways (if necessary) to overcome this. In this article I will explain how I construct these devices and suggest some tips for possible mass production techniques.

### FIGURING THE SIZE

The first step in building serpents is to decide what size shell they will be destined for. Small serpents tend to get lost in the sky when employed in large shells and large serpents will overpower the primary effect in small shells, so some forethought is required. I have found that 3/8" i.d. x 2-3/8" are a good size for 3" shells. For larger shells the size can be scaled up accordingly, but for the purposes of this article I will describe the 3/8" i.d. size only. The basic procedures will be the same for the larger sizes, with the exception that the larger sizes allow room for the addition of a report effect, if desired. This is simply a charge of flash powder [the traditional "bounce" added to serpents is done with black powder - ed.] that is added after the serpent is rammed.

### TUBE IS MOST IMPORTANT

The 3/8" tubes required may be hand rolled using kraft paper and white glue or pre-gummed kraft packing tape. A 24" piece of 50lb. kraft is what I have found to give good results. When these tubes are hand rolled I find that after they dry their diameter is slightly smaller than the former that was used to roll them on. This is due to shrinkage of the tube while drying and may require that a non-standard sized rammer be used when charging them. Lacking a lathe, I find that reducing the diameter of an aluminum dowel to be a tedious process. Instead, I roll the tubes on a former that is slightly larger than 3/8". When they dry, a standard 3/8" aluminum dowel will slide smoothly inside them. I have found that

whenever a tube is wet rolled by hand some shrinkage will occur. It is helpful to compensate for this before hand, so that standard sized rammers and nipples may be used.

An alternative to the above is to buy pre-rolled casings. These can be purchased already cut to the desired length and save a considerable amount of time, although the expense is greater. A way I have found to reduce the price of pre-rolled tubes is to buy them uncut. These are then cut to the desired length using a band saw or similar tool. However, I have found a way to cut these to length by hand that produces a finish cut superior to a band saw, although it is somewhat slower. The process is as follows: First, I mark the lengths to be cut on the outside of the casing. Next, I procure a dowel the same diameter as the i.d. of the tube. This is slid inside the tube. The tool used to do the actual cutting is an automotive hose cutter, although a similar type used by plumbers to cut PVC tubing will work also. These are plier-type affairs, except one jaw is a razor. I simply line it up on the mark previously made and squeeze while rotating the tube. A clean, flush cut is quickly produced. The dowel inside the tube keeps the inner layers from being pushed inward from the clamping force applied. This method has worked well for me and a hundred or so tube lengths can be cut in an hour or so.

I have found the selection of the tube a somewhat trial and error process. The problem is that the tube needs to be strong enough to withstand the high interior pressures generated, but not be heavy. A heavy tube, especially in the smaller sizes, will not have enough thrust to overcome the force of gravity and will tend to fall to the ground while spinning, a sort of "helicopter in reverse" effect. On the other hand, too light a tube will tend to detonate or deflagrate. The size of paper for the hand rolled tubes I mentioned earlier is a balance between strength and weight which leans towards the "too heavy" side. If the reader employs a composition which is less aggressive than the one I will mention later, the

# THE BEST OF AFN III

tube should be made with correspondingly less paper.

The machine-made tubes that may be bought from the various pyrotechnic suppliers are generally described as to what particular application they are intended for and should be selected on that basis. However, since these are already made, their weight and strength cannot be easily altered. Consequently, compositions employed with them may need to be made more or less vigorous in terms of their burning speed. At any rate, the machine-made tubes selected should be the parallel wound type.

Attention to variables that cause excess weight should extend to the plugs or nozzles used at either end of the tube and to the amount and type of composition as well. One end of the tube is usually plugged with clay, even if it is not the nozzle. The other end can also be plugged with clay, but this is not necessary. A considerable weight savings may be realized if a lighter weight plug is used - a paper end cap perhaps. Too much or too heavy a composition is also undesirable, unless it can produce enough thrust to overcome its additional weight. These variables need to be worked out on an individual basis by trial and error before large quantities of devices are constructed, for obvious reasons. Hopefully, the method of construction of the serpents I'm about to describe will serve as a starting point.

## CHARGING THE TUBE

Now that I've selected a tube, the next step is to construct or purchase a nipple and rammer. A nipple is simply a short length of aluminum or wood dowel that is set into a base so that it only protrudes 1/4" above the surface of the base. The base may be made of any convenient material (wood, aluminum, etc.) and need only be 2 - 3" square and 1/2 - 3/4" thick. The diameter of the nipple is the same as the i.d. of the tube. The rammer is a length of aluminum or wood dowel the same diameter as the nipple. Any length that is comfortable can be used and 5" - 6" is a good choice. However, if it is to be pressed with an arbor press, it will need to be short enough so that

the base, tube and fully extended rammer will fit between the base and ram of the press. For the purposes of this article, the ends of the nipple and rammer are flat, although shaped nipples and rammers are discussed at the end of this article. One end of the rammer can be cross drilled so that an appropriate sized steel rod may be inserted. This will serve as a sturdy handle, so that if the rammer should become stuck in the tube, it can be easily removed.

If the tubes are to be charged with a hammer, it should be non-sparking and weigh about 1/2 lb. Due to noise considerations, I use an arbor press. Imported arbor presses in the 1/4 - 1/2 ton sizes may be purchased rather inexpensively and come in handy for other pyrotechnic manipulations as well. Careful attention needs to be paid to the working height of the press. This is the height between the base and the ram. On smaller presses this is only 4 - 5" and may be too short for pressing larger serpents and rockets. If an arbor press of this size is purchased, it should have an open base. This will allow one to bolt an extension to the base so that taller devices may be pressed with it. Of course, simply purchasing a larger press also would eliminate this problem but the expense is greater.

## MY FAVORITE COMPOSITION

The formula I use for the smaller (3/8" i.d. x 2-3/8") serpents has been determined through trial and error. It is a flexible formula in that it can be made to burn faster or slower depending on the ratio of hand made meal to 4Fg.

The formula:

Hand Made Meal w/5% Dextrin	40%
4Fg	60%
Titanium, Cut -40 Mesh	+12%

112g. will make about 30 - 32 serpents.

To begin the actual construction of the serpents, I first place a tube on the nipple. A small funnel is placed in the tube and 1/4 tsp. of bentonite clay is charged. The funnel is removed and the ram-



mer inserted. The assembly is placed under the ram of the press and, steadying the assembly with a gloved hand, the press is operated with the other. The amount of force applied is rather subjective, but with a small press I generally apply force until the clay can be compressed no further. I would not recommend using that much force with a larger (over 1/2 ton) press. The assembly is removed from the press bed, the rammer withdrawn and the tube removed from the nipple. I now invert the tube and shake out any loose clay. A point on the outside of the tube just above the level of the clay is ascertained and marked. Using a 3/16" drill bit, I now drill a hole through the side of the casing on this mark. A 2" piece of black match is inserted in this hole until it is against the opposite wall of the tube. I bend it up the side of the tube and tape in place. The tube is returned to the nipple and 1/4 tsp. of composition is pressed in the same manner as the clay was. This is repeated a second time for a total of 1/2 tsp. of composition. Another 1/4 tsp. of clay is pressed in or, as mentioned earlier, a paper end cap may be glued in. I now slurry prime the black match and press it in 2Fg, although this step should be omitted if the serpents are to be hand fired. The serpent is now complete.

## MANY VARIATIONS POSSIBLE

It should be noted that the above is a basic description that can be modified in many ways, depending on the effect desired. The most influential variable, besides the composition and weight/strength of the tube, is the angle and size of the hole. Anything from a hummer to a corkscrew effect can be achieved by manipulating this.

A hummer usually has a hole drilled at a tangent to the tube bore, but at a right angle to tube wall. Additionally, the titanium is eliminated and the composition made as fast burning as possible. The hole size may be reduced to increase the thrust to the maximum that the tube can handle

without exploding. Additionally, the hole can be relocated to the center of the tube. This will produce a device that spins on its axis with such force that a loud humming sound is generated.

A corkscrew effect is obtained by drilling a hole at a tangent to the tube bore and at a slight angle relative to the tube wall. The hole is located at the end of the tube, but still on the side of the tube. The titanium is retained in the composition and to prevent the hot sparks produced by it from enlarging the hole, a "U" shaped charge of clay is rammed at this end and the hole drilled through it. When ignited, the tube will spin and shoot forward, leaving behind a trail of titanium sparks in a corkscrew pattern against the sky.

A more erratic serpent type effect may be obtained by drilling the hole into the center of the bore and at a slight angle relative to the tube wall. The titanium and "U" shaped clay charge are used and the hole is drilled at the end of the tube wall. The serpent will squirm this way and that, tracing an erratic pattern in the sky.

The pattern produced by a hole drilled in the center of the bore and at a right angle relative to the tube wall (as I described in the construction of my small serpents), is a looping sort of corkscrew that makes the most of those small devices.

The larger sizes of serpents may have the holes bored in the end of the tube and have nozzles similar to rockets. Frequently the holes are at some sort of angle in order to produce a corkscrew or similar pattern.

Serpents may be mass produced by simply fabricating multiple nipples and rammers that are fastened to a common base or ram. This speeds production and lessens the tedium associated with the construction of large numbers of these devices. SAR

## GLITTERING REPORT TOURBILLIONS

Both comps are screened two or three times. To make ramming the base mix easier, I usually dampen it with about 12% water, then push it through a 20 mesh screen onto sheets of newspaper. The granules are left to dry for about two days. The base mix granules should be soft enough to be crushed between two fingers; if not, the percentage of water is decreased.

For granulating the glitter mix, I use a somewhat unconventional solvent system. I add about 10% water, then an additional 6% acetone or petroleum paint thinner. Using an insoluble liquid has the advantage of not affecting the solubility of the dextrin in the water, like alcohol would, but it still produces harder granules and speeds drying. The dampened glitter mix is well kneaded and forced through a very coarse screen with openings of about 3/16"; this screen is available at most hardware stores. Then I would spread out the granules on newspaper and allow them to dry for at least two days. When both the hard glitter granules and the softer base mix granules are dry, they are mixed in a ratio of 80% base mix to 20% glitter.

Once all the mixing is complete, the tourbillions are ready to be rammed. First, a clay plug is made by solidly ramming 1 tsp of clay. The length of this plug should be determined and then marked on the outside of the tube as a drilling guide. On top of the clay, 1 tsp increments of the glitter/base mix are rammed to about 1 1/2" from the top of the tube. This can be changed to alter the timing of the report. I am very careful when ramming ghtter mix because it is quite a bit more sensitive than most plain mixes!

Using a low speed drill, I then drill a 1/8" hole into the side of the casing and 1/4" into the rammed mix, just above the

clay plug. Once again, I use extreme caution when drilling into aluminum mixes, keeping all live items away from the work area!

After drilling, the tourbillions are ready for priming. Meal powder, or some of the base mix, is mixed with water until a slurry the consistency of toothpaste is produced. This slurry is then spread into the drilled hole, and over an area about 3/8" square on the surface of the tube, to ensure ignition of the tourbillion.

Once the priming is dry, I add the report charge. For safety's sake I prefer to use a barium nitrate/pyro aluminum/sulfur flash, with perhaps a few percent antimony sulfide. But the added punch of perchlorate report comps is a nice feature. Chlorate flash comps I would never use, especially in the presence of sulfur! I funnel in the flash, leaving 3/4" empty at the top of the tube. Next I glue in the end plugs. If the proper end plugs are not at hand, a tube

can be closed using a different method. A dulled knife is used to push a quarter of the wall thickness inwards, then some glue is added and more paper is folded over. This is repeated until finally the outside of the tube is folded completely over the top. To ensure a perfect seal, the top of the tube is coated with glue, and a strip of masking tape is used to hold everything in place.

### MATERIALS LIST

- \* 1/2" i.d. x 3" long x 1/8" wall tube
- \* 1/2" non-sparking rammer
- \* 1 tsp composition scoop
- \* Medium weight mallet
- \* 1/8" drill
- \* Small funnel
- \* Powdered clay
- \* White glue

### BASE MIX COMPOSITION

Potassium nitrate	5
Charcoal (softwood)	1
Sulfur	1

### GLITTER MIX COMPOSITION

Potassium nitrate	53
Charcoal	10
Sulfur	12
Sodium bicarbonate	4
Antimony sulfide	8
Aluminum, atomized, 12 micron	9
Dextrin	4

When the glue has dried, the tourbillions are ready to be used in any shell, mine or candle. The effect should be a rapid spin with bright white/yellow ghtter flashes, terminating in a loud report. These tourbillions can be upscaled or downscaled according to the size of the shell they will be used in. An interesting effect is achieved by varying the delay of each tourbillion in a shell, producing a neatly timed string of reports. JB





## TOURBILLION CANDLE CONSTRUCTION

Roman candles have always been a favorite of mine since I was a kid. Not just plain colored candles but fancy candles like Happy Bee and Stars with Reports. In this article I'll explain how I make a tourbillion candle, sort of like a Happy Bee but with a gold effect. I call it "The Dancing Spider Candle".

I start by rolling a 12" long tube out of a piece of 12x12" kraft paper bag. I use wallpaper paste, homemade paste or white glue. The former is a 3/8" steel or brass rod. I cover it liberally with paste so the tube doesn't stick. I let the tubes dry thoroughly before loading.

I make the tourbillions by getting a roll of gummed paper tape, the dry kind that is activated by water. It usually comes in 3" wide rolls and is good for making many small sizes of convolute tubes. I cut a bunch of pieces 1" square. I use a 1/4" brass rod, wet the paper and roll the tubes. I always remember to keep the rod wet or the tubes will stick. Before I remove the tube, I slide it to the end of the rod so approximately 1/8" of the tube length can be crimped over the end of the rod. I tap the crimped end of the case on a firm surface to seat the crimp, then slide the tube off the rod and let dry. The tubes are filled with a medium burning meal powder (polvorone works best). I slide the 1/4" rod back into the tube on top of the powder. The powder is compacted by holding the rod and tapping the tourbillion on a firm surface. Then I remove the rod and repeat the filling and compacting process until the tourbillion is almost full. Rod and funnel may work well also to fill the tubes. Now I crimp the open end to close the case. The finished tourbillion should be 5/8" long although they can be made up to 7/8" long. Now I take an awl and punch a small hole about 1/8" from the end into the side of the tourbillion. I place a 1/2" long piece of tissue fuse in the hole and put a small piece of masking tape over the hole. Only a small piece of fuse needs to be bare for the tourbillion to light. See Figure 1.

The tissue fuse I use is made of model airplane tissue. The tissue from the craft stores just won't work. I cut strips 3/4" wide and as long as I like.

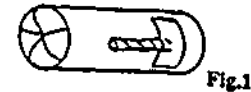


Fig. 1

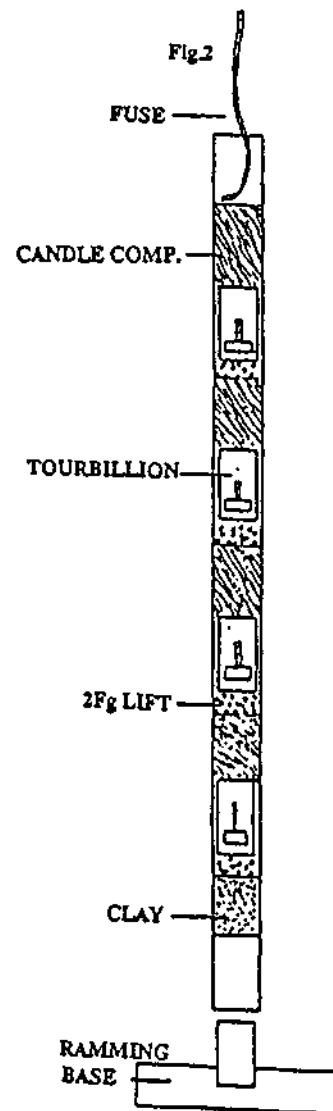


Fig. 2

# **THE BEST OF AFN III**

I wet the strip with a solution of meal and water, then dust lightly with meal powder. I weight one end of the tissue so it won't move and pick up the other end and twist until all the tissue is rolled up tightly. I allow the fuse to dry and cut it to the desired length.

The candle composition used for the fountain effect between the tourbillions is made from a formulation in Weingart's *Pyrotechnics*. The formula below has been converted from its original form of pounds to ounces.

Potassium nitrate	11 oz.
Charcoal, fine	7
Flowers of sulfur	4
Dextrin	0.64
Water	5 oz. by volume

After I sieve the dry ingredients three times through a 30 mesh sieve, I add the water and run the wet mix through a window screen, then dry in the sun.

With all components ready I begin the construction. I plug the bottom of the candle tube with 1/2 teaspoon of clay and ram it tight, then insert 1/2 teaspoon of hot homemade polvorone or 1 scoop of 2Fg black powder. The scoop size is 1/4" diameter by 1" deep. Now I place a tourbillion in the tube and make sure it sits on top of the lift charge. I place 1/4 to 1/2 teaspoon of candle composition in the tube and ram with six light blows of a small mallet. I repeat this process until the candle is full. It should hold 4 to 6 tourbillions, depending on the length of the tourbillion and the amount of candle composition used. I find it important to use just a little more lift on the last 2 or 3 tourbillions due to the increasing shortness of the tube. This reduces the pressure build-up and therefore more lift is needed (about 1/2 as much more than the first few lifts works well). After I ram the final scoop of candle composition, I place a tissue or visco fuse in the tube so it touches the composition, making sure the fuse extends far enough out of the tube for 3 to 6 seconds of burn time. This tourbillion candle needs no internal fusing. Ignition of the lift by the candle comp, which is separated by the 5/8" length of the tourbillion, seems to never fail. MP

## GLITTERING SPARKLERS

Over the past ten years or so, I have run the gamut of fireworks from fountains to 12" round shells with a few Dragon Egg's thrown in. Well, here I am back to one of my first loves, sparklers. Over the years I have tried many sparkler formulas, but there is only one that stands out to me. It comes from Tenney L. Davis' *The Chemistry of Powder and Explosives*, pg. 117.

To produce these beautiful sparklers I use the following formula:

Potassium Nitrate	
Sulfur	10
Antimony trisulfide	10
Dextrin	10
Barium Nitrate	17
Charcoal (Air float)	10
Aluminum, 12 micron	5

- Bamboo skewers 12".
- PVC pipe, 1" i.d. or larger, 14" long, plugged at one end.
- A funnel to fill the PVC pipe with the sparkler composition.
- Staple gun to attach bamboo skewers to a 1x2 for dipping.

I mix 500 grams of this composition to produce about 100 sparklers. The mix is moistened until it sticks to the bamboo and is smooth. I retain about 50 grams of dry composition for adjustment of the mix. When the comp. is mixed, I fill the PVC pipe with comp, and dip the bamboo. I dip the sparklers at least 3 times, with about 30 minutes between dipping, depending on the outside temperature. Then I dry them for three or four days and ENJOY.

Just one hint: I find these sparklers to be extremely flammable. To stop back fires on these sparklers, after they have completely dried, I spray them with a 10% nitrocellulose lacquer solution. BJV

## SMOKE OF A DIFFERENT COLOR

*The Best of AFN II* contains some iodine-based smoke formulations. Bennett's *Chemical Formulary*, published by Chemical Publishing Co. has some too. Let's have another look at iodine-based smoke.

The formulas given in the *Chemical Formulary* have very little descriptive text, and little reference to their origins. For example, one volume contains a lot of pyrotechnic formulas which have obviously been obtained from Weingart but with no reference to any of Weingart's work. Fortunately, the iodine-based smokes given have patent number references and thus more information can possibly be obtained by consulting the original patents.

None of these formulas use iodine itself but rather use iodine compounds in the form of iodides or iodates. Here they are:

### PINK SMOKE

(ref. The Chemical Formulary, Vol. V, 1941) U.S. Patent 2,091,977.

#### Formula #1

Calcium salicide	4
Potassium iodide	6
Potassium chromate	1

#### Formula #2

Magnesium	5
Calcium iodate	13
Potassium chlorate	2

### SMOKE FORMING COMPOSITIONS

(ref. The Chemical Formulary, Vol. XIII, 1967) U.S. Patent 2,995,526.

Most of these formulas took the form of metallic salt, alkali iodate, alkali iodide, alkali chlorate or perchlorate, sulfur (depends on metallic salt used).

Similar formulas were obtained by substituting other halogen (fluorine or bromine) compounds for the iodine compounds. These are beyond the

scope of this discussion. Some examples of these formulas are:

#### Lemon colored smoke

Calcium stearate	3
Potassium iodate	5
Potassium iodide	5
Potassium chlorate	17

#### Deep Violet colored smoke

Cuprous oxide	1
Potassium iodate	1
Potassium iodide	1
Potassium chlorate	2 - 2.5
Sulfur	1

(This mixture burns with a blue flame).

#### Yellow-Green colored smoke

Antimony powder	0.8
Willow charcoal	0.5
Potassium iodate	1
Potassium iodide	1

#### Pale Peach colored smoke

Cadmium stearate	3
Potassium iodate	2-3
Potassium iodide	2-3
Potassium chlorate	9-11

(Cadmium ricinoleate can be substituted for the cadmium stearate. The smoke color varies between pale peach and flesh colored).

#### Pink-White colored smoke

Copper stearate	5
Potassium iodate	4
Sodium iodide	2
Potassium chlorate	15

(Gives a pink-white smoke streaked with orange-brown).

#### Heavy White smoke

Barium stearate	3
Potassium iodate	2-3.5
Potassium iodide	2-3.5
Potassium chlorate	10-15

### Gray to Orange-Brown smoke

Ammonium iodide	1
Ammonium carbonate	0.5
Potassium iodate	0.5
Potassium iodide	1
Potassium chlorate	0.5 - 1.5
Sulfur	1

(The smoke color depends on the amount of potassium chlorate. If only 0.5 parts are used, the smoke color is gray tinged with yellow. This changes to gray tinged with green and an orange-brown color as the amount of potassium chlorate is increased. If 1.5 parts are used, the color is orange-brown.)

By no means are these the only iodine-based formulas given. Others used compounds from the more exotic elements such as beryllium, bismuth, cerium, cobalt, columbium, germanium and gold. Such compounds would not only be hard to find, but in some cases, prohibitively expensive.

Note that some of these formulations use both chlorates and sulfur and should be treated with the extreme caution needed. Note too that potassium iodate is a powerful oxidizing agent. Certain formulas which contain toxic substances such as arsenic have been deliberately omitted but this does not mean that the smokes produced by the formulas given are safe to inhale. Antimony is toxic and it is not advisable to breathe in smoke from a mix containing antimony. Similar precautions are advisable with mixes containing any metallic salt. It is best to err on the side of caution and avoid breathing in any of the smokes described here.

I have not tried any of these formulas and personally doubt that they provide viable alternatives to the tried-and-tested dye-based formulas.

ImM

## FIRE BALLOONS

This is for all you pyros who don't have access to chemicals or Class C items. This idea was demonstrated to me by Nancy Henk, of Detroit. Her father, Alfred, during WW II found himself without fireworks and with a family to entertain one 4th of July evening.

The effect: A fiery ball ascends, turning into a glowing orb with faces and cracks of volcanic rivulets changing with each moment until finally breaking up 50 - 75 feet in the air. Perhaps I missing my calling and should exercise hyperbole by writing descriptions for fireworks catalogs. Anyway, here's how it's done:

I take a common double sheet of newspaper (a single sheet, that is) and cut off a strip along one side so that I end up with a square sheet of newsprint. Then I bring all four corners together so that they very slightly overlap. I sew them together with needle and thread; one or two loops will do. I've even used rubber cement with success. At this point I have an unfolded envelope joined at the center. (By unfolded I mean that it should have no creases). That's it.

I take this loose, bag-like construction outside, far away from flammables or buildings, and make sure there is no wind. I place the fire balloon so that the slits and sewn area are resting on the ground. Now here's the trick - light all four corners at once. This may require a friend's help.

As the fire balloon lights and consumes itself, the heat and sudden lightness cause the still-burning ash to take off vertically and zoom gracefully upward with surprising speed. The colors are mainly yellows and golds. I wonder what the addition of some artificer's powder would do for its limited palette.

Something's amiss if it takes more than a few minutes to construct a fire balloon. And when you watch it glide into the heavens, think of a 4th long ago when there were no fireworks to be had, and a child's memories which bring this story to you on this Independence Day. eeh

## MICRO MINES

Micro mines are miniature fireworks. Like larger mines, they can produce a variety of effects.

Micro mines are not limited to the special formulas for micro stars that work in fountains. Virtually any star formula can be made into these micro stars and produce beautiful effects, but the main difficulty is ignition. As a rule, the micro stars will not light without priming, which must, of course, be coated on the micro stars. Pulverone, H3, and perchlorate-charcoal primes will all work.

The mines are made of common 1/2" bore, 1 1/2" long spiral wound tubes, such as may be used in salutes. All sorts of wad and load techniques were tried with different micro star formulas with poor results until a special nosing of paper was added to the tubes before they were glued to the wooden boards. This nosing must extend beyond the body of the tube for two or three inches. The tubes are charged with grain black powder, very small charges, then about half filled with primed micro stars.

The real trick is the special folding of the paper nosing: three or four creases, collapsing the nosing tube, a slight twist, and folding over a little above the main tube.

The best fusing results were obtained by fusing from the top of the mine tube, piercing the nosing near the mouth of the main tube. The unfolding of the paper nosing takes just enough time to ignite the priming, without producing too much pressure. Fast and violent prime, such as H3, may eliminate the need for other propellant. These little mines are quiet and produce a nice effects. They can even be reloaded.

With electric ignition, small boards equipped with a good number of these mines make a nice ground piece. Since the tops are fairly well sealed against fire from neighboring tubes, they can be fired like a comet rack, with visco fuses taped to a long piece of visco that reaches all the tubes.

Gummed paper tape can be used to make the nosing. The tubes can be simply glued to a board

or equipped with pieces of dowel and the units stood in holes drilled in a board. The dowel technique makes reusing and renosing easy.

The most important tricks are to light the top of the star charge, and the technique to crimp and fold the paper nosing.

This is an excellent beginner item and perfecting them is a challenge in priming and ignition. Skills developed have obvious uses on other micro star fireworks. RK

## ENHANCING SUCCESSIVE HAPPY NEWS EFFECT

At the very end of a PGI convention, I ran into a friend on the way to the storage facility and he showed me a pack of 180 *Successive Happy News*. He said, "You really ought to try these - they make a bright color just before the noise." I must say that I found his description hard to imagine, and in the midst of mental retro-engineering, I bought a pack. Sure enough, they did the hard-to-imagine feat of shooting two balls of color before the bang.

The effect is simple enough to produce. It involves inserting a lady cracker into a paper straw and then putting two round 1/8" mag stars on top of the cracker with a bit of wadded paper to hold it all together. The fuse lies between the straw wall and the stars so as to light them first.

Here's a really great effect I made with these crackers. I tied a long pack of 180 onto a vertical wheel, then fused it so the crackers would start about 5 seconds into the wheel rotation. The centrifugal force threw the mag stars in a 10-foot circle around the wheel, giving an effect that will be long remembered after the show was over. I tied the crackers to the diameter of the wheel, not the circumference, eeh



## PROBLEMS WITH GOLD SPARKLER MANUFACTURE AND COATING ALTERNATIVES FOR COMPOSITIONS CONTAINING IRON/STEEL POWDERS.

Just before the holidays, I attempted to try my hand at making some sparklers. I had intended to give them out as Christmas gifts (stocking stuffers). But, due to the inevitable pitfalls that await the hobbyist at his first attempt at anything, it was the beginning of January before I was able to make any that were even ignitable. So much for stocking stuffers! The purpose of this article is to point out some of the problems that I encountered and how others who may wish to construct these devices might avoid them. It bears mentioning that, although there are a number of fine books available on the subject of pyrotechnics, most contain precious little on the matter of compounding or of particle size/types used. A formula and a brief description is usually all that's given, the rest being left to the readers imagination. For the experienced pyrotechnician, this is no problem, as he/she is aware of the correct procedures to employ. But for the budding pyrotechnician, weeks of trial and error testing will lay ahead, with successful results usually dependent on the quality of the advice available from their peers. I have found this to be true in nearly every field of endeavor I have undertaken. Most text books and technical manuals run a distant second to common sense, luck and sound advice from experts in the value of their contribution to the process of learning nearly any subject.

There are various reasons for this and a feature article could be written on that topic alone. Suffice to say that, in pyrotechnics at least, the situation is improving. This is due mainly to the efforts of a handful of individuals and we all owe them an enormous debt. We can pay back a portion of this by subscribing to their publications and, perhaps more importantly, by contributing articles for publication.

Having concocted various types of unignitable chemical soups, I do not yet consider myself to be experienced in this field; inevitably, I seek the advice of someone who knows. The late Dennis Manochio of *The Fourth of July Americana* &

*Fireworks Museum* was one of these, and I thank him for his helpful advice on this subject.

The formula I elected to employ for my sparklers can be credited to the Reverend Ron Lancaster. It is found on page 178 of his book, *Fireworks Principles and Practice*:

Barium nitrate	50%
Dextrin	10%
Steel filings	30%
Aluminum	8%
Charcoal	0.5%
Boric acid	1.5%

The two areas that I ran into trouble with this formula concerned the steel filings and the aluminum. Readers will no doubt recall the warnings in nearly every formula that contains steel or iron filings and nitrates: the steel must be coated with paraffin or linseed oil, or the device will be ruined by the reaction between the two. Reportedly, the steel is oxidized by the nitrate, whose energy (oxygen) is depleted in the process. Well, this does happen, but how soon it happens is dependent on several variables. In the case of sparklers, which don't have much mass and are dried fairly quickly, I'm told that the iron/steel won't begin to oxidize for about six months or so. Consequently, if you intend to use them before then, you don't have to bother coating the steel with anything. This is a good thing, because the process of coating iron/steel can be messy and complicated. Since they are slow burning fuels, the thickness of any coating on iron or steel needs to be very thin, or it will greatly slow down the burning speed of the mixture - if it can be ignited at all. Pouring linseed oil onto powdered steel, as I can attest, will result in a composition that is unignitable. If one attempts to burn off the excess linseed oil by heating the steel in a pan on a stove, you will produce one of the most noxious odors known to man. I would imagine that when properly performed, this is a slow process and so should be done outside. However,



I'm not sure how long it actually takes, or how you determine when it's been "cooked" enough.

The other popularly publicized method of coating the steel is to use paraffin. Again, this is a slow burning fuel and needs to result as a very thin coating. I didn't have any paraffin and was not about to begin what was sure to be a 4 - 5 hour search for yet another common enough sounding substance that proves impossible to locate. Good God, I must spend half my waking hours running around or on the phone in yet another quest for some material that was as common as table salt thirty years ago, but as hard to find today as a real hardware store. However, this process does prove useful as an apprenticeship to anyone considering entering the home improvement store/retail clerk field, as I can state without hesitation that I know every aisle in every home improvement, lumber yard or hobby/crafts store within twenty miles like the back of my hand....

But back to paraffin, which as you recall, I didn't have. So I tried the closest available alternative: I simply melted down a candle and mixed it with a pound or so of powdered iron. After it cooled, I had a very heavy and oddly shaped candle, minus the wick. A word to the wise: do not try to grate this stuff while it is still soft through your expensive brass mixing screens, or they will become hopelessly encrusted with the wax after it dries. The proper solvent to cut wax costs about five dollars a quart and you will need about ten dollars worth to clean your ten dollar brass screen. Anyway, next I tried re-heating the wax/steel "blob" to a molten state and filtering it with the wax solvent, in an attempt to remove the excess wax. This resulted in a promising substance that looked like the original powdered steel. However, after incorporating it into the formula, I was left with another unignitable mixture. I can only guess that the coating was still too thick and was slowing down the burn rate.

At this point I received Dennis' advice and mixed a batch of composition without coating the steel with anything. Low and behold, it was ignitable, although it burned very slowly. At last I felt I was now on the right track! I just had to speed up the burn rate and I was sure I would have a decent sparkler mix. I finally achieved this by

switching from atomized aluminum to a fine, bright flake. I now had a mix that burned at medium speed and shot out gold sparks that energetically fire branched. It is even ignitable while it is still damp.

Dennis stated that those wishing to coat powdered steel or iron on a home workshop scale should use silicone spray (e.g., WD-40). The powdered iron/steel is spread out in a thin layer on a sheet of paper and is lightly misted with the spray. The powder is allowed to dry, mixed up, then spread out and sprayed again. The more times this is repeated, the more the powder will be protected. But, eventually the coating will become too thick and the burn rate will be inhibited, so there is a certain degree of trial and error to this process. Remember though, if the device has a low mass, can be dried quickly and will be used within six months or so, no coating is necessary. I would imagine that sparklers, small stars and small dry-rammed gerbes/drivers would fit into this category.

Now that I'm aware of this, steel/iron powder may become a very popular spark producing or fuel component in my pyrotechnic mixtures. It produces attractive amber/gold sparks (depending on ignition temperature) and can be had for the asking at nearly any automotive repair facility that owns a brake lathe. You need only sift out the larger particle sizes (and the rust!) and it's ready to use. Even if it is necessary to coat it, the silicone spray method sounds quite easy, at least when compared to previous methods.

In our profession, as in others, there is a decided tendency for newcomers to attempt to begin at the same level as their more experienced peers. Since there are other more sophisticated metals that have generally replaced iron/steel in the advanced pyrotechnician's repertoire, we find the beginner also discarding these "old" substances. Indeed, one feels somewhat out of place in the (current) pyrotechnic community if one is not working on 8" chrysanthemums with triple color changing glitter stars, strobe comets or the latest crackling micro star formula. However, we need to learn how to walk before we can run. Getting "old", vague (but safe) formulas to work serve as

# THE BEST OF AFN III

a basis from which to proceed forward on, as they provide an invaluable education. Perhaps this is one of the reasons why the compounding instructions in most books are vague.

In summary, here is the same formula as before, but with the inclusion of specific particle sizes/types:

Barium Nitrate, > 100 mesh	
Dextrin, yellow	
Steel, uncoated, >100 mesh	
Aluminum, 20u	
>325 mesh flake	
Charcoal, airfloat	0.5%
Boric Acid	1.5%
Water/alcohol, 70%/30%	ad lib

Remember that barium nitrate is poisonous. Also, the fine flake aluminum will become airborne no matter how careful one is: I wear rubber gloves and a respirator (with the correct filter cartridges), as well as safety goggles when working with this mixture.

I begin by weighing the individual chemicals on a reliable scale, then carefully place the chemicals in a bowl and mix slowly but thoroughly with a spatula. These cautious mixing instructions are not due to the sensitivity of this formula (although cautious mixing is a good habit, regardless of the formula), but more to prevent an excess of particles from becoming airborne. In fact, mixing this formula with the bowl inside a large plastic bag, or better still, outdoors, is a good idea. Next, I add the water/alcohol in small increments while mixing with the spatula, until the composition is about the consistency of cold maple syrup. It should now be a smooth, thoroughly homogeneous mix.

The wire used to coat the mixture on should be 20 gauge and about six inches long. Dipping small quantities of wire is best done by pouring the composition into a glass and tilting it on it's side. The wires are now dipped one by one. It will be noted that how fast and at what angle the wire is removed from the mix will determine how thick the coating will be. 2 - 3 thin coats seem to

work better than one thick one and in fact the first coat will be quite thin, as the mixture has trouble sticking to the bare wire. Successive dip-pings will coat the wire much thicker.

During the dipping process the mix will gradually become thicker and so some water/alcohol will need to be added from time to time. Also, the iron/steel will tend to settle to the bottom of the mix, especially if too much water was added. I periodically agitating the mix to alleviate this.

After each wire is dipped the uncoated end is stuck in a block of styrofoam, where it should remain in a vertical position until dry (about 24 hours). After drying, they can dipped again and will probably need a third dipping as well. The final thickness should be about the same as a commercially made sparkler (approximately 3/16") - that is, if one wants to be able to hold the sparkler in his hand while it burns, without being burned himself. The last drying time is not critical as these sparklers can be ignited while still damp. However, they are easier to light if dried for 2 - 3 days, perhaps longer if the air is humid.

A nice feature about these sparklers is that they produce no smoke while burning and so, with adequate caution, may be used indoors. SAR

## TIMING TIPS

One inch long timed siatines... Well, they're too short to time from inside with extra clay or rammed sawdust, so if an inch of match is left outside of the clay, this can be coated with Liquid Nails that is slightly thinned with acetone. The coating can be adjusted to about five different timings. The procedure has the advantage of maintaining the excellent ignition qualities of black match, while the miniaturization allows as many as fifteen hefty reports in a five inch ball shell. SW



## INFORMAL 8 OZ. ROCKETS

I needed a small Class C rocket to liven a celebration. Here is one which never bothered the neighbors. I rammed some 8 oz. rocket motors with the following mixture:

### "IT ALWAYS WORKS" ROCKET FUEL

Potassium nitrate	17
Sulfur (flour only)	4
Charcoal (air float)	4
Charcoal (80 mesh)	3
Charcoal (36 mesh)	2

I use bentonite clay for the nozzle and top plug. I mark my rammers with correction fluid so they don't jam on the spindles. I get excellent rocket tools from a gentleman in Watsonville, California. I buy six spindles and mount them on a railroad track baseplate. I can fit six or more spindles where the track rests. I leave enough room around the spindles so that the entire motor casing is supported by the baseplate.

I use stainless steel, flat head screws to mount the spindles, countersinking the screwheads with a 1/2" diameter drill bit, so that the plate will rest flat on the support base, but countersinking isn't absolutely necessary.

A support base for the plate can be made by cutting 2x12" boards and screwing the pieces together to form a sandwich of the desired height. Or a heavy square timber could be squared up on both ends with difficulty. I don't make it too tall as working with my arms above waist height is tough.

I screw the railroad plate to the support base. I use big washers rather than drilling 2 more holes in the railroad steel. Since the top and bottom surfaces of the plate often are not parallel, I make the holes slightly larger than the screws. Then the spindles will rest flat on the top surface.

Building rockets in groups of 6 or 9 is faster and much easier than singly.

I buy plastic fin sets and cut them so that they can be sprung open to fit on the motor case. I hot glue a 1.5" piece of plastic soda straw in the gap between the cut fin ends, then run a bead of hot glue around the top of the fins. I sometimes use cane and masking tape for stability. Any rigid plant stalk will stabilize a rocket. Hollow plant stalks are ideal because they are very light.

I hold a 1.5" long piece of fuse in with a small piece of tape secured to a fin.

Next I needed a payload case, but as they are bums to build, I don't. I buy spiral wound paper cases with a 3/4" inside diameter and about 2.5" or so long. I clean the top edge of a rocket motor then glue the cases using hot melt glue. I plug the casing with a paper plug of the proper diameter, or sometimes I buy plastic nose cones (the large ones from Firefox work with a little effort on the 3/4" internal diameter spiral wound tubes).

For some payloads, I often include up to 10% pyro flake titanium. I think that 10-20 mesh works best.

I never use salute mixes for a payload. The perchlorates could explode on impact with the ground or water. Chlorate flash mixes, such as those in Davis' book *Chemistry of Powder & Explosives*, are too dangerous to mix or use.

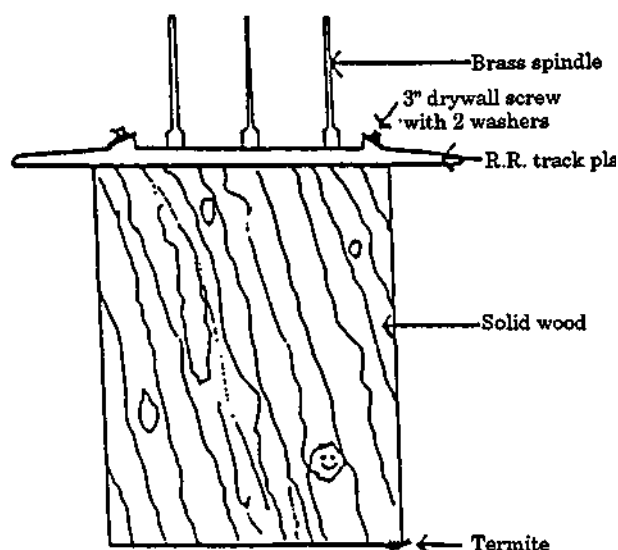
I make sure to tape on the nose cone, so as to prevent any leakage.

I always launch these rockets with the aid of a 3/16" diameter steel rod about 3 feet long. I get away from the launch area in case the heading ignites prematurely. I always remember to use a plastic spoon and plastic funnel when filling the payload case with any pyrotechnic material. Also, I don't scrape the plastic spoon against the bottom of the container when filling the heading. I always wear a full face shield when using flammable mixtures, and remember, even an 8 oz. rocket comes down hard. I've got a dent in my car hood to prove it.

# THE BEST OF AFN III

I do each step of the construction process with a group of rockets. It is much faster than trying to complete one rocket at a time. I easily mix various headings to keep the interest of the spectators high through variety. Longer payload cases are also commercially available, but I make sure the rocket reaches a safe height before the heading ignites.

I'm always careful not to overload the headings. A little extra payload weight can radically degrade rocket performance and put burning stars in a crowd of friends -- or at least, a group of people who used to be friends. BS



## THOSE DAMP ROCKETS!

I never had a problem with rocket engines until I moved to Florida. For over 25 years I've used the loading tools I bought from the now-defunct Caseco, and after experimentation I found that the right mixture for 4 oz. engines using those tools is 20 parts potassium nitrate, 10 parts airfloat charcoal, and 3 parts sulfur. This mixture always worked perfectly - until I came to Florida.

In this very humid climate the charcoal picks up moisture, and the rockets just fizzle out on the launch pad (or else barely get off the ground before falling back). This was a little embarrassing when my advance-placement chemistry class and their rockets were on WPEC-TV, the ABC affiliate.

I tried letting the charcoal dry out on newspaper indoors, and even put finished engines in a drying oven at 110° F. for 48 hours. Nothing seemed to help.

Finally, I decided that there must be another solution. I raised the percentage of potassium nitrate to 65 or 70%, hoping to increase the burn rate. Now the rockets are starting to work OK once again. ST

## ROCKET TIP

End burning rockets are nothing new, but since I've been making them, I'm really amazed at how simply and quickly they are made. They are actually nothing more than a gerb with solid commercial Meal D as the fuel. They fly quick and high and the only drawback that I can see is the fact that the fuel must be extremely fast burning because of the lack of the hollow central core. This, of course, eliminates any possibility of additives to produce a spark trail. SW



## BLENDER ROCKETS

After perfecting blender comets, [*Blender Comets*, AFN, June, '89 or page 70, *Best of AFN II*] the next step must be blender rockets. Having vowed to report this technology after it is perfected, I now realize if I wait for perfection we will all be gray Greenmen before this is published, so here it is. With the aid of my trusty garage sale blender I whip up 3 pound rockets at 500 each.

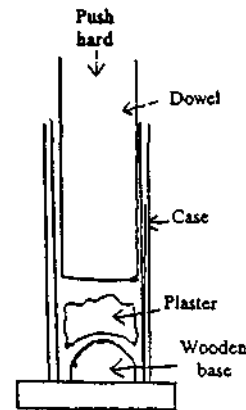
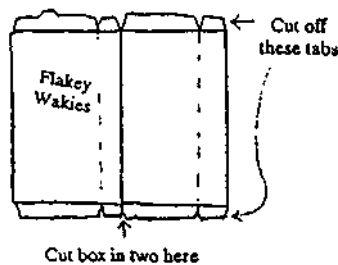
### CASES FIRST

Rather than spend 500 for a case, I roll my own from cereal boxes. After flattening the box and trimming off the top and bottom, I cut it in half along two creases. Thus I get 2 similar sheets of cardboard, sufficient for one case.

I dismember about 10 boxes in this fashion and anoint their inkless side with wheat paste. I roll them tightly around a 1" dowel rod, first one sheet then the other. The grain is parallel to the dowel, with the pasted side in, pretty side out. Thus I create rockets adorned with Snap, Crackle and Pop; rockets fortified with vitamins and potassium, and so on. The premium cereal, of course, is "KABOOM".

The paste acts as a lubricant, allowing the case and dowel to be slid apart. It also lubricates my hands, so a dry rag is handy to help my pasty paw grip the rod.

I now mix some non-shrinking plaster and water to a playdough-like consistency, and force it into the damp case. The optional wooden base is whittled from scraps. I press forcibly to bulge ever so slightly but not to rupture the case. Quickly, before the plaster hardens, I form the nozzle with a 5/16" rod or twist drill.



### ROCKET COMP FORMULA

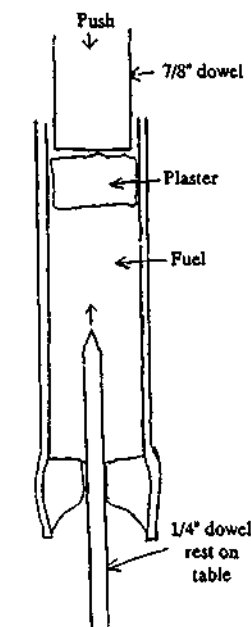
An efficiency minded pyro rebuked me for my wasteful surplus of fuel in this mixture. Lest I suffer reiterative verbal castigation, let me clarify that specific thrust is not the objective. The extra charcoal makes a nice tail. Furthermore, charcoal briquettes are the best deal around, because each bag contains several square feet of real estate in the form of clay, which adds a pretty dross to the tail.

Water	250 grams
Potassium nitrate	600 grams
Charcoal briquettes	300 grams
(sliced and diced to 4 mesh)	
Sulfur	100 grams

### HERE'S THE SECRET

Now I am prepared to commit chemistry. I heat the potassium nitrate and water until dissolved (near boiling). Into the blender it goes, then I start the motor and add the charcoal and sulfur.

Since we're in the kitchen, it would naturally occur to such masters of modern technology to pop the potassium nitrate/water in the microwave. A pyro friend writes that this is effective, but should not be attempted on a paper plate. Once soaked with nitrate, the paper gleefully acts as fuel. If you enjoy the hearty aroma of simmering nitrate soup, wait till you get a snootfull of that. Move over galloping gourmet... enter exploding glutton.



After blending the gunpowder daiquiri for 5-10 minutes, I frequently take a sample outside and ignite it. I find it to be ignitable even when wet, and I wonder what sort of fire would result from a whole kilo burning in a blender. Would it boil off the water, then explode? Probably not, but the thought inspires me to re-evaluate MY safety precautions: Fill the water bucket, clear out the flammables, put on the face shield, and above all - keep the women out of the kitchen.

Yet another pyro friend did not keep the Mrs. away when making his first batch of blender boom. When she learned that he was verily not preparing her a chocolate milk shake, she verily did explode.

I ladle the hot glop into all ten cases to within 2" of the top. That annoying drip-drip-drip of propellant oozing out the nozzle can be cured by first loading some cool propellant in the bottom. Tapping the rocket on the table helps eliminate air bubbles. I scrape excess propellant off the inside wall where the top plug is to seat and force dampened plaster in with a 7/8" dowel rod. Then I push a pointed 1/4" rod through the nozzle. This pushes the propellant tightly against the inner wall and leaves a centerbore, or combustion

chamber. The dowel is withdrawn after the propellant cools.

No ramming is necessary in this process, which allows weaker homemade cases to be used. While my cases are too thin to withstand ramming, I have had only one out of a hundred rupture when fired.

While Mr. Pyro Friend was blowing up his wife's microwave, I was devising new ways to load the propellant. The soup in the blender is runny enough, so why not suck it into the case with the vacuum cleaner? Diabolical! In a matter of seconds the blender was empty, the rocket was a mess, and the vacuum cleaner was full of ooey-goey gunpowder goop. Try explaining that one to the Mrs... "Honey, why does the vacuum smell like eggs?"..."KER-BOOM!"

After the rockets have dried a couple weeks I attach sticks made of wood lath cut twice lengthwise. The result is a cheap rocket that produces a pretty tail when it works and a pretty comet or gerb when it fails. As I never announce which result is intended before firing, most spectators construe the surprise effect as a success.

PM

## PRIMING STARS ON ONLY ONE SIDE

Priming micro stars on one side only can be done by arranging the stars in a single layer, crowded together, by holding the box or tray at an angle and shaking or tapping the box or tray so that they arrange themselves. This layer of stars is sprayed with solvent suitable for the priming binder, then priming dust is sprinkled on. After a few seconds they are shaken to flatten the priming to the microstars and round them out for best fire transmission. This trick was stolen from the Chinese with the help of my little microscope.

LSO

## ANOTHER LOOK AT ROCKETS

There has been much written on rocket construction over the years, some good and some barely informative. I hope to show things that will be helpful in making good rockets, some of which I have never seen in print.

The rocket is one of the oldest of all fireworks, and down through the ages it has required considerable skill to make it so as to function properly.

### SIZES

As described in Brock's *History of Pyrotechnics*, page 94, rocket sizes were figured by the weight of a lead ball which would fit the inside of the mold which holds the tube for ramming/pressing (not which would fit the bore of the tube as some have said). Why the pyrotechnists chose this method of sizing is anyone's guess. I won't list the standard sizes here; most books and supply catalogs list them.

### SPINDLES

The spindles should be made of either aluminum or stainless steel - preferably stainless. They can be made on a lathe, or bought from a pyro supplier of tools.

### POUNDING BASE

The pounding base should be very solid like a tree stump, or a piece of tree log about 12" dia. This is an important detail. It should be placed on very solid ground or a concrete base. If it is to be set up indoors, like in a shed, I would hang a fireproof material, like sheet metal, overhead and on the nearest wall(s), in case a rocket should take fire while being charged. It would act like a big fountain. Think about it.

### MALLET

Drifts should be made of brass or aluminum, in various lengths, and bored to fit over the spindle. See Weingart's *Pyrotechnics*, page 91. All of the drifts should be made like the drawing (fig. 1) except the longest drift for the clay nozzle. Rockets

seem to have better performance if the inside of the nozzle is tapered, so the clay drift should have a taper of about 30° (fig. 2).

### SCOOPS

Scoops can be bought or they can be made if the maker knows how to solder. It is difficult to give a size. They are best made from copper, brass, or aluminum. It is best to make some out of chip-board first, to get the right size for the application. Then the pattern can be used to make the metal scoops.

The easiest way to make one is to take a piece of copper or brass tubing, saw it down the middle, then solder a metal slug on the end. Then a piece of heavy wire, like a piece of brazing rod, is soldered to the end as a handle.

### STICKS

Sticks must be square, not round, so as to keep the rocket from wobbling erratically while ascending. Forget dowel rods. The best way to figure diameter is to look at the diameter of the nozzle. For instance, a rocket with a nozzle of 3/8" would use a 3/8" square stick. As for length, there seem to be a lot of ideas. The main thing is to not cut them too short. They do need to stabilize the rocket on its ascent. What I've seen work best is:

4 oz. - 18"	1 lb. - 48"
8 oz. - 24"	4 lb. - 66"

Any other sizes can be figured from these numbers. The stick is glued or taped on the tube for about 3/4 of the length. It needs to be fastened well, but I wouldn't use wire, which is a hazard and also may crack the fuel core when it is tightened.

### CLAY

Bentonite day is best, but fireclay works good too.

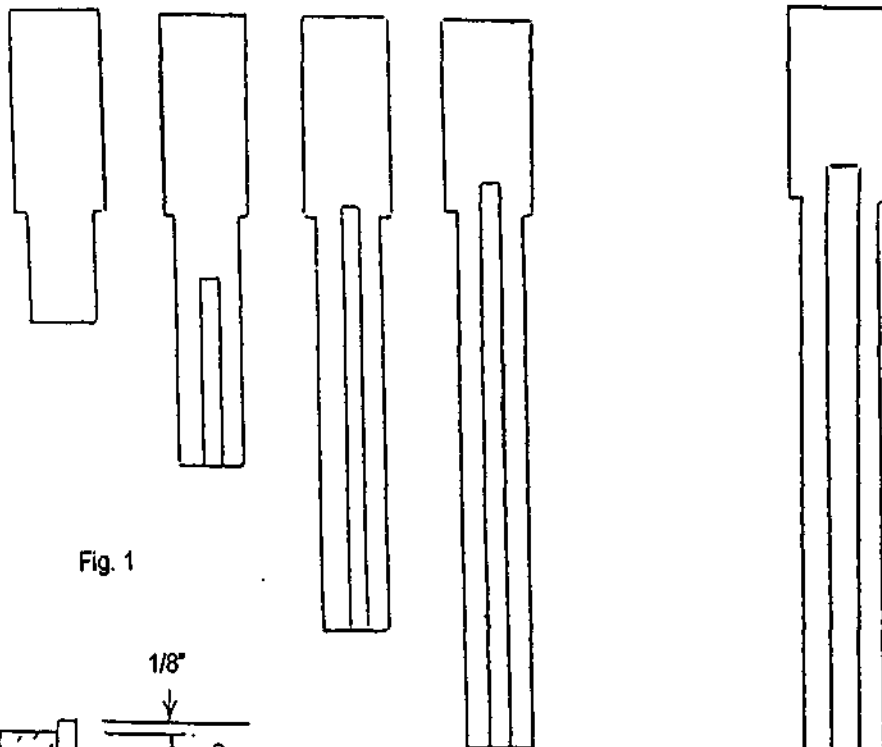


Fig. 1

Fig. 2

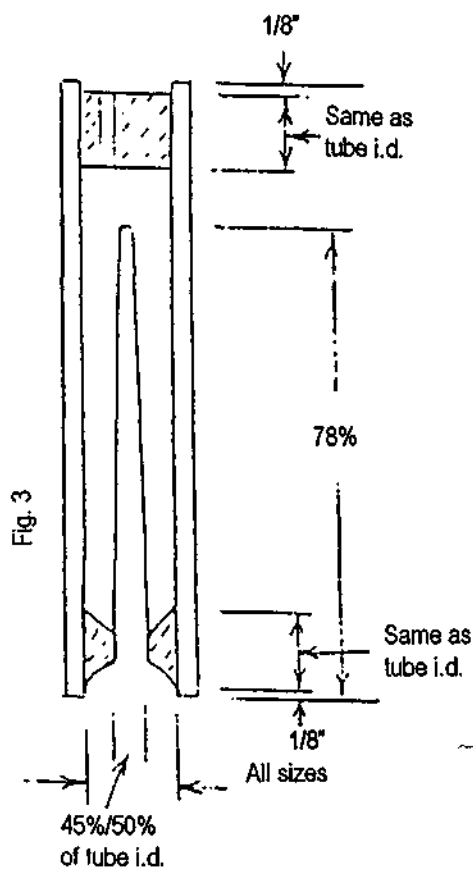


Fig. 3

Top of cavity is  
1/2 dia. of bottom

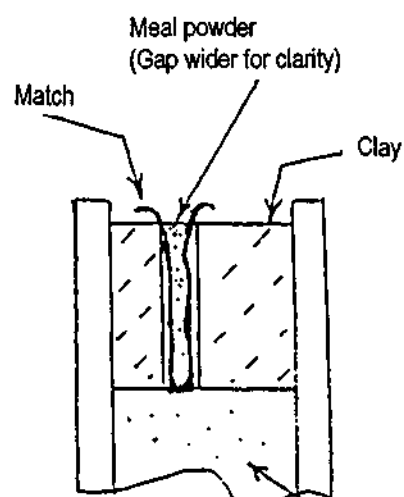


Fig. 4



## ENGINE DESIGN

We've all seen rockets going up, arching over, then coming back down, or blowing through either end. This may be of some help: First, the nozzle. Most books and drawings show the nozzle flat on the inside. I think it is a big help to form it funnel-shaped, approximately 30°, as was stated before, and to make the outside end concave, per fig. 3. This should let the gasses flow out smoothly. Look at the NASA rocket engines. Next, the clay nozzle should be at least the same height at its top outside edge, as the case inside diameter, per fig. 3. Finally, I believe there should also be a clay plug at the top to contain the gas pressure, again the same height as the i.d. of the case. I have had no failures since using this method. Using a thin clay plug, or no plug, too often allows a blow-through.

## THE FUEL

Most fuels are potassium nitrate, charcoal, sulfur mixes. There is a great deal of information in print about the mixes and it is wise to try several to see what works for the builder. Here are some:

	4-8 oz.	1-2 lb.	4-6 lb.
Potassium nitrate	16	16	18
Mixed charcoal	9	12	12
Sulfur	4	3	3

A good mix for the charcoal is 50% air float, 25% 40 mesh, 25% 80 mesh. If the fuel burns too fast, it is necessary to either add more charcoal or cut back a little on the potassium nitrate.

The usual safety precautions are used as with any pyrotechnic composition. I like to screen my rocket mix three times. Some workers like to dampen the mix after screening. If I did that, I would use alcohol only, and dampen it very little, just enough to keep the dust down. To do otherwise would risk the fuel swelling and later shrinking and cracking, with the rocket exploding.

## PRESSING

A mold is necessary to keep the case from split-

ting in most instances when they are pressed in an arbor or hydraulic press. Since few AFN readers have such equipment, this article will deal only with ramming.

## RAMMING

Here is my technique. I pour in a scoop of clay. Using the long clay nozzle drift, I ram it solid with a few blows of the mallet. The nozzle will actually slightly expand into the tube sidewall. Then I pour in a scoop of fuel and ram it with several blows (for a smaller rocket and 30 to 35 firm blows for 4 - 6 pounders). Each fuel increment should compact to about the same height as the case i.d. Many small blows are better than a few heavy ones and I never rush here. Now before starting, I had measured and marked a spot near the top of the tube that is the tube i.d. plus 1/8". When the fuel reaches this spot, I stop. See fig. 3. I then add clay and ram to equal the tube i.d. That will leave 1/8" of tube left. I remove the case from the spindle, then bore a 1/4" hold off-center through the clay to communicate fire to the head. The way I like to do that is to use a 1/4" flat blade screwdriver and just twist back and forth. When the breakthrough to the fuel is felt, I stop as I want to just touch it.

Then I insert two pieces of bare match and tamp a little meal powder in between so as to wedge them firmly in place, per fig. 4. If I have properly left 1/8" of empty tube, I can bend the match over flat. That leaves the top of the tube flat to accept a disc, can, ball shell, or whatever kind of heading I choose. I won't get into headings in this article.

Please note that some tool sets have a special drift that pierces the clay plug as you ram it. Special care is needed when using this tool as it is necessary to get the clay solid enough and not pierce into the fuel. I haven't used one because I think boring is best. Also, for the clay, some people use grog (clay and ceramic supplies) mixed with clay, but I've been told that this mix is a bit hard on the tooling and is not really necessary. However, it does work well. RMHC

## SHELL BURST ROCKETS

Up until a few years ago the rockets I made I think were typical of most: A long motor to take the rocket as high as possible and a relatively small payload of stars or effects which pop out high in the sky. What changed my way of thinking was a box of rockets called *Rocket 25*, 15 medium and 10 large rockets from the German maker Zink. These and some other European rockets explode with the ferocity of a shell.

The techniques below will produce a rocket to truly invigorate the neighbors. Be warned that good performance is hard to achieve; everything has to be measured and carefully regulated. It is no good just dumping some flash powder into a standard rocket top. I've seen rockets from two of the big manufacturers which made this mistake, with embarrassing results. This article describes a 1/2" i.d. rocket (UK 1 oz., US 4 oz.), the easiest size. One needs to be able to make good motors as it would be stupid to attach these tops to anything not guaranteed to attain enough height.

Rocket i.d	1/2"	5/8"	3/4"
top mm	28x65	35x80	55x110
stars mm	4...5	5...6	7...9
mass stars g	25	55	110
flash burst g	3.5	4	5

### ROCKET TOP AND NOSE CONE

Short of buying an injection moulding machine there is no easy or quick way to make nose cones. Unlike the normal rocket top that simply pops off, the shell burst top is torn apart in a carefully controlled explosion. Kraft paper is OK for making the top; the paper sold for wallpaper lining is perhaps better but needs more layers. In either case it is essential to measure the strength of the paper. Using a spring balance and a 1 cm wide strip of paper, I measure the breaking strain both with and across the grain, then take the average. See *Fireworks The Art, Science and Technique*, p. 251. Then I apply Takeo Shimizu's formula  $N = 5.6 \times D/J$  where N will be the required number of turns. D is the diameter of the nose cone in cm and J is the average breaking strain of the paper in Kg/cm.

This formula in theory applies to the steady state, like a balloon or soap bubble and the dynamics of an explosion are different. However, in practice it is a good starting point. To make a nose cone, I take a 4" wide strip of paper and wind it around a 28mm diameter former (1-1/8" copper pipe is ideal). I use the formula above to calculate the number of turns required. The strong paper I use has an average breaking strain of 6 kg/cm so I need  $5.6 \times 2.8 / 6 = 2.6 = 3$  turns. Lining paper could need as many as 9. Now I cut as many strips as needed to length and paste well with wheat paste. I use a scrubbing brush to work the paste right in. I roll the paper around the former; a lick of PVA (white) glue will hold the edge down.

Now I slide the former 15mm back inside the tube and pinch the tube in 4 places to form a diamond shape (see fig. a.). I press down on top of each wing to fold flat as b. (look at the crimp on a shotgun shell for inspiration). I take a rod the same size as the OD of the motor, 3/4", and push into the tube, thus folding the crimp into the tube c. This takes a bit of practice at first but produces an integral top which makes a very good fit with the rocket motor, it's also 100 times quicker than making an adapter ring. I remove the former and set aside to partly dry.

The nose cone needs to be quite strong and is best made from a cardboard file folder. These have the advantage of coming in several colors. I mark and cut out a circle of 60mm diameter, punch the centre and cut a slot to the edge. Using PVA glue I turn two times to form a cone. There should now be a double thickness cone 30 mm at its base. Next I cut 15mm deep slots around the part dried rocket top to form a sort of crown shape (see fig. d) and using lots of white glue I push the top into the cone. I set it aside to dry, and with practice there will be a nice top of even breaking strength, about 250 psi in fact.

### STARS

There are three main factors to worry about: Mechanical strength, brightness, and priming.



## Mechanical strength:

Shimizu, p. 156, lists the strength of a number of stars when crushed with the flat end of a 3mm diameter rod. Such a test is easy to do with the aid of junior's Meccano set and some bathroom scales. From experiment the magic figure is 5 Kg.; less than this and the stars will be pulverized by the explosive compression. I also test the edge of the star. If the prime is not bonded properly, it can be torn off.

## Brightness:

There is much less room in a rocket top than a shell and so much less scope for fancy stars. I like to use a tailed star as bright as possible. The following formulas perform well cut as 4 mm cores. They are all basically Lancaster's formulas modified to suit the materials I had available.

I bind all of these with a 10% solution of shellac in alcohol, using as little as possible so as not to spoil the colors. The ideal way would be to use the plastic as the binding agent but all my attempts so far have resulted in a sticky mess. I have made stars of formula #a bound with lactose and water which, despite theory, have kept for 3 years. Not recommended, but interesting.

**#a Silver Cascade.** One of my favorites - the magnesium gives brightness. Other formulations work well using aluminum and barium nitrate.

**#b Deep red.** Works during the summer but goes wet by October. I would be pleased to hear from anyone who has a way round this drawback. Silver reds can be made with aluminum.

**#c Yellow illuminating.** I think the bag method (see below) should be used as this is basically a flash powder with 15% additional cryolite. I have changed the ratios of Lancaster's formula p.93 which did not work for me.

**#d.** This is a good deep green; the ratios are correct. Formulas using PVC/Parlon increase the chlorine donor to about 30% at the expense of the magnesium. (It is possible to make green with aluminum but barium chlorate must be used; you could also take a daily dip in a crocodile pond.)

Electric blue and violet so far have eluded me, so I use resin chlorate formulas and use fewer but larger stars.

	#a	#b	#c	#d	#k
Potassium nitrate	45				45
Barium nitrate			57	55	
Strontium nitrate		55			
Cryolite			14		
Magnesium 20 mesh	20	25		25	
Aluminum powder	20		19		10
Aluminum bronze					30
Sulfur	10		9		10
Home meal powder	5				5
Chlorovinyl acetate		20		20	
Boric acid			1		

## Priming:

Priming is essential. The star in the first quarter second goes from over 1000 psi through a vacuum and into a 100 mph air flow. Few (if any!) compositions survive. The priming must also be hot enough as metal fuel stars are hard to ignite. I use two steps. First I coat the cores in what I call prime #k, (Lancaster's electric streamer p.90 again). The type of aluminum is critical: I use what's called 'bronze powder silver' sold by paint pigment suppliers. It's not bronze of course but a very fine bright flake aluminum coated in stearine, and it's most obnoxious to handle. Prime #k should easily light with a match, if not you need finer aluminum. Prime #k makes an attractive star in its own right identical to the Spanish 'Case Blanca'. The Bright Gold Comet formula in *Best of AFN II* p. 65 also makes a good middle prime.

I spray the cores with the 10% shellac in alcohol and dust with #k until they are 6mm, then roll to about 8mm with home meal. The idea is not to have a sudden change over but a gradual transition from prime to meal. Rolled in one go they usually obligingly mix together without the need to make up little batches of 50/50 or whatever. The stars take a couple of days to dry. A well made star should survive being shot from a Roman candle with a 1/2 tsp of best black powder.

I prime stars containing chlorate with a single layer of the following composition after a suggest-

ion in an article by David Bleser.

Potassium Chlorate	52
Potassium Nitrate	8
Charcoal	30
Lampblack	10

The nitrate is added in solution and the mixture granulated in the normal way. When dry the composition can be passed through a fine mesh to give a good size for rolling.

### FLASH BURST

A swim with the crocodiles. Please read all the safety advice.

I use a mixture of potassium permanganate and bronze aluminum with some additional potassium nitrate to slow it down. There is an excellent article in the *Best of AFN II* where the author uses a mixture of fine and course potassium perchlorate with aluminum to get the same result with a less sensitive mix. I do not use sulphur so the powder can be used with nitrate or chlorate based stars.

Good ignition is analogous to what an engineer would call an impedance matching problem, raw flash is just too fast to light the stars. I cannot say what is the right amount of excess oxidizer to add as this is the variable used to fine tune the flash burst system. 10% may be a good place to start. The 1/2" i.d. rocket carries 25 grams of stars and 3.5 grams of flash burst.

### THE BAG METHOD

I use this method to mix anything dusty. I weigh out the ingredients and mix the oxidants and inert ingredients together. I place these directly in a grease proof paper bag (never plastic). I dump the fuel on top and gently screw the top shut. Now I turn the bag over 20 times and that's it! I label the bag with a felt tip pen. The mixture can be used directly from the bag and when empty the bag can be safely disposed of on the bonfire. This works particularly well with lampblack, is about the only way to cope with paint aluminum, and of course, helps with barium nitrate and other poisons. I would use the bag method if making flash powder for salutes, but for stars I

mix the flash powder after it's in the rocket!

### SAFE PRACTICE

I strictly follow this system for mixing and loading: I wear cotton clothes and gloves and eye protection and have a bucket of water on hand. I clear everything from the work table, star pumps, spatulas, even drifts can all become lethal shrapnel in an accident. Then I line up the cardboard tops for loading. It seems safe to mill or grind potassium perchlorate or potassium permanganate on its own. I now make use of a lucky fact that with the mix of oxidants I use and the brand of paint aluminum, one volume of oxidant plus one volume of aluminum is the correct proportion. So using a measure I put one spoon of oxidant in each rocket top and then one spoon of aluminum. Next the stars are added. Still keeping the rocket top upside down I push the motor into the top. I use white glue to stick the motor to the top.

When dry I turn the rocket right ways up and rotate it 10 times. The flash powder will be mixed perfectly in its own mini ball mill. There is just no need to sieve flash powder. This method uses the divide and rule safety technique, at no time is more than 5 grams of flash powder in contact. An accident with 5 grams of flash will hurt but it won't kill you.

Once, by way of education, we placed 'just' 1 oz. of flash in an ordinary plastic powder bottle and safety fused it through the cap. This was stood on a large marrow (squash) to act as 'witness' and we retired to await developments. No one who saw the subsequent devastation would wish to store flash again. The correct amount of flash to total a marrow is about 3 grams, but I digress.

### TESTING

Quite a bit of room is needed to test these devices and there is no discreet way to do it. With a video camera and single frame playback it's easy to see how many stars ignite. A clever trick and cheaper than a camcorder is to add 5 stars of a different color into the pay load and just look for these. If you see 4 green in a basically red burst you have approximately  $4 \times 100/5 = 80\%$  ignition! Three out of 5 is doing well as my videos of commercial



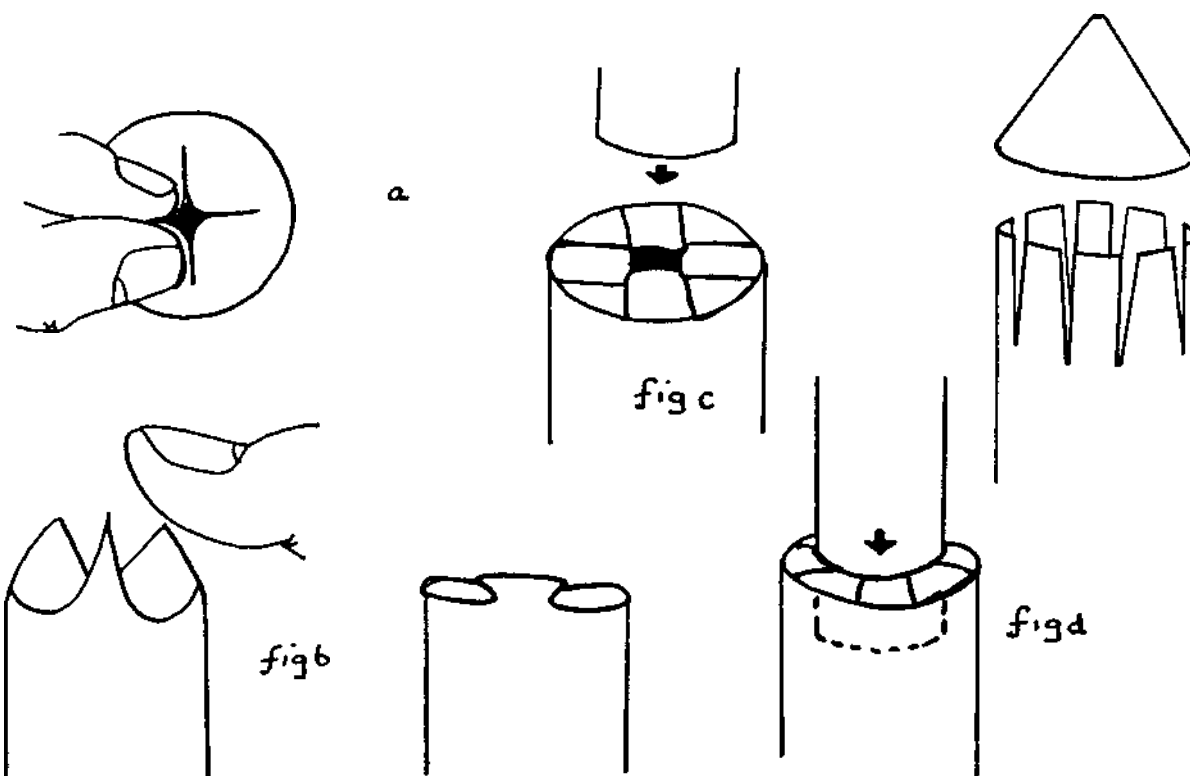
shell burst rockets show some struggle to light more than half their stars. This idea came to me when I noticed some European color shells contain one star of a different color. This may be for testing or to provide the brain with a color reference. If you closely follow the techniques above, ignition should approach 100%.

## OTHER SIZES

Once proficient with 12/" i.d. rockets, larger rockets can be tried. I'm still working on the question

of what are the best dimensions for tops and stars and have most recently used smaller stars. The following are near ideal. The larger sizes will need 6 or 8 pinches to form the crimp.

These rockets are more trouble, both to make and with the neighbours, but I find them well worth while the time and effort. Wouldn't you like to see them fired 500 at once like they do in Valencia! SH





## MORE ON SHELL BURST ROCKETS

The *Shell Burst Rockets* article didn't really stress the point that these rockets are not simply a small flash-opened shell fitted to a traditional rocket motor with the central hole. The motor is, in fact, of the end burning type, described in Lancaster 2nd ed., page 163, pressed in an aluminum tube and rising with either a gold or silver tail. I believe that this point is important since the traditional motor with the charge pressed around the central spindle is much less reliable with respect to blowing through on ignition, and is not so well suited to carrying the flash burst payload.

If, for instance, a 4 oz. (3/4") motor were fitted to the largest head described in the AFN article, (110 g. stars, 5 g. flash), and the device blew through on ignition, then the results would be very unpleasant indeed, especially if the rocket were loaded in a rack with twenty or so others.

I realize that the production of these more sophisticated motor units is somewhat difficult for the hobbyist, but I believe that potential experimenters should exercise caution if fitting this type of payload to traditional, especially homemade, motors.

The author mentioned in the first paragraph that these rockets burst "with the ferocity of a shell". I would expand on this by saying that the burst is also highly symmetrical, in a well filled circular pattern. Unfortunately, inferior rockets with messy bursts and poor star ignition appear to have flooded the shop goods market here, and they are frighteningly expensive. I've seen certain ones sold in central London at \$38 each! On examination these seemingly impressive rockets are mainly full of fresh air, with only a small end-burning motor lifting an enormous paper pot containing only a small quantity of stars and a gram or so of flash. A few years ago I remember seeing some German rockets which were made to look very imposing by encasing the actual device in a light expanded polystyrene outer case. We do not need this kind of deception!

While on the subject of poor commercial rockets, in his December AFN article, the author men-

tions less than successful results of certain manufacturers. One of our manufacturers seems to be marketing 2 oz. (5/8") [oz. sizes mentioned in this article are UK rockets sizes, not US - ed.] rocket in which a conventional motor is fitted to a plastic star pot containing a small quantity of stars and flash. The result is little better than a traditional pop-open rocket head.

The point I'm trying to make is that in my experience, many of these flash head rockets, with the exception of Germany's Zink variety, are not all that impressive, and their production does require more than a little effort.

On the subject of star brightness, I have carried out considerable experimentation on the production of metal fuel color stars. I was surprised at Sir Steve's formula #a which uses magnesium and potassium nitrate for cut stars. Could such stars give good ignition when made as primed cut stars in a flash head, especially when no potassium perchlorate is present and the magnesium is as coarse as 20 mesh?

I have experimented with flash-opened 3" shells using my own mixes similar to Shimizu's Mg/Al-parlon based red and green stars (Lancaster 2nd edition, pg. 258-259) with good results. I prefer to use a larger quantity of nitrate-aluminum based flash than a small quantity of "hot" perchlorate/aluminum, since the exact quantity of burst charge becomes less important with a slower flash. It is very easy to overdo things and blow your stars blind with a very fast flash.

That brings us to the point of using potassium permanganate as a flash component. To my knowledge, this material is not normally used in fireworks and must, therefore, be something of an unknown quantity. In view of the potential danger I see no advantage in its use, especially when more conventional flash systems are relatively well understood.

Another potential hazard must be the use of an aluminum flash powder in contact with a chlorate-primed star. I, for one, would prefer to avoid it. AUKP

## SCREAMING BANSHEE ROCKETS

An article in AFN called *Stinger Missiles* [AFN #70], described how one man made small, spin stabilized rockets that make an interesting sound as they lift off, much like a hummer or Z-Bomb. I used tooling of the same design and similar tubes to make an interesting whistling rocket. These "Screaming Banshee" rockets sound something like a gigantic bird of prey screaming its head off, when fired, very different than an ordinary large caliber whistling rocket.

The formula I used is a variation on the "Screaming Rocket" formula that appeared in the PGI Bulletin article dated May '90. I had on hand some potassium benzoate, but I had none of the sodium salicylate called for in that article, nor did I have a set of whistling rocket tools for my 3/4" tubes. I did have, though, a set of tooling for making the "Stinger Missiles", which has a spindle 1 1/4" long - somewhat shorter than called for in the "Screaming Rocket" article. On a whim I mixed up a small batch of propellant, substituting the benzoate, milled to a fine powder, for the salicylate, and pressed a few motors. The results astounded me. They were some of the loudest, highest performance whistling rockets I had ever seen.

For reference, the formula is as follows:

Potassium perchlorate	64%
Potassium benzoate	32
Red Iron oxide	1
Petroleum jelly	3

The original version of the formula used sodium salicylate as a fuel, which is readily available from all major suppliers of pyro chemicals in a powder form that requires no additional preparation. The benzoate I had was obtained in a prilled form, i.e., small round beads about the size of bb's. The powder needs to be very fine for these rockets. At a garage sale my wife found a small food processor which she bought for a pittance; it works well for reducing small amounts of the prilled benzoate to fine powder. I simply

added the appropriate amount of red iron oxide catalyst to the benzoate prior to milling to produce a reddish mixture composed of a ratio of 32:1 benzoate/red iron oxide. Next, I placed the required amount of petroleum jelly in a beaker over a hot plate and gently heated until the jelly melted. Donning my respirator, I removed the petroleum jelly from the heat, and turned off the hot plate. Lacking the pure toluene called for in article, I then added about 5 parts lacquer thinner for each part of petroleum jelly by weight, continuously stirring to dissolve the two together. I next added the petroleum jelly solution to the fuel/catalyst mixture and stirred the mixture until homogenous. Then I slowly added the oxidizer while stirring continuously with a wooden spoon for several minutes. At this point the mixture had the consistency of a thick soup and the beaker was warm to the touch. If the mixture seemed too dry or thick, I could add extra lacquer thinner at this stage. I spread the composition out, in a layer about 1/2" thick, on kraft paper over newspapers to dry overnight. I have found that it is important to be sure that the lacquer thinner has thoroughly evaporated before pressing the motors. A slightly damp mix can cause some shrinkage of the propellant grain over a period of days or weeks, transforming the rocket into a large ground salute. I always do the steps using toluene or lacquer thinner outdoors because the vapors are highly inflammable, besides being toxic to humans.

When the composition had dried overnight, I then carefully ran it through a 20 mesh sieve and then stored it in a paper container so that trace amounts of solvent could evaporate. After several days, the mix was ready to press. Screening a mix of this sensitivity required extra care.

I used custom made tooling originally designed to make spin stabilized Warhead Launcher-type rockets from 3/4" i.d. convolute wound tubes. Interestingly enough, the 3 1/4" long tubes cut for the WHL rockets worked very well for these "Screaming Banshee" rockets, too. The process



for making the motors differs mainly in that the Screammers use no clay choke (as will most, if not all whistling rockets), and in lacking a side vent. These rockets seem to require no significant length of open tubing below the propellant grain to achieve their characteristic wail. Mine contained a propellant grain that ended about 1/8" from the rear end of the motor tube; several casual observers have erroneously assumed that they were looking at a red clay nozzle, when in fact they were actually seeing the end of the propellant grain.

I found a one ton arbor press worked satisfactorily for pressing the motors, using all care and caution due the sensitive composition. I pressed the composition in increments of about one i.d. per pressing, until reaching about 1 1/2 times the i.d. above the spindle. I finished with my favored garniture, and fastened to a stabilizing stick of appropriate length. For ignition I used a length of slow thermolite taped to the stick and just touching the outside of the propellant grain. I found that quickmatch inserted into the orifice caused the motor to detonate.

Of course, I exercise great care in both making and firing these high energy, "Screaming Banshee" rockets. I think they have some potential as a display item, but are more prone to detonation than ordinary black powder type rockets. Certainly, the "Screaming Banshee" is still subject to the same stabilization and fallout problems as are other stick stabilized rockets, but the combined audible and visual effect of these rockets make them unique and noteworthy. AJS

[Experienced operators have found that the use of solvents with explosive vapors adds an unusual degree of risk in fireworks formulations. Likewise, whistle compositions are unsuitable for hand ramming into cases - Ed.]

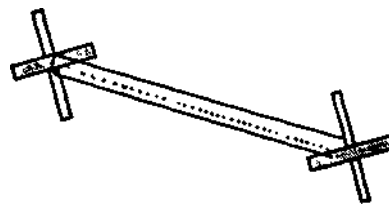
## CHEAP & EASY ROCKET GIMMICK

Here's a cheap and easy, spur of moment gimmick for igniting a lot of bottle rockets quickly. It's great for a lawn party or even the 4th! Sure to please young and old alike, it's made with little effort and scraps found around the garage or shop.

Here's how I make mine: I slice off an inch or two the long way from a 2x4 that is just laying around the garage. Even an unused furring strip would do. I drill holes approximately 1-inch apart with a drill bit big enough to allow bottle rocket sticks to move freely in and out (mostly being made of split bamboo, all sticks are not the same diameter). I attach the simple cross legs, per the diagram, with one nail on each side of the center strip. This will allow for some height adjustment, plus some adjustment for uneven ground.

Next a few rockets are put into the holes to see where their fuses will lay. Making sure the rockets move freely, I now draw a pencil line down the length of the strip, then lay down a bead of white glue or carpenter's glue the full length of the strip, right over the pencil mark. Then I lay down a length of black match on the glue line, and let it dry. If I don't have any black match available, I can do it like in those old cowboy movies and just pour a bead of meal powder on top of the glue and let that dry. Then I load the rockets.

I just make sure that all the fuses are atop the match or meal, and let 'er rip! A sure pleaser is to alternate the rockets: whistle, salute, stars, whatever. There should be room for about 100 bottle rockets to ignite in sequence, and I get a few moments of ohs & ahs at a bargain price! DR





## QUICK WHISTLE ROCKETS

I've come up with a quick method for making small but very powerful whistling rockets. I build them backwards! The only tools needed are a small arbor press (or a Doc Barr press) and two rammers as shown.

I made my first one using 1/2 i.d. tubing cut to 2" long. Actually, they can be made with any i.d. tubing cut to 2". The spindle length is important. If the length is too long, you lose the whistle sound, and longer than that, they deflagrate. The shorter length gives a good, shrill sound and still has lifting capacity. The mid-length gives lots of power and only whistles during the delay burn.

Here's how I make them. This applies to any i.d. tube. I start with a 2" length of tubing and tape one end off so the powder doesn't fall through. I funnel a scoop of fuel into the tube and press until the tube just starts to bulge. This technique is continued until a column of hard-pressed delay fuel is accomplished, approximately 3/8" to 1/2". The next few scoops of fuel are pressed with the palm of my hand until the tube is full. All this is done with the flat ended rammer. Now, using the rammer with the spindle machined on the end, and eyeballing the center of the tube, I press the spindle end into the fuel until the full diameter of the rammer enters. Then just one squeeze under the press completes it and the rammer is removed. The rocket engine is finished.

There should be a recess of 3/8" to 1/2" in the tube. This recess will vary until the right feel is achieved when pressing with the palm. Whatever the length, it doesn't affect the performance of the engine. It's unnecessary to skimp on tubing, like I do. They can be made longer than 2", but the spindle length must be close to the length shown.

Any fuel ratio between 70-30 and 76-23-1 will work, with 70-30-1 giving lower power but a raspy sound, and 76-23-1 giving the loudest whistle and the most power. The 70-30-1 uses sodium benzoate, while the 76-23-1 uses sodium salicylate. All the fuels use the melted Vasoline method, with 3% Vasoline. Whatever the ratio, this is how I make it.

I weigh out the potassium perchlorate and sift it through an 80 mesh screen. My screen is a 3 lb. coffee can with both ends removed and the wire screen fastened on one end with a hose clamp. Whenever I use a coarser screen, I pass the material several times so as to remove all the lumps. I weigh out the red iron oxide right away and screen this mixed right in with the perchlorate. I mix it until the color is uniform.

Then I weigh out the salicylate or benzoate, and screen it through a gravy strainer. This stuff refuses to go through anything finer than 10-20 mesh. Then I add it to the perchlorate.

While this is happening, the weighed out Vasoline is melting on my wife's clothes iron, which is sitting upside down in my bench vise.

Now I enter the hazardous stage. Once the dry chemicals are mixed together, I gently run the comp through the gravy strainer. Then I remove the Vasoline liquid from the iron and add lacquer thinner. Of course I do this away from all chemicals and anything else that is flammable. This part is common sense - I don't pour the lacquer thinner from the can but measure out the exact amount into another container and then pour from that into the melted Vasoline. There's no sense in having more than needed for the batch size.

Note: Melting is done in a pop can cut a little less than in half, say 2 1/2 high. With comp batches of around 500 grams, the most I use of lacquer thinner fills this container a little over 3/4 full, around 140 grams. The Vasoline melts at a very low temperature so it is not necessary to get things very hot. Lower temperature means less fumes.

After adding the lacquer thinner to the melted Vasoline, the liquid turns cloudy. I return it to the iron and heat and stir just until it starts to turn clear. Now it's ready to add to the fuel. The temperature is around 120°F, which shouldn't pose too much danger when adding the liquid to the fuel.

# **THE BEST OF AFN III**

I then mix it together, using a kitchen fork and easily squeezing it through the teeth. I like to get it pretty wet. If it isn't, I'll add more lacquer thinner. I keep mixing until it thickens and starts to get pretty heavy. The thinner evaporates pretty fast, and even faster if the process is done in front of a 20" fan. That's the way I prefer, as I don't wish to breathe the fumes. There's little choice here - with proper ventilation I'll do this in my shop and wear a proper vapor mask, otherwise the process goes on outside in fresh air.

Practice tells when the comp is ready for ricing. For this step I use another coffee can with a screen on one end, with the mesh the same as a window screen. With the screen end up, I place the fuel on it and push it through onto newspaper taped onto cardboard.

After four or five piles are squeezed onto the paper below, I spread it out nice and even and then place it about eight feet from the 20" fan, stirring it three or four times. It should be dry in about half an hour. I store the finished fuel in small plastic-lidded coffee cans. Working with 500 gram batches, I can make a lot of small engines, but it doesn't last long when pressing 1 1/4" by 6-foot long rocket engines!

Once the fuel is mixed, I haven't detected any problems with moisture absorption. Our climate is pretty humid in summer but it doesn't seem to affect a finished rocket engine. Still, I keep them stored in plastic bags until I'm read to use them.

During this whole process of screening and mixing, I don protective clothing, gloves, face shield, and long sleeves, and no polyester. I will not pound on whistle mix to make a rocket engine. I heard that some people do. Here's a test: I place a tiny pinch of whistle comp on an anvil and tap it with a hammer. Then tap a little harder. Sometimes it takes only a light tap to make it blow. It can bite. In fact, when I use the press, I use a shield between it and me.

## FUEL

### For raspy rockets:

Potassium perchlorate	70
Sodium benzoate	30
Iron oxide	1
Vaseline	3

### For power:

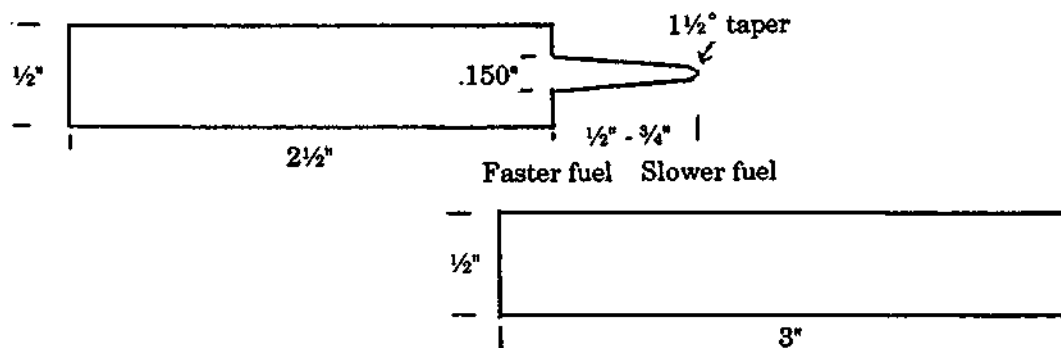
Potassium perchlorate	76
Sodium salicylate	23
Iron oxide	1
Vaseline	3

### References:

"Screaming Banshee Rockets", A. J. Smith, AFN #110, November, 1990.

"Screaming Rockets", Barry Vreyens, PGI Bulletin #70, May, 1990.

SLaD



**Material: 6061 T6 aluminum  
or stainless steel  
or bronze**



## LINE ROCKETS - HOW TO MAKE THEM

For a relatively small expenditure of time and money, the venerable line rocket is one of the most effective and amusing pieces of Class-C fireworks that can be constructed. Only a few readily obtainable materials and a minimum of skills are needed to make the device, and the driving composition, a simple mixture of potassium nitrate, charcoal and sulfur, is about the safest pyrotechnic combination that can be made. Moreover, even the very small "sub-ouncer" size to be described in this article puts on a surprisingly brilliant and animated performance in a limited space, is not noisy enough to arouse the ire of neighbors, and, best of all, is confined to the immediate area where it is fired rather than taking off in unpredictable directions as skyrockets and some other devices are prone to do. Because of these factors it is ideally adapted to small backyard displays, although its commercial equivalent in larger sizes is frequently used to good effect in public displays. Finally, the construction of small line rockets is an excellent first step for the beginner to acquire manual skill and an understanding of how many other firework devices are built and operate. (It certainly beats starting out by trying to make firecrackers and salutes, which is, unfortunately, the usual approach of the novice pyrotechnic experimenter!)

As with most fireworks, the first step in making line rockets is to roll a few cases. One of the simplest ways of doing this is to get a roll of 3" gummed tape at a hardware or stationery store. This must be the dry type with mucilage backing used for sealing cartons, not masking tape, and as noted, in the 3" width rather than 2" as more often found in various stores. I cut off as many strips of the tape, 14" long, as is intended to make cases - about 2 dozen is a good number for starters. Better yet, I tear those strips off the roll along a rough-edged implement such as a hacksaw blade; this will make starting and finishing the cases easier in the next step.

A 3/8" diameter length of rod or tubing about 6" or more long, called a mandrel, is required for rolling the cases. This can be simply a piece of wooden dowel, in which case it should be well rubbed with wax or varnished to make the rolled

cases easier to slide off, as well as to prevent moisture from soaking into the wood and glue from sticking to it. A 2-foot length of this dowel is enough to make the mandrel and the ramming tools described below. I use a solid aluminum rod with a wooden handle at one end and a loose-fitting washer sliding on the rod, normally against the handle but helpful in pushing finished cases off the end. The washer, if used, should have its hole filed out so as to fit just barely over the rod and still slide along its length.

The other equipment for rolling the cases can easily be improvised. All that is needed is a flat, fairly smooth surface on which to lay the strips, say a piece of one-by-six board, which need not even be as long as the strips. If the mandrel has a handle, it must of course overhang the edge of the rolling board so that the rod can press the strip down against it.

There are two tricky steps in rolling the cases: first, getting the initial turns started tight against the mandrel, with the rest of the strip exactly at right angles to the rod so that it doesn't wind on spirally and, second, removing the rolled case from the mandrel. A good way of getting the roll started is first to wind it dry for a few turns around a rod of smaller diameter than the mandrel, which gives it a sort of set in the right direction, then I put it on the mandrel, still dry, and pull the first turn-and-a-half or so tight while gripping it firmly with the fingers of my hand. At this point the tape could be laid gummed side up on the rolling board and the remaining length moistened with a wet sponge or brush, but I have found that stronger cases result by dipping the rest of the tape very briefly in a bowl of warm water, squeezing the excess off between the fingers of the other hand, holding it over the bowl to catch the drips, then finishing the winding on the board.

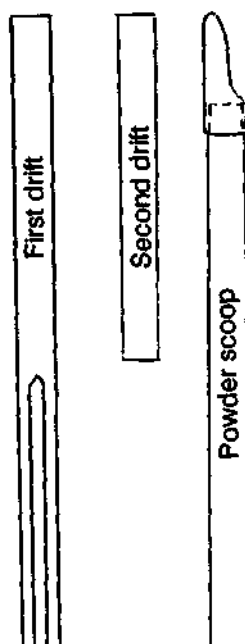
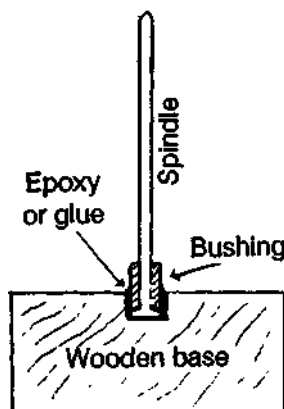
Actually, this part is just as well done without

using the board if the mandrel is equipped with a handle that can be twisted in one hand while pulling the wet tape with the other and guiding it to form even turns. With the tape this wet, any spiral protrusion that is evident after the entire tape is wound can usually be evened up by pressing the case ends between the thumb at one end and the first or second finger at the other, after removing it from the rod. Usually, getting the wound case off the mandrel without deforming it is fairly simple when the inner turns have been left dry as described; if it seems reluctant to come off, I give the mandrel a slight twist in the direction opposite to the way it was wound to help free it. A firmer case will result if it is laid on the board while still on the mandrel and rolled back and forth under another board before removal, but I haven't found this step really necessary.

Now we have a case of about 10 layers with an inside diameter of 3/8" and an o.d. of about 1/2", strong enough when dry for line rockets. The cases could be made even stronger by cutting the strips about 1 1/2" longer for each extra turn desired. The fact that the inner turn or so was not moistened seems to have no adverse effect. I have not mentioned whether the rolling should be done toward or away from the operator, or which hand should hold the mandrel and which one feed the tape, since this would be a matter of individual preference, besides which as a southpaw I have already confused enough readers by giving left-handed directions!

While the cases are drying, which usually takes about 24 hours under average conditions, they can be stacked in bundles of about a dozen each to keep the outer turns from loosening, with a rubber band around each bundle. If the last turn does separate a bit, it will be for only about 1/4" to 1/2", which can be torn off, and any protruding spiral bits at the end can be trimmed even with a sharp knife. The drying period is a good time to clean up the rolling paraphernalia, especially the mandrel, which should be washed clean before accumulated mucilage dries on it, and to prepare the ramming tools.

The first of these to make is the spindle for consolidating the clay nozzle and forming the hollow core in the body of the rocket. For this, an



8-penny flathead carpenter's nail (1/8" x 2 1/2") is used, filing the point to round it off, although this is not absolutely necessary. The nail is then pressed or driven into a metal bushing 3/8" in diameter and 1/2" long with a 1/8" hole running through it the long way. If such a bushing is not available, a 1/2" length of the 3/8" dowel can be cut off and a 1/8" hole bored through it lengthwise, but a metal bushing will hold up better in use. In either case it is best to bevel the top edge slightly, but again not essential.

A block of hardwood about 6" square by 2" or so thick is used for the spindle base. (Those are the dimensions of mine, having access to some old lumber cut back in the '50s before they started making it undersize, but almost any sturdy block found in lumber yard scrap piles will do as well.) A 3/8" hole is bored in the top of this to about 1/4" depth or slightly more, and the bushing, with the head of the nail flush against the bottom, is inserted, securing it with epoxy glue if metal, or wood glue if made of dowel.

Two drifts are required for ramming the clay and composition, about 5 and 3 inches long respectively and again cut from that very handy 3/8" dowel. The first or starting drift must have a 1/8" hole drilled into the bottom end far enough for it to slip down over the spindle against the bushing, with perhaps 1/8" more at the top. Drilling this hole with a hand drill so that it is centered

exactly in the dowel and parallel all the way is quite tricky and best done on a drill press, but if that's not possible, dowel rod is cheap and several tries can be made! Trueness of the hole can be tested by slipping the drift over the spindle and turning it around to see that there is no noticeable "wobble".

The second or finishing drift is just a 3" length of solid dowel. The powder scoop shown to the right of these is extremely handy for loading the clay and powder accurately and without spillage. It is made from another piece of the dowel of any convenient length, 6" being about right, with an aluminum, brass, copper or even plastic sleeve press-fit over the end and shaped as shown. The sleeve can be made of thin-walled tubing, and if this can be obtained with an o.d. of 3/8", it will fit right down into the rocket case (the end of the dowel can be whittled down to fit it).

With the cases and ramming tools prepared, the next obvious step is to provide something to ram, which consists of clay and propellant. I have found ordinary white fireclay, cheaply obtainable at ceramic and sometimes hardware stores, to work very well for the nozzles and end-plugs, although I've seen other types used with good results. Fireclay generally consolidates and hardens perfectly well with no dampening, however, even though it comes as an apparently dry powder.

While the best propellant ingredients must be obtained from a chemical or laboratory supply outlet, particularly the double-refined powdered potassium nitrate, I am going to describe the method I have generally employed, using ingredients bought at a local drugstore and the nursery department of Sears. Starting with this formula:

Potassium nitrate	15
Charcoal	3
Sulfur	2
(parts by weight)	

I was not surprised to find all three of the ingredients on the shelves of a nearby drug store, since they all have medicinal uses, as is the case with so many chemicals that are also used in

firework compositions. The potassium nitrate was labeled as a diuretic and meat preservative; the charcoal, in tablet form, was sold for the relief of gas on the stomach; the sulfur was presumably for use in everything from spring tonics in combination with molasses to a fungicide for the treatment of athlete's foot.

My first mixing of these drugstore ingredients did not produce spectacular results. I powdered the charcoal tablets with a glass mortar and pestle, stirred in the sulfur, and finally added the potassium nitrate, thoroughly mixing all three. The end result was a black powder that burned quite vigorously with a lilac-blue flame but definitely did not provide enough propulsive force in a choked case to drive a rocket of any sort very far. This was mainly because the drugstore variety of potassium nitrate is in the granulated grade - grains about the size of table sugar - rather than the almost impalpable powdered variety recommended in most firework formulas. There are methods of reducing this grade to a powder by boiling a water solution of it, but I obtained fair results just by putting a quantity of it in an electric food blender and letting it run for about a minute at high speed. (Don't try this with potassium nitrate that has been mixed with charcoal or sulfur, though!)

The drugstore sulfur I first used was the yellow flowers of sulfur and worked quite well in this mixing, but I later found an almost white variety at the aforementioned garden supply department which was labeled as "sulfur dust", intended for use on rose bushes, which was a much finer powder, about 300-mesh, and considerably easier to incorporate with the other ingredients. This was probably sulfur flour, which is considerably different from flowers of sulfur.

The grade (particle size) of the charcoal is the principal factor that will affect the performance of the rockets. A very fine powder will make the mix burn faster, especially if it is made from willow or alder wood, but at the sacrifice of a handsome, glowing tail. For small rockets like these, I found the best results were obtained by mixing finely-powdered charcoal, including the dust produced in the grinding process, with about an equal amount of about 60-mesh grains, later

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mixing and sifting both together through a coarse tea-strainer. I have even powdered the common charcoal briquettes sold for use in barbecues and used the resulting mixture of coarse and fine particles with good results, even though this is hardwood charcoal.

I next weighed the 3 ingredients separately and mixed them together, and at this point it should be noted that only a comparatively small amount of the finished propellant is needed for charging such small rockets. When they are loaded as will be described, it takes only about 5 grams of powder to fill each case, so that 100 grams, approximately 3 1/2 ounces or about enough to half-fill a coffee cup, will be plenty for loading 20 or so cases. Following the formula on the preceding page, a 100-gram batch of composition will require 75 grams of potassium nitrate (2.65 ounces), 15 grams of charcoal (.53 ounce) and 10 grams of sulfur (.35 ounce).

The charcoal and sulfur should first be well mixed together and stirred until of a uniform color throughout. It will be found that the mixing process renders both of these ingredients easier to handle, as it reduces the tendency of the charcoal to fly about - even splash out of the container when dumped in - and that of the sulfur to stick to the implements. Then I add the potassium nitrate and stirred the mixture again to a uniform consistency and color. From this point on, two important facts should be borne in mind: first, with the addition of the potassium nitrate as an oxidizer, the mixture has actually become a low grade of black powder, which is extremely flammable and susceptible to ignition by a stray spark from whatever source! Second, further manipulation of the powder, such as sifting and more mixing, will only increase its strength and flammability.

Knowledgeable readers will have noted that the formula given: 75% potassium nitrate, 15% charcoal, 10% sulfur by weight, is the one generally recommended for producing the strongest black powder possible, other factors being equal, and since we are dealing here with a propellant for rockets, not an explosive charge for firecrackers or salutes, the advisability of including such a high percentage of oxidizer might be questioned.

This was intentional, because in fact the "other factors" seldom if ever are equal, and no experimenter grinding and mixing his own black powder ingredients by hand can expect to produce a powder as fast and "hot" as the commercially-made grades starting with the same proportions of ingredients. As frequently mentioned elsewhere, any printed formula is merely a starting point, after which the results obtained depend largely on individual method of procedure. If very finely-powdered potassium nitrate, charcoal and sulfur were thoroughly mixed in the proportions given and intimately incorporated under heavy mechanical pressure, one would indeed end up with a potent black powder that would blow his rockets up rather than driving them, but this degree of "perfection" is so unlikely to be attained by the average manipulator, that his end-product, even starting with the most potent formula, will probably fall somewhere between a very fast powder and a much slower propellant, just as if he had started with a smaller percentage of potassium nitrate. In the end, of course, he could fall back on Weingart's sage advice: "If rockets burst before ascending add more coal; if they ascend too slowly add more potassium nitrate."

Regarding proportions, it is standard practice to give the amount of each ingredient by weight, or as a percentage of the total weight of the mixture, except for liquids, where the quantity is more conveniently expressed as a certain volume such as pints, quarts, liters, cubic centimeters, etc. This is because dry chemicals vary considerably in density, even from one grade to another of the same chemical, so that a formula giving the parts by volume would produce quite erratic results from one batch to another.

A simple method of further combining the ingredients after stirring them together as described on the preceding page, is to dump the mixture into a small plastic bag, seal the opening with a rubber band, and knead it for several minutes until it appears to be a smooth blend throughout. At this point a rough check can be made by placing a small amount of the powder, as much as held by the scoop, for example, in a pile on some non-flammable surface and igniting it. Since this test should be made in the open be-



cause of the clouds of stinky smoke given off, and if the sky is clear, I have found the best method of ignition to be by focusing the sun's rays on the pile with a magnifying glass, which does not physically disturb the powder as holding a lighted match up to it might do.

The powder should burn rapidly, with the whole pile consumed in something less than a second and very little residue remaining. If the burning takes longer than about a second and whitish globules of melted potassium nitrate remain afterward, the ingredients were either not powdered finely enough or sufficiently mixed. This is only a crude test, however, and even a mixture that seems to burn sluggishly in the open may prove to be strong enough to propel the rockets after being further consolidated by ramming into the cases. (CAUTION: the bag of powder should always be re-sealed and moved to a distance before igniting the test-pile!)

To charge a rocket, one of the cases should be slipped over the spindle and pressed all the way down over the bushing (sometimes called the "button" or "nipple"). Then 2 scoops of clay are dumped in, the starting drift pushed over the spindle as far as it will go, and the clay consolidated with about 10 solid blows of a 1-pound hammer on the end. At this point it is well to remove the drift, twist the case off the spindle and examine the choke or nozzle that has been formed. The clay should be quite hard and not easily scratched or chipped with a blunt implement or dislodged if a length of solid dowel is pressed strongly against it from inside the case. If it cracks or disintegrates when so tested, or does not adhere firmly to the tube walls, this step should be repeated using a slightly dampened clay. The spindle block should rest on a firm, solid support to obtain the full impact of the hammer blows.

When examination shows that a smooth, solid clay choke has been formed, it is replaced carefully over the spindle, 2 scoops of propellant composition poured in, the drift reinserted and given about a half-dozen solid blows (a number of sharp blows compact the powder better than just a few heavier ones). This process is repeated, adding just 2 scoops of powder at a time and ram-

ming, until the charge completely covers the spindle top, after which the solid drift is used to ram the remainder. The changeover point can be determined by looking into the open end of the case, and for convenience in charging further cases, the starting drift should be reinserted until it contacts the composition and a mark should be made on it even with the open end of the case. Then the ramming is continued in 2-scoop increments until charged to within about a half-inch from the top, another scoop of clay is inserted and rammed to form a solid end-plug.



The rocket is then pulled off the spindle with a twisting motion. I should mention that the only reason for making most rocket spindles tapered from bottom to top is to facilitate removal of the charged case after ramming; in fact some small rockets are rammed solid, with the central cavity being bored afterward, which of also produces a cylindrical hole, not a tapered one. With the present method, removal is easier if the spindle is smoothed with fine emery cloth and rubbed with wax occasionally, which also helps to keep it from rusting from contact with the potassium nitrate in the composition. It is also a good idea to bind the top half-inch or so of the drifts with a few turns of wire or drive a metal sleeve over them, to prevent splitting or cracking after continued hammer blows. As a further refinement, this end of the drifts can be coated with the always-helpful epoxy resin, especially if iron wire is used to wrap them, which will provide even more protection and help prevent loosening of the binding or sleeves.

Each charged case must now have an empty one attached to it in order to run on the stretched line that gives these rockets their name. The attachment can be as simple as just placing the two cases together lengthwise and wrapping them with a few turns of masking tape, but I have found from experience that it is safer to twist a couple of turns of wire around them first, then finish with tape. It's a fact that at every public display where I have seen these devices used (the commercial ones, known as "rats" or "radios") at least one of the cases has torn loose and sailed off



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on its own unpredictable trajectory, often right over the heads of the spectators!

A fuse, preferably 3/32" safety fuse although black match and even touch-paper can be used, should be inserted in the nozzle of each rocket and secured with a little priming-paste to insure ignition. The paste can be made from the propellant itself mixed with about 10% starch or dextrin and dampened. The running line should be firmly attached to two upright posts at least 50 feet apart for maximum effect, first securing one end, then slipping the empty case over the other and pulling the line quite taut while tying it to the second support. Wire or even plastic-covered clothesline can be used, but great care should be taken to see that it is perfectly smooth the whole way, with no kinks that might cause the rocket to hang up instead of sliding freely from one end to the other.

The effect is enhanced if two or more rockets are fired in sequence, and several can be threaded on the line, igniting first the one farthest from the post, then the next, and so on. Even better, a length of fuse can be led from one nozzle to another to achieve the same result after the front rocket is lit, as is generally done with 5 or so of them at commercial displays. (If anything but safety fuse is used to convey the fire, black match for example, it should be covered between rockets to prevent accidental ignition by the spark-trail

from the preceding rocket.) For public displays, two parallel lines are usually strung, with such a group of rockets at opposite ends and facing each other, which with good timing gives the impression of a single rocket scurrying back and forth several times from one end to the other like a "rat".

The same effect can be produced by taping two cases facing in opposite directions to the empty case, perforating the solid clay plug of the first to fire, and leading a piece of fuse from that orifice into the nozzle of the second rocket. This method has the advantage that only one operator is needed, to light the first rocket, and only one line need be strung.

There are several alternatives for mixing the propellant, one of which - the "wet" method - is claimed to produce a much more vigorous black powder almost equal in strength to the commercial type but not requiring machinery for its production, using the same ingredients in the same proportion given here. I have described the method that I've found to produce very good line rockets that will even ascend in the air if attached to a light stick and can be used as wheel drivers. One final caution: while black powder is relatively insensitive to shock or friction, it is easily ignited by any stray spark, so only non-ferrous or wooden rammers should be used with a steel spindle. MPVH

## STICKS FOR THE PICKING

Over the years of gathering pyro construction literature, I have noticed little, if any, attention given to materials for rocket sticks. The main thrust of these construction articles is on engine and payload. They always left the question unanswered: where does one obtain the sticks?

In times past, stained and dyed bamboo splints of various sizes were available from pyro tool and chemical suppliers. But not now. At the 1985 Franklin PGI convention I noticed some impressive sawed pieces of pine attached to the Lords of the Air - Ten Pounders!! When I questioned the producers of these ponderous vehicles of delight about the sticks, they replied that they "just cut them to meet the stability requirements". From that time on, I have been in search of literature on rocket stick materials.

Rather than purchase or saw out my sticks, I have found a superior substitute where I live in the frozen land of northern Pennsylvania. Goldenrod stems. Yes, you read that correctly: those nasty weeds that make you sneeze, make your eyes water, and in some people even provoke asthma attack. What better revenge than to launch them to the stars, scorching their tails, and allowing their burnt hulks to plummet back to earth.

Where to obtain them? Here's how:

1. If you already know what to look for, move on to #5.
2. Obtain a copy of a good plant guide from your local library. Suggestion: A *Field Guide to Wildflowers* by Roger Tory Peterson and Margaret McKenny.
3. Look on old abandoned farms, logged over tracts and stripmined areas. Generally, seek waste areas with high acid soil.

4. For sure identification, perform your searching in the blooming season. There are over 69+ species of this plant in the eastern U.S. alone.

5. Once you have identified your plants, note locations and wait to start your picking until the first snowfall.

6. Select stems that have aged one or two years and are still standing. These are easy to spot because of their loss of leaves and bleached-out appearance.

7. Some of the best varieties to select are the tall, showy, flat topped and clublike ones. Examples are Tall Goldenrod, *Solidago altissima*. and Late Goldenrod, *Solidago gigantea*. both species grow to six feet in height and are found throughout the northeastern U.S.

8. Last of all, if goldenrod is just too offensive or too short, you might try Joe - Pye - Weed (various species) or the Iron Weeds (various species). Both Joe - Pye and the Iron weeds usually exceed seven feet in height!

I have not tried to stain or dye any of these stems, But I have tested them on rockets ranging in size from 4 oz. up to 1 lb. Again it should be noted that the older weathered stems work best. Stems that are slightly bent can be easily straightened by using gentle heat from a gas range. If you wish to save a dollar on sawed timber or mail order, go out and gather your own sticks for free.

### References:

Peterson, Roger Tory and Margaret McKenny, *A Field Guide to Wild-flowers*, Boston, Houghton Mifflin, 1968.

Newcomb, Lawrence, *Newcomb's Wildflower Guide*, Boston, Little, Brown & Co., 1977.

DM

## CROSS-SECTION OF A COMMERCIAL CHINESE WHISTLING BOTTLE ROCKET

Have you ever wondered what a cross-section of a commercially made Chinese Whistling Bottle Rocket with report looks like? Well I have. They look like this drawing.

They have an outside diameter of 5/16" and are approximately 2-1/8" in length. The sticks are 10 to 11-inches long. The tubes are not even filled half way. There's a brown powder that separates the whistle fuel from the flash powder. I assume it is some sort of clay.

The only safe way I can take one of these apart is to freeze them overnight in the refrigerator! After I know that they are frozen solid, I don safety goggles, heavy gloves, and apron. I don't want to take chances! Even though frozen solid, I still use safety precautions. I take a razor-sharp steak knife and split the tube lengthwise.

If I were to reproduce these rockets, I'd put in more whistle powder, because some of their devices have very short whistles before they

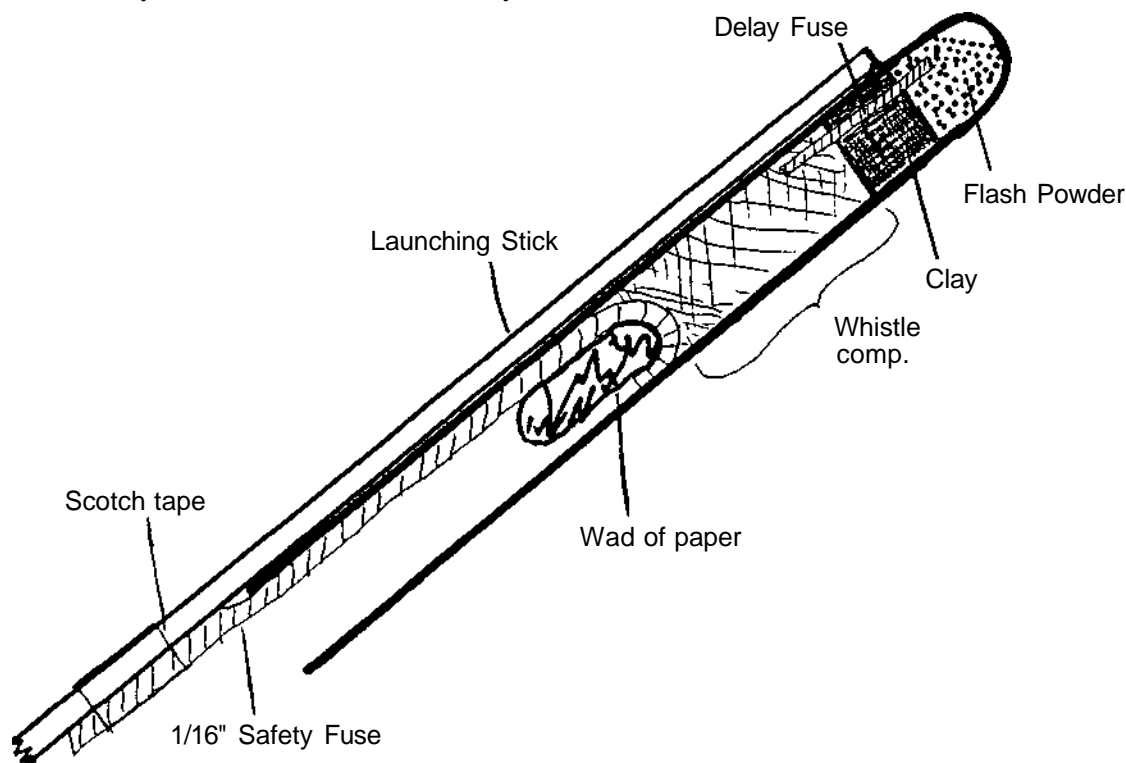
report, and some of them go more like "poof instead of BANG!

I like to make whistling rockets in several sizes, like 3/8" i.d. x 2" long, and 9/16" x 2 1/4". My observations concerning using sodium benzoate or sodium salicylate for the whistle: I notice that the benzoate gives a little more raspy sound, somewhat different than the salicylate. I guess the benzoate is OK but I prefer the sound of the salicylate.

It's true that privately made whistling devices far surpass the performance of mass produced Chinese whistling devices, especially those we make on an arbor press. A recent question in AFN asked if it is safe to dampen whistle comp before pressing it. I tried it and it didn't quite work for me.

I prefer potassium perchlorate, sodium salicylate, iron oxide and some Vaseline to make my comp.

RS





## THE BASIC TECHNICIAN - PART I

The slogan, "He who hath once smelt the smoke is ne'er again free" is, in my case, true. Back in the early 60's I was allowed to set off a number of pieces of high altitude fireworks at a private lake. I mean I actually loaded the tubes and "FLARED" them off into the sky! What a mind-boggling experience. Now, at 43 years of age, this first experience has not left me yet. In fact, it led me to experiment further through the years, even as far as setting off some of my own displays.

Nowadays, everything seems to be high tech and very complicated. But some basic stuff works too. I found that plain iron filings do wonders for a basic star formula. Big deal you say? Well, the easiest place to get these filings is from your local auto mechanic's garage. When a mechanic turns down brake drums on a lathe, just look at what comes off. Pounds of this item can be acquired free, just for the asking. Want aluminum? Simple, scrap tossed-out pieces can be filed with a very fine file, and will render all the metal needed for many experiments, and the cost will be at a minimum. This is a form of re-cycling too.

A simple mortar and pestle can, to some extent, grind the tiny pieces further if needed, but I found they work just fine as is.

Having a hard time finding rosin? This old time binder can be found at most any bowling alley that sells supplies. They call it "Sports Rosin" or a similar name. Again, it's a reasonable cost for a cheap supply of a binder that not much is needed to obtain fairly good results.

If you don't want the bother of making your own metals or other items needed, think fireplace crystals. In some formulas they work OK too. Just watch out for the high moisture content if left exposed to the air for too long. They too can be ground for a finer texture. When using the crystals, I found they worked best using a 4F black powder for ignition.

Perhaps after reading the "Blender Rocket" story, and possibly after reading my article, you will begin to realize that there are other alternate ways to construct fireworks, other than hi-tech.

Just remember, as always, I stress SAFETY FIRST, LAST, AND ALWAYS!

How about a cheap dietitian's scale for weighing ingredients? Or a 290 scoop set for basic measuring, or spoon set. I just substitute the set's gradations for grams, ounces, pounds, etc. I found that as long as I use some kind of basic measuring device, although not as accurate as a balance beam, the formulas will work reasonably well.

Most sodium based formulas tend to draw moisture. If not careful, the best made stars or whatever will not function as well as we would like. I happened to come across a sodium chlorate supply by accident one day. Welding sticks in a can, most likely named "Metal-Ox" or, "Weld-Ox", I found at a local hardware store. They are designed to be used with a specific holder, but I found they work great ground up. Just one precaution, they contain a self ignition type of substance on top. Extra care is needed when removing it! Then I save it; it too makes a nice colored star in its own right. It is the same type of igniter as on road flares, which I have also used.

Looking for #200 tube inserts? I have tried LEGGS pantyhose eggs. Reinforced with standard flour paste paper, they work excellently. Fusing them takes some trial and error, but I generally leave protruding about 1/4" of visco fuse, and find it works. I have achieved some spectacular heights and delayed effects too. Packing the egg with stars, crackers, or other formulation, properly spaced, has given me a starting point for further experimentation.

PUMPED STARS? I have made the mix in old plastic butter, or topping containers. Easy, then they can be thrown away, or washed out for use again. I take ordinary hangers, with pants bars, plastic or paper type, put the mix into the tubes and push out with a simple wooden dowel. When using plastic tubes, I tape one end and fill with mix, and put it outside in the sun to dry, but not thoroughly dry. If the mix is left in the paper tubes, it will then have a form of "boxed star", or I peel off the paper; it works either way.

I save the old tubes, as most can be re-used later to fit manufacturing needs. Even the most simple star formula can be tailored to make gerbs, fountains and the like. Old fireworks cake tubes, untied, work too. I look for some of the tubes with chokes in the tops, to be cut off, or I gouge out the clay bottoms, reload, reseal, and use over again for whatever purpose.

Amazing how much old fashioned ingenuity you can come up with, and I might add, inexpensive, yet effective too. Have any unfired duds, or otherwise not-fired pieces? I save mine. I usually cut open several of them just to gain composition knowledge. Nothing ever gets wasted this way. I check around carpet marts, and find lot's of various sized tubes, which can be reworked to suit a particular need. GH

## THE BASIC TECHNICIAN - PART II

Getting back to basics, black powder was still more effective in 90% of my work. Anyone with a good basic formula, that he considers to be accurate, should use it. I obviously have a formula of my own, but for the sake of the novice, 4F or 3F is good for starters.

If I take plain 4F and mix with iron, aluminum, or even copper powders or filings, using a loose bulkier amount for filling, let's say, in a Leggs egg, then I will probably experience what I describe as a golden colored glitzer. In the egg canister, when loading stars, I used a powdered false teeth adhesive for the binder, as it seemed to work the best. I never did follow up on the basic ingredient, I just knew it worked.

Round stars were my favorite. I could roll to any size I wanted. When they were still damp, I dusted them with 4F for a more positive ignition. I could roll stars to perform any way I needed them to. Layer 1 could be a base powder metal, with a binder; continuing to successfully roll another color, or any desired effect, the trailing tail effect was phenomenal. I would sometimes stay up until the wee hours of the morning, just rolling and packaging my stars. I found by saving old yogurt containers, with lids, made a great storage system. Old peanut butter jars were good also.

But I do want to tell you that, from all my years of individual experimentation, I came up with some mighty fine fireworks, both in ground and aerial displays too. And although it may not sound like it, I did sell some of my earlier formulas to individual jobbers, who in turn sold them to some of the fireworks manufacturing

plants. It has been personally rewarding to me, even though my name has not gotten credit. It thrills me to know I had a hand in the commercially produced items.

Most of our technology today comes from such individual experimentation. I praise anyone who uses their brains to come up with any kind of new ideas. This is what makes the world today what it is!

I do want to state my own personal opinion on one thing, the fireworks laws, as we now have them. We can have laws governing the age limit for driving, drinking, and many others, but why not have some kind of law, let's say, age 21, for allowing the use of our favorite item, FIREWORKS! The regulating forces regulate everything else in our world, I'm sure some kind of compromise could be used in the fireworks part also. Just because a specific number of people get injured is no just cause to ban something. If that were the case, then it appears that the automobile, for instance, should be banned too. I could continue for years on the subject, but I'd better get back to my original story of the basic STUFF. On metal casings: Even though I have tried them, FORGET IT. They are the worst form of flying shrapnel I have ever seen, and I STRONGLY ADVISE ANYONE NOT TO USE THEM. I stick to paper goods, as they are far safer and fun to make besides. It is easy to make formed tubes. All it takes is a wooden former dowel, wax paper, newspaper, and some kind of glue. The glue can be a simple flour paste, or wood glue, or any other. All depending on the strength of the casing you require.

*Continued on next page*

I take a piece of flat board, drill a hole for the size of dowel used, and glue fast to the board. Next I wrap one or several layers of wax paper around the dowel and tape the overlapped end.

Next I wrap newspaper, precut to any length needed, or kraft paper, or even the stiffer colored part of the Sunday paper. I wrap as many layers as I want, because it can be pulled off the form at any time, since the wax paper won't stick to the dowel, and that is the trick. I use a 2"x4"x2' board, and many dowels for mass production of my tubes. And to this day, it is still cost effective, in lieu of some of the commercially produced paper tubes.

Even the most easily found drugstore items can be very useful. Simple baking soda, used in moderation, will slow down any flash formula enough to use it for a fountain, etc. Epsom salts, or standard flour can also be used to modify any mix. A basic sparkler formula has, in fact,

dextrin, shellac, or gum arabic for the modifier base.

Has anyone out there ever purchased a tube item called "HOLIDAY SHELL"? Look at the construction. Look familiar? If so, then you can't help but see the "Leggs" egg! You see, there are ways to use common ordinary items to your advantage.

How about a shampoo called "Lemon-Up"? At one time, and still available, though hard to find, they used a plastic cap shaped like a lemon. I just popped out the cap, and had a container I called "8-ball". I have put aerial mixes into it, and no metal involved. The hot plastic, once exploded in the air, would cancel out all sharp edges.

I save the empty plastic bottle, use the cap, and store a lot of finished product in it, airtight too. Those lemon juice, or lime juice little squeezers are ideal for any aerial application too. Even aerial bombs. The strength of the case will have to be improved, but they can be used. GH

## **PART 3 - THE PYRO GETS UNDONE**

### **THE SAFETY FACTOR**

Everything I have written for AFN so far was to pass on my experiences in avoiding hazardous experimentation, such as mixing chemicals indiscriminately while searching for a new formula. Although there is always danger present in experimentation with chemicals, the uninformed person is most likely to be the victim. Although safety cannot be guaranteed, the following precautions, followed religiously, have given me a much better chance than if left to guess-work.

#### **PRECAUTIONS:**

1. I never experiment with or mix chemicals without first determining the results to be expected.
2. I use common sense when working with chemicals, and never take chances with those which are poisonous or dangerous in themselves.
3. I keep the work area clean. Dust from previous experiments can be an explosion hazard when working with pyrotechnic chemicals.

4. When mixing acids and water, I always add the acid to the water. Pouring water into an acid can cause the generation of enough steam to drive the acid from the container.
5. When heating or mixing chemicals, I use a transparent shield between the chemicals and my face.
6. When testing, I always do so in an open area and away from people.
7. Protective clothing, such as gloves and goggles are used when I'm working with pyrotechnic compositions.
8. I never dry a mixture of pyrotechnic chemicals by use of heat.
9. I never grind chemicals which could be ignited by friction.
10. I always wash out the containers when done.

One extra note on chlorates. They are powerful oxidizers, and react violently with many chemicals. I'm always sure that all tools are clean before grinding chlorates.

Some chemicals have such great affinity for each

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other that simply placing them in combination can start a reaction releasing heat, gasses and new compounds. Three examples of the combos I would mix outside, or in a well ventilated area **are:**

1. Equal portions of powdered aluminum and iodine crystals. I do NOT grind them. Next I add a drop of water.
2. One GRAM of potassium chlorate with two GRAMS of confectioner's sugar (not ground together). To this I add one DROP of sulfuric acid.
3. Three GRAMS of potassium permanganate on an asbestos sheet. To this I add two DROPS of glycerin.

Being extra careful, I always wear eye goggles and gloves.

Note: Some of these chemicals are on the dangerous side, but I find it increasingly difficult where to draw the line of "basics" vs. more advanced formulation.

Ah yes, the good old days of fireworks; days before the "Child Protection Act", etc. Why back in those days I used such chemicals as ammonium picrate, picric acid, mercurous chloride, and lead chloride, just to name a few. Today, picric types are considered unstable, although I found that under proper conditions and understanding of these chemicals, I was able to produce spectacular effects.

There are other available chemicals now in use that are supposed to be a lot safer. But even some, or all of them, need to be handled with care.

Some of the 'older' chemicals for color were:

YELLOW - sodium chlorate  
GREEN - copper nitrate & or borax  
PURPLE - lithium chloride  
RED - strontium nitrate  
ORANGE - calcium chloride

These are relatively safe to use, and are, for the most part, still available today, although some searching may be necessary.

The basic three groups of pyrotechnic language are:

GROUP 1 - Oxidizing agents: These are chemicals which release oxygen when they "burn" or combine with other elements.

GROUP 2 - Reducing agents: These combine with the oxidizers to produce the burning or explosive effect. The speed with which these react determines the nature of the explosion. Carbon compounds are very common for this purpose.

GROUP 3 - Moderators or catalysts: These are other materials introduced into a formula to produce a desired effect. A catalyst is used to speed up or slow down the reaction. It can be used to produce more smoke, or to produce a colored or sparkling effect, etc.

Armed with the information I gave you up to now, you should have a much better understanding of basic fireworks, yet sticking to the basics of it, SAFELY!

## THE PYRO BECOMES UNDONE

Not long after I wrote the above piece, a dreadful accident occurred, leaving me with 2nd and 3rd degree burns on my hand, arm and face. It seems that while using a blender to get my material ready, the blender shorted out, throwing sparks 15 feet away on some stars drying in the sun, and causing one hell of a daytime flash. I was burned really bad. Luckily, I had separated all items in different areas, not putting stars with oxidizing agents, etc., or probably I wouldn't even be writing (trying to anyway).

This accident happened even though the blender had a 3-prong grounded wire, with an extra ground I installed on the housing. To avoid it, how about enclosing the blender in a clear plastic case with lid on top held down with rubber bungee straps and only a small access area to get at the controls? Even though it may be cumbersome, it may save some pyros from this kind of freak accident. Freak accidents occur, and all we can do is somehow guard ourselves against them, thus giving ourselves a better chance of not getting injured. GH



## UNEXPLAINED EXPLOSIONS AND PROBABILITY THEORY

Having just finished Dr. Conkling's book, *Chemistry of Pyrotechnics*, I have enjoyed the articles on the dreaded Globe Torpedo mixtures. If any readers think that such a mixture can be handled safely, they might wish to learn of the following very simple experiments I did when I first became interested in fireworks many years ago.

I took a small pinch, maybe one-twentieth of a gram or so of potassium perchlorate and placed it on a thick steel plate. I put on a face shield, grabbed a hammer and gave the potassium perchlorate a good hit. It decomposed explosively without ANY fuel being present! I was impressed and gained immediate respect for the instability of strong oxidizers.

I next mixed a 7:3 batch, a SMALL batch, of potassium chlorate and sulfur flour. Upon striking a bit of this mixture in a similar way, I noted an ear ringing detonation, almost as loud as when I heated a bullet primer in a flame until it exploded. The surprising thing is that, very often, unexploded but compressed residue of the mixture will stick to the hammer or steel and upon another hit, will explode violently again! Be aware that striking more than a tiny pile of the chlorate-sulfur mixture can shatter the hammer face and inflict serious injury.

It is a well known fact that large quantities of sulfur and potassium chlorate can detonate and cause enormous damage. Yet we have some of the mixture remaining unexploded after a detonation on the hammer face. Why?

Part of the answer may lie in the crystal lattice structure of many oxidizers. Dr. Conkling mentions that the crystals which compose these compounds contain defects in what is otherwise an ordered arrangement of atoms. Such defects are probably wide-spread, at least in pyro compounds containing impurities - as nearly all do.

When we mix sensitive pyro compositions, we are mixing millions of defective crystals. The theory of probability suggests that this could be dangerous if the defects somehow increase the reactivity of the particle. The random coming together of an unknown number of defective crystals in some particular way might lead to spontaneous electron transfer which would liberate enough energy to make the reaction self-sustaining. More probably the slightest impact or static electric spark, could either force the defective crystals close enough, or supply enough external energy to cause a reaction. While this idea has no mathematical foundation, it could explain what many pyrotechnists consider mysterious explosions and infrequent impact ignitions.

One possible way to keep from getting incinerated would be to place a moderator molecule, like water, in the way - in between - the defective crystals. Water could cause problems, but dampness or high humidity might greatly reduce the chance of spontaneous ignition by getting in the way of the reactive regions of the crystals. Of course, this involves a very limited time frame, so chemical reactions caused by the presence of the water, i.e., aluminum reduction or sulfuric acid conversion, are not considered in this treatment.

So anyone planning to mix sensitive compositions in dry weather may be playing Russian roulette, especially with torpedo mixes containing a sensitizer like manganese dioxide. The manganese dioxide might do the opposite of the water molecule and act as a catalyst. It might fill a gap - act like a little wire if you will - between crystal defects, and help the electrons transfer. This could prove quite unfortunate and unpleasant which is why it is of utmost importance to keep batches of sensitive compositions SMALL (or better yet, don't make Globe Torpedo mix at all). WS

## Pyro Emitting Digital Display Device - (The PED<sup>3</sup>)

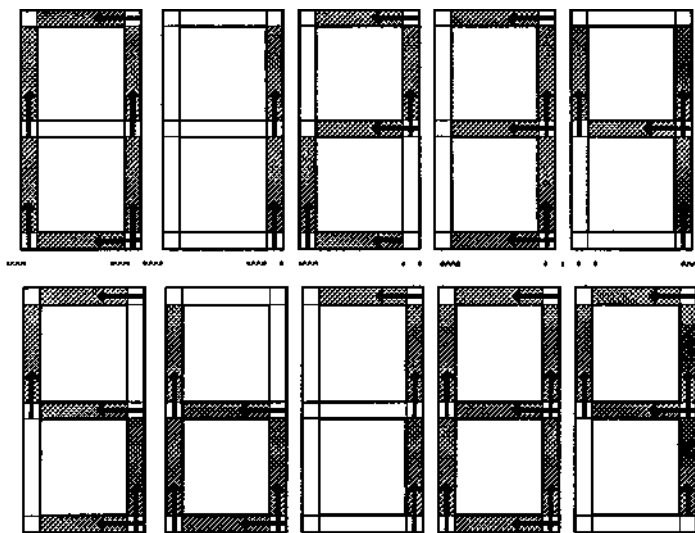
The Pyro Emitting Digital Display Device, or the PED<sup>3</sup> is a digital readout system using pyrotechnic "light bars" emitted by specially designed "readout gerbs". The gerbs used in the PGI countdown, Pyropak® 3/4 X 6 Readout Gerbs, have a 3/4 second burn time and produce a 6-foot long, 18-inch diameter shaft of silver sparks, forming a solid bar of light.

The bars produced by this device can be used to create a display of any pattern which can be executed in straight line segments six feet long.

To make a simple 7 segment readout requires that the digit be 12 feet tall and 6 feet wide. A display this size can be easily read by an audience from a distance of 100 to 1000 feet.

The simple pattern of 7 segments allows you to create the following alphanumeric characters: 1, 2, 3, 4, 5, 6, 7, 8, 9, 0, A, C, E, F, H, I, J, L, O, P, S, U.

To produce the numbers 0 through 9, use these patterns:



The placement and direction of each gerb is indicated by the position of the arrows in the diagram. This arrangement is the same geometry used in most digital clocks. Slanting the vertical lines 5 to 10 degrees to the right of vertical will make the display more legible, and pleasing to the eye. A maximum of 7 devices are required to display one digit. The countdown uses 51 readout gerbs wired in 10 circuits. Each digit must be wired as a separate circuit connected to a controller capable of firing them in the proper sequence.

The PGI countdown display was fired with all squibs wired in series and used a controller with a 24 volt power supply. For reliable firing of 8 Pyropak® 3/4 X 6 Readout Gerbs in series, a minimum power supply of 16 volts at 2 amperes, is needed. The success of the display depends on reliable gerbs and careful wiring.

It also requires gerbs which perform with identical time, height, and diameter during their burn.

For countdown-type displays a burn time of 3/4 of a second works well. For messages that require more time to read, like the date of the new year, it is more effective to use a longer lasting Pyropak® 10 X 6 Readout Gerb, with a 10 second duration. This technique has been used since 1983 for New Year's Eve displays, both indoor and out, with excellent results.

If letters other than the ones possible with the simple 7 segment display are required for the message, a much larger character is needed. The major limitation with the PED<sup>3</sup> display is the lack of gerbs that will produce curved lines. This means that while it is possible to produce almost any message it is most practical to work within the 7 segment readout limitations. TD



## FIREWORKS ON A BUDGET

I love fireworks! So does everyone, I guess, judging by the attendance at public displays. My wife and I aren't satisfied with once or twice a year, so we put up a few shells, and rockets two or three times a week. We go to a small local lake with a public boat ramp at about 9:00 p.m.. At this hour, there are only a few people sitting in their cars, watching the night go by. They seem to enjoy our mini-displays, especially when everything works perfectly. The only problem is that I shoot so many shells and rockets, I simply had to devise economical short cuts and budget methods to keep expenses within bounds. There have been many disappointments and set-backs, of course, but finally many of my ideas and procedures are taking shape.

The first problem that I solved was a method of making consistently good meal powder. I tried hot saturated nitrate solution, into which I stirred the proper amount of sulfur and charcoal. I didn't like the results, and the process is messy. No matter what I did, the re-crystallized nitrate particles were much too large for a clean burning, fast meal powder.

The next step was to beg, borrow or steal a ball mill. Since I own a machine shop, I decided to make one. The result was a heavy duty, 5 lb. capacity long drop ball mill constructed out of spare parts. The receiver is a 24" long piece of 6" dia. P.V.C. tubing with end caps, held in place by heavy rubber bands.

This arrangement minimized confinement, in the unlikely event of ignition. With this mill I get a consistent "green" powder, that with modifications fills the bill, from candle comp to rocket mix. I also built a wheel mill, with a spring loaded, pressure down feed, to simulate commercial stone wheel mills. I can see no difference in my powder and commercial rifle powder, except that I'm not too fussy about sizing the grains, so it probably wouldn't be as good, ballistically.

Years ago, when I only made rockets, my problems were few. But now I'm so fascinated with aerial shells, that I can't wait to learn everything I can about them. I quickly discovered that

making a rocket fly was one thing, but a 3-break aerial shell that works was another.

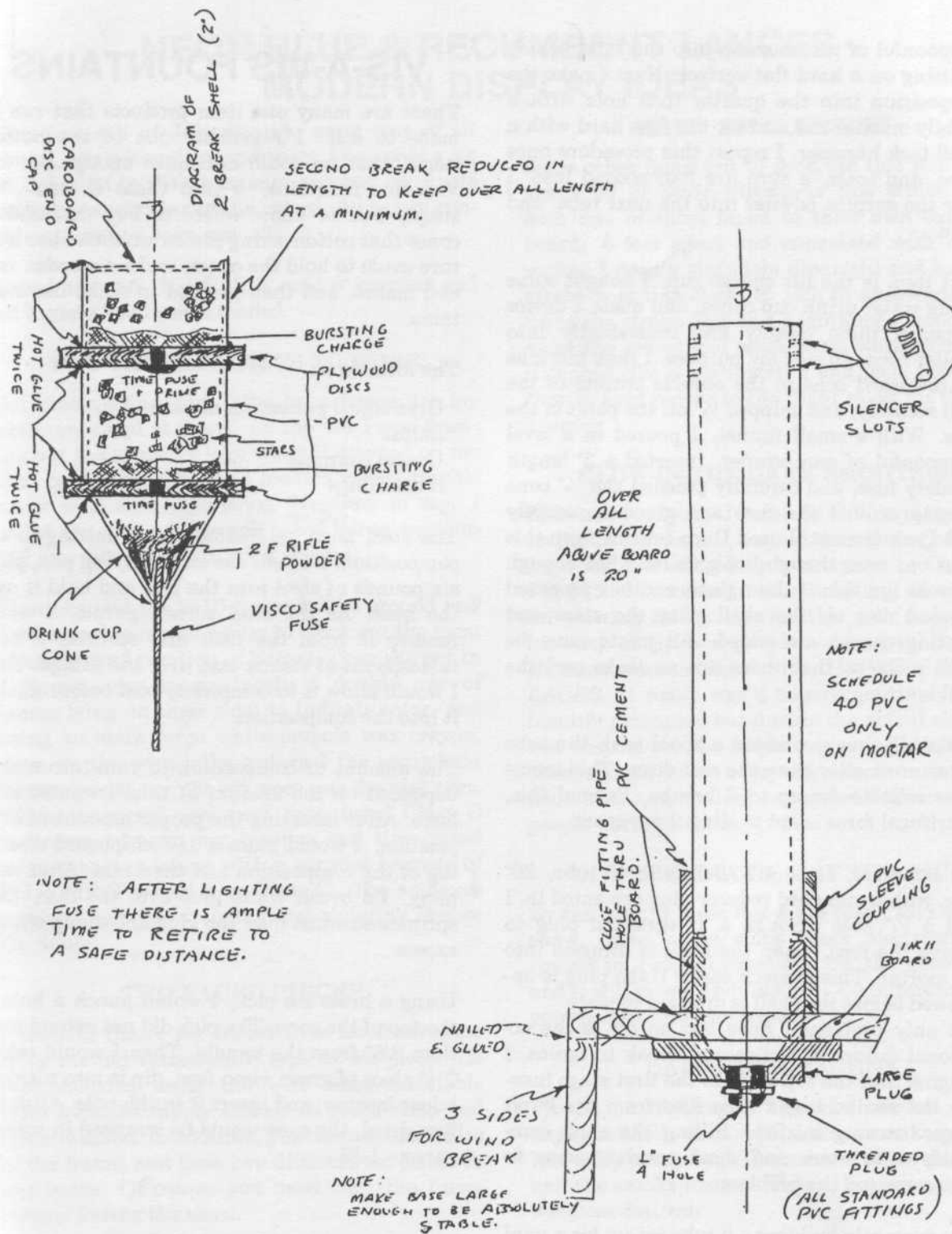
At first I had no success. I either got flower pots, stars that didn't light, or shells that came apart before reaching full height. Finally, I'd had it with scrap paper and Elmer's glue. I must have rolled a million tubes of every size and description in my life. There had to be a better way.

One day I stumbled over a length of 1" thin-wall PVC tubing in my garage. This might be the answer to quick, cheap rocket tubes, if only they were strong enough. And what about shrapnel, I thought, remembering the cautions about metal components. I'd simply make sure that no one was around when I tried one. I had some rocket comp that was a little too vigorous, and I had been meaning to tone it down some with charcoal before using it again. I thought to myself that this would be the acid test regarding the strength of PVC tubing. When the rocket was ready, I instructed my wife to roll the car window up, just in case. I lit the fuse, ran like blazes and scurried behind the car to wait for the shattering blast. To my amazement, the rocket suddenly disappeared with a deafening roar. It leveled out at about 300 feet, then flew horizontally for quite a distance, finally falling into the lake.

I hadn't put stars in it because I really expected it to explode or at least "blow through". PVC tubing is incredibly strong, even though it softens from the heat. By the time this happens though, the rocket is well on its way, so I don't think it matters.

I then realized that I could probably use PVC for shell components too. I cut 1 1/4" PVC tubing into 1 1/2" lengths and squared the ends on a belt sander. 1/4" thick plywood and a 2" hole saw was next on the agenda, which supplied me with 1-15/16" dia. wooden discs. Plywood has since never cracked or broken on me from lift blast. The hole saw also conveniently leaves a 1/4" pilot hole in the center of the disc, which is perfect for the time fuse. Instead of using quarter inch blasting fuse, I merely hot glue the P.V.C. tubes onto the plywood discs fairly centrally. I then pour a

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teaspoonful of rocket comp into the tube, which is sitting on a hard flat surface. Next I poke the composition into the quarter inch hole with a slightly smaller rod and set the fuse hard with a small tack hammer. I repeat this procedure once more, and *voila*, a sure fire four second fuse. I pour the surplus powder into the next tube, and so on...

Next item is the lift charge cup. I bought some spring water drink cup cones, and made a device to punch them cleanly and consistently into smaller cones to suit my purpose. I then hot glue the reworked cone to the outside bottom of the shell securely, and snipped 1/4" off the point of the cone. With a small funnel, I poured in a level teaspoonful of gun powder, inserted a 2" length of safety fuse, and carefully pinched the 1/4" cone opening around the fuse and glued it securely with Duco cement. I used Duco cement from this point on, even though hot glue isn't hot enough to cause ignition. I then glued another prepared plywood disc on the shell after the stars and bursting charge are added. All joints must be glued twice so that there are no leaks and the shell is strong.

The shell now resembled a spool with the tube diameter smaller than the end discs. This seems to be reliable for up to 3 breaks. Beyond this, centrifugal force is apt to sling them apart.

For a mortar, I use a 2" Schedule 40 tube, 20" long, with a standard reducer plug cemented in. I drill a 1/4" hole through a 1" threaded plug to receive the fuse, when the shell is dropped into the mortar. This is much easier if the plug is unscrewed before the shell is dropped in place.

The only problem I have had so far is the occasional failure of the second break to ignite. I imagine that the top stars in the first stage insulate the second break time fuse from the burst flame, causing misfire. Filling the shell completely with stars and meal powder seems to have corrected the problem.

I am presently building a 5 tube set-up for a mini finale! It sure is fun. SW

## VIS-A-VIS FOUNTAINS

There are many one item products that can be made to sell. I remember one of the hottest items, that we could not make enough of, was Vesuvius fountains, a nice Class C item. We simply had to know where to buy the used 6" cones that cotton string comes on, then have a fixture made to hold the cones, make a wooden ram and mallet, and then proceed to make the fountains.

The formula is:

Granulated potassium nitrate	8 lbs.
Sulfur	1%
Coarse charcoal	1 3/4
Steel filings	3

The steel must be treated before mixing in the composition. I would use an old frying pan, place six pounds of steel into the pan and hold it over the heat. As the steel turned purple, I would remove it from the heat and sprinkle 2 or 3 tablespoons of stearic acid over the filings. Then I would allow it to completely cool before mixing it into the composition.

The amount of composition to ram into a cone depended on the amount of time I wanted it to burn. After inserting the proper amount of composition, I would place a 1 1/2" chipboard disc on top of the composition and then ram. After ramming, I'd brush white glue over the disc, then sprinkle sawdust over the glue and dump out the excess.

Using a brass ice pick, I would punch a hole in the top of the cone. The pick did not extend more than 3/8" from the handle. Then I would take a 2 1/2 piece of green visco fuse, dip it into nitrocellulose lacquer, and insert it in the hole. After the fuse dried, the cone would be wrapped in colored paper. LJS

## NEON BLUE & RECUMBENT LANCES - MODERN DISPLAY IDEAS

This last 4th of July display, as is true of all shows, was a learning experience. I had paid a lot of attention to W.O.'s articles and had my finale racks perpendicular to the crowd. All safety considerations had been met.

I used high lift HDPE 4", 5", and 6" mortars and all leaders had been extended.

### PUT THOSE ARTISTS TO WORK

Set pieces using wire lathe on a frame are my preference and at 3 p.m. on the 4th I was drawing out the sponsors logo when it dawned on me that one of my first time loaders was a graphic artist with sign experience. Needless to say, I called her to the frame and asked her to work on it. I was intrigued with what she did.

First she laid the 8x10 frame on the ground and used a double row of lances to block out the most pleasing configuration of letters. Then she put in different color lances (again a double row of lances lying on their side) to indicate color, and using an extra large white crayola wax crayon, drew on the wire lathe **around** the recumbent lances. I must say, the set piece was the best ever. When completed, we used time fused Class C hummers, dragon egg candles and time fused color changing lances with a surprise barrage of Fairy with Flowers (also Class C). The audience was on their feet clapping and shouting, *before the finale*.

### TWO-FACED PIECES

I need to thank my friend Lyle for freeing me from the old rattan/lance type of set piece. He recommended using the wire lathe (available from builders supply stores) as much time and space is saved. In addition, you can use both sides of the frame, and have two different set pieces in one space. Of course you must turn the frame around during the show.

### KEEP 'EM GUESSING

Some other items put to good use this year were about 20 of Starr Fireworks fine strobe pots, each one of them taped to their own 6x6-inch board, 6 feet apart and connected with quick-match. I fired a girandola (Spanish) and had the strobe pots time-fused to kick in afterwards. By using the strobe pots as a beginning, it tended to quiet the crowd and cause some wonderment as it looked like a malfunction and gave plenty of time to hoof it over to the flight racks for the big opening.

### GLOW-IN-THE-DARK SHOOTERS

Like many of you, I received C.W.'s piggy back mailer in mid June. I noticed the offering of glowing necklaces offered by a company in Chicago. For \$15.00 I received a sample kit full of wonderful glowing things. So for this year's show all loaders, ready box people, videographer, and shooters were outfitted with *GLOWING NECKLACES*. It really was a success; not only did it identify personnel but during the actual show, it was easy to see the brightly glowing circles and always know where everyone was. From now on, neon blue and opulent orange will be on all my people during a shoot.

### DIFFERENTIATING BY THE INCH

By the way, if these items are being sold at your show, simply put some black electrical tape spaced in 1-inch increments on the glow band and it will give a dash/light (—) differentiating your people from the crowd.

### DAYLIGHT DRAGONS

Finally, a 3" Dragon Egg shell makes a nice daylight shell, as it will make a smoke pattern like a dry dandelion. The noise attracts attention and the smoke lingers. This will work only on a windless day. eeh



## MOLECULAR SIEVES AS CORES FOR ROUND STARS

The production of round stars with good size uniformity is critical for the construction of spherical shells with multiple-effect stars. Expert star makers have an uncanny ability to roll stars onto virtually any core, including small seeds and tiny grains of sand, but the novice has a limited number of cores to choose from. Bleser, in his excellent book (*Round Stars & Shells*) suggests that beginners use bentonite-coated #6 lead shot as cores for round stars because their uniform size, relatively large weight, and near-perfect roundness are highly likely to produce favorable results. In practice, however, any serious star maker - novice or not - must quickly find an alternative core unless he/she is planning to distribute safety goggles prior to every exhibition.

There are probably as many different cores in use as there are round star makers, but I have found that spherical "molecular sieves" are nearly perfect cores for both novice and more experienced star makers. Larger sizes (up to 3/16" diameter) provide an excellent start for beginners, who often encounter difficulties during the earliest stages of the process. As a person's ability to roll stars improves, progressively smaller molecular sieves can be used as cores without making major changes in the routine. The transition from novice to ace can be quite painless - especially for spectators or curious neighbors who inadvertently stray into the fallout zone!

The name "molecular sieve" is used to describe a family of aluminosilicate zeolites which are capable of separating small molecules on the basis of their molecular size and shapes. Most are synthetically prepared. (Clays are common aluminosilicates, but their molecular structures do not allow them to act as sieves.) Molecular sieves are available in a very large variety of shapes and sizes, ranging from fine (~2u powder to large cylindrical pellets. One of the most common forms is microporous spherical beads, which are available with relatively narrow size distributions ranging from 1/16" to 1/4" diameter. I am particularly fond of the 8-12 mesh Linde Type 4A molecular sieves available from Fisher Scientific Company (catalog number M514-500) because of their good size uniformity and because I obtain

them at no cost, but there is no reason to believe that other sieves (e.g., Types 3A, 5A, 13X) could not be used. (4-8 mesh Linde Type 4A sieves are excellent cores for beginners.) At the time of this writing, Fisher's list price for 500 grams of molecular sieves (approximately 100,000 cores) was \$23.95, but don't let that worry you. This is the same outfit selling 500 g of potassium nitrate for \$47.90! In reality, molecular sieves are downright cheap when purchased in bulk, and a pyro retailer could probably offer a large discount and still make a healthy profit.

Molecular sieves should be thoroughly soaked in a wet solvent prior to use. This saturates their internal molecular structure and allows them to become wet when sprayed with mist from a spray-bottle. I prefer to use acetone/water (80:20 v/v) to soak the sieves, but other wet solvents can also be used (e.g., ethyl, methyl or isopropyl alcohol). It might even be possible to condition sieves by simply allowing them to stand in a very humid environment for a day or two, but this strategy may make it difficult to uniformly wet the sieves prior to adding the first increment of star composition.

I usually condition my cores by adding the sieves (~ 1 cup) slowly to an excess of acetone/water (~ 8 oz) and allow them to stand for an hour or two in an open one-pint glass jar. The excess solvent is then decanted, and the slightly wet sieves are stored in a tightly sealed jar for future use. The amount of heat evolved when sieves are initially added to wet solvent depends on their initial state of dehydration. This can vary enormously, and highly dehydrated sieves are actually capable of making the solvent "boil". (In fact, the addition of pure water to highly dehydrated sieves in a metal pan will produce a "sizzling" sound as the water boils!) This is quite surprising to those unfamiliar with molecular sieves, but it should not be a cause for alarm. Except for the usual hazards associated with flammable solvent vapors (which should never be taken too lightly!), there is no danger of an explosion or fire. Nevertheless, it is always best to add small amounts of sieves slowly to an excess of cold solvent. As common sense should dictate,

this should be done in a well ventilated area, far away from any potential source of ignition.

Once hydrated (i.e., conditioned), molecular sieves are ready to use. I like to start with somewhere between one and three teaspoons of molecular sieves (approx 750 - 2500 cores) in a large stainless steel bowl. The wet cores will initially stick to the pan and themselves, but as the pan is swirled to evaporate the acetone, the cores will begin to roll freely. Once they are all in motion, it is time to begin: a squirt or two from the solvent spray bottle, a small increment of star mix, and we are rolling! The cores will quickly pick up most compositions to produce well-formed spherical stars with excellent size uniformity. FJF

## LANCE DEVELOPMENT

I have been assigned to construct a lance piece in orange and blue saying:

GO ILLINI

After much consideration, I have formulated the following as a possible dynamic solution. Most lance pieces use a rigid framework to build on. I think the piece can actually be written out - in longhand. Here's how:

I would use a low-burning colored lance of fire pots and string them together with electric fence wire, then light them with black match. This could then be spelled out on a sheet of cheap 4x8 paneling, using black match to ignite. As the black match burns, it would appear to be written as the flame advances down the board. The fire pots could be strung in 6-ft. lengths and attached at will to the back-board. The black match would be added last to string everything together, like Christmas tree lights. DD

## ILLUMINATION BREAKS & SHIMMERING CURTAINS

We asked a display manufacturer why some of his shells seem to break with a super bright light, while other shells have a break that gives a shimmering (and audible) appearance. We expected a mind-your-own-business reply, but the operator said he was pleased we asked and was quite willing to share the technology.

He calls the bright break "Illumination strength photo-flash shells". He says that the effect is like a camera flash unit, and "illuminates the ground below". Simple to make, he says. "We place 1 oz. of 100 mesh magnalium (by volume) and 1/2 oz. (volume) of sawdust in a sealed plastic baggie, and throw it loose into every shell." What could be simpler?

He said that the shimmering break was equally easy. He said the effect is "a shell break of white shimmering curtain of sparks following the stars." How is it done? Again by volume: 1 oz. of "extremely coarse" titanium and 1/2 oz. sawdust in a sealed plastic baggie and added into the shell. He says, "The vacuum created by the burning of the stars pulls the burning titanium behind each and every star, forming a shimmering curtain of white light".

It must be emphasized that unlike standard practice in the trade, the chemicals in these effects are measured by volume and not by weight. The reason, of course, is that the production person making up these baggies is scooping the chemical and sawdust, rather than having to go to the trouble of weighing each component. JD



## PYRO SURPRISES

Pyrotechnics have lots of surprises: some nasty, some pleasant. Here are some that I had.

The nasty ear splitting, finger burning, surprises I will leave out of this account and focus on the others. It's not that I don't believe in sharing the nasty ones, however. There are certainly lessons to be learnt from one's mistakes which are worth passing on to others but perhaps some other time.

In my early pyro experiments I attempted to duplicate one of the red aircraft flares described in Davis. Here I used some newly acquired aluminum powder and at that stage I did not know whether it was flake or atomized aluminum. I made a small pile of the mix and proceeded to ignite it. What a battle! It eventually took fire but then almost immediately lost its flame and started smouldering. As a flare it was a disappointing failure but I was soon rewarded by witnessing a different phenomenon. The pile of material suddenly burst into flame, just like a volcano erupting. The flame then died and this process repeated itself several times until the mix burnt out.

I later found out that my aluminum was the atomized type and not flake as specified in the formula. It was nevertheless an interesting experience and probably worth investigating further.

Early attempts at Roman candles bring back many memories. My first stars were white stars which usually blew blind. I then made some red and green chlorate stars. "No problem here" I thought. After that I made two short tubes for testing and placed one red star in each. That evening I invited Yvonne and the kids to watch. I lit both fuses simultaneously and watched rather apprehensively while the candle comp burnt down to the stars.

Suddenly BA-DOOPF as both stars were shot virtually simultaneously, followed by half the dogs in the block barking. No one saw the stars leave the tubes and my first thought was that they had blown out blind, again! I then looked upwards

and there, directly above me, were the two red stars high in the sky. They were high, almost in orbit. I was elated but sobered with the thought that my estimates for propellant quantities still required quite a bit of work.

For some jeweled fountains I decided that I needed some non-chlorate colored microstars. I hunted around for a red formula and eventually decided that instead of one of the standard perchlorate reds I would try something different. I would use some of the ruby firestick mix described in Weingart. I then duly proceeded to make up the mix and transform it into microstars. The shape of the stars was my first surprise. Try as I would, I could not make them round. They all ended up looking like small grains of rice. The stars were still slightly damp when I lit a few of them as a test. Nice red color.

After thoroughly drying the stars I mixed a batch into the fountain mix. The resulting fountain was beautiful except that the stars were silver, not red! Perhaps this was due to their burning at a much higher temperature than my test batch. What I do know, is that they make a superb silver jeweled fountain.

My first experience of fountains which made crackling noises came from the little "Hornet Fountain" made by the British fireworks company, Standard. From that day onward I have coveted being able to duplicate this phenomenon. At that stage in my pyro experience I had no idea how to achieve the effect. Then one day I ended up making a crackling fountain quite by accident.

The mix I used was a simple sodium nitrate, sulfur and charcoal yellow fire, loaded into a paper tube. I mixed this a short while before firing to prevent too much moisture being absorbed by the sodium nitrate. To my surprise the device burnt with a crackling sound. I guess the crackling might have been due to moisture in the larger pieces of charcoal, giving a similar effect to crackling logs on a wood fire. If this was the case then the crackling was due to mechanical action rather than chemical reactions. To the best of my knowledge nothing in the chemical content of the

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mix would suggest the latter. What I do know for sure was that my crackling fountain was different to Standard's Hornet and similar Chinese devices.

I still intend experimenting with mixes which could properly emulate the commercially produced devices but also intend investigating my discovery. One could possibly make a "poor man's crackling fountain" by deliberately driving moisture into charcoal chips and then sealing them. Some purists might not consider this true pyrotechnics but what the heck.

A Chinese Class C "Jack-in-the-Box Surprise" recently gave me a surprise I had not bargained on.

We shoot our family backyard displays next to the swimming pool. This enhances the effect by adding reflections from the water. The "Jack-in-the-Box Surprise" is basically a fountain together with some ground spinners which it ejects. On this occasion some of the ground spinners found their way into the pool and scooted along the water, much to the delight of the kids. Mom and dad were also delighted of course, but specially dad. Here was a "water firework" at a much lower cost than the rip-off prices asked for the genuine things!

A chain, they say, is only as strong as its weakest link. If one equates each link in a chain with each step in constructing pyrotechnic devices, then this is certainly true in making anything pyrotechnic. Skimp on just one step and the whole thing can end up being a failure. This happened to me in a way that I will not easily forget.

My pride and joy was a new experimental cone device. Instead of the standard cone casing, this was a pyramid; a large pyramid, made with very strong walls. The tip was specially strengthened to withstand a large amount of comp being blasted through under pressure. It took me a fair amount of time to make and I figured that the walls and tip would withstand anything. They did. The weak link in the chain did not.

After all the long and tedious preparations I hastily filled the pyramid with comp and glued a

rather flimsy bottom plug in place. I don't think the glue had even fully dried when I lit the fuse. My pride and joy started emitting a thin stream of sparks, then suddenly blew its bottom. A large mass of burning material spewed all over the place. Consternation! My special firework was a flop!

But the audience, thinking they had just been privileged to witness some never-before-seen pyrotechnic phenomenon, clapped appreciatively. That was - perhaps - the greatest and best surprise of them all. IvM

## **PUSH STICK AIDS LOW BREAKS**

Here is a performance improvement that AFN readers may find interesting.

For some time I have had problems with low breaking shots when firing *Garden in Spring*. Upon inspection I found that the shells were seldom firmly seated in the mortar tubes.

My solution: I found a broom handle that just happened to be a perfect diameter to fit inside the mortar tubes. Now I could push the little projectiles down to the bottom of the mortar with this homemade rammer.

For convenience, I cut the handle about a foot long. I tear off the cellophane and tissue paper from the device, extract the fuse and then use the rammer to seat the shell firmly (but not jammed too hard against the bottom). Now I always get 40-foot breaks!

I make a point of always checking my #5, #100, and #200 aerial items for this problem. Many time I find that the chipboard or plastic plugs have worked loose in shipping, unless the manufacturer glued them in place.

I have found that the trick is to use the correct size rammer for each size tube, and not to jam them overly tight. LF

## EIGHT EXPERIMENTS IN NON-COMMERCIAL BLACK POWDER

Everything I've ever read said it was almost impossible to make commercial grade black powder, but it seemed to me that something that has been around for so many years could not be that hard to make. While I'm fascinated by all forms of fireworks, for some reason this black powder thing really got to my intellectual side. So I started my investigation and sent off for every possible article, publication and book that mentions black powder. It quickly became apparent that it's a fascinating history, with lots of ways to make it.

There are two basic qualities to look for in black powder: *speed of burn* and *gaseous output*. The first is relatively easy to objectively measure, but the second is not so easy except in a subjective way (e.g., shoot some shells and estimate the results) unless you have sophisticated measuring equipment.

After researching all the literature I could find, I decided to make up eight different 40 gram batches of powder, all based on the 15-3-2 ratio, with only slight adjustment to compensate for filtrate loss when employing variations of the "CIA Method". I performed two different burn rate tests on each sample and used a Sony Hi-8 video camera with frame-by-frame analysis (accuracy of .0333 seconds) to calculate the actual duration of the fire. The Burn Rate Test procedure is shown below. -

Keep in mind that my goal was to produce commercial quality powder as an experiment, (perhaps better described as an intellectual challenge), not necessarily an economically or commercially feasible technique. The results were a bit surprising based on the literature, and it turns out that the best method I found was one which combined the CIA potassium nitrate solution methodology with the old fashioned ball milling approach.

### BURN RATE TEST PROCEDURE

A 1.8 gram mound of composition is ignited by a foil wrapped length of visco fuse with the length

of burn determined by counting up the total number of video frames depicting "composition flame". The last frame or two of the rising fire ball above where the composition was is not counted. A "linear burn" timing test is performed on an 8.5 gram sample of composition evenly spread out over an area of 45cm. Tests were done three times for each sample with mean burn times reported.

Important note: For Tests 4 - 7, potassium nitrate and sulfur/charcoal were ball milled in two separate tumblers for 60 hours before doing the rest of the procedure(s).

Also note: Charcoal/sulfur is a pre-milled composition. That yields a big difference versus individually adding charcoal and sulfur. AP

*[Procedure and results are tabulated on the next page.]*

## QUOTE OF THE MONTH

The Hard Core Pyro. Everyone knows at least one. He's the guy who's covered with dust, hasn't eaten in 2 days, and desperately needs a nap, but you can ask him any pyro question and he'll gladly give you a 20-minute answer.

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TEST PROCEDURE	MOUND	LINEAR
TEST 1. Simple 15 minute hand mix procedure.	2.7 sec.	10.3 sec.
TEST 2. West mix/screen granulate: Repeat comp. 1 above but add water to final comp until a paste form is obtained, hand grind 15 min. then granulate by crushing mass thru 18 mesh screen, let air dry, then pass thru 40 mesh to eliminate fines.	.04 sec.	1.4 sec.
TEST 3. Hard hand grind mix: Grind components in mortar, then hand grind comp, for 1 hour. Add water to paste, grind strongly by hand for 1 more hour. Then granulate as above.	.03 sec.	1.25 sec.
[See important note] TEST 4. Milled comp/hand grind wet: Screen mix and ball mill complete composition (outdoors, safe area) for 72 hours. Add isopropyl 70% to paste, hand grind for 1 hour, then granulate.	.25 sec.	1.0 sec.
TEST 5. Milled/CIA precipitation technique/granulate: CIA base technique. 30 grams potassium nitrate in 30ml water dissolved at 75°C, remove from heat and add c/s comp.; mix well. Add to 50ml 15°C isopropyl with vigorous agitation. Filter, then granulate.	0.4 sec.	1.5 sec.
TEST 6. Milled/modified CIA precipitation technique/granulate: Modified CIA technique. Dissolve 32gm potassium nitrate in 30ml water at 90°C. Mix thoroughly c/s comp, in 60ml 91 % isopropyl at 10°C. Remove nitrate from heat and with vigorous agitation, add sulfur/charcoal slurry mix to nitrate.(20 sec. to complete). Mix, filter, granulate.	0.4 sec.	1.6 sec.
TEST 7. Experimental: Experimental version (done after running above tests). Dissolve 30 grams potassium nitrate in 25ml water at 90°C. Mix with rapid agitation the ball milled sulfur/charcoal comp, into the potassium nitrate solution after removing from heat. Mix thoroughly. It will take some time to completely mix the sulfur/charcoal, but as the nitrate precipitates out of solution the s/c will begin to mix in faster. After mixed, place back on heat and mix continually until black slurry is obtained and mix begins to boil up. Once the steam process sets in strongly, remove from heat, place on ice block and add 10ml 91 % alcohol at <5°C while mixing rapidly. When cooled down (2-3 min.) spread out slurry in a thin layer on a foil sheet and let air dry. Crush dried comp and place in ball mill after misting slightly with water. Ball mill will cake powder to inside wall of mill within 4 hours; let run for 24 hours total. Remove comp., crush and thoroughly air dry, then return to mill and mill 48 hours (no caking this time). Wet with alcohol to paste, then granulate.	.17 sec.	0.7 sec.
TEST 8. Standard commercial 2Fg	0.1 sec.	0.4 sec.





## METHOD FOR CONDUCTING PYROTECHNIC EXPERIMENTS

In this article the author attempts to outline simple methods for performing controlled experiments. These methods are typically associated with experiments with chemical compositions, but they may be applied to physical construction of devices as well. The triangle diagram is the main resource for these methods and its usefulness is explored.

### Introduction

The author understands that these methods are probably in use (more or less) by experienced or better "schooled" pyrotechnicians on a regular basis. This article may present nothing new to them and, in fact, it is not intended to. Rather, this article shows how my use of triangle diagrams allows me to make progress when attempting to refine formulas or construction methods. The advice of experts is helpful in these situations, but is sometimes unavailable. Progress can still be made in this case and the respect of experts earned as well.

### The Triangle Diagram

The main prop in use for logical and systematic refinement of formulas is the triangle diagram. (A discussion of reading and using triangle diagrams will not be included in this paper. Readers unfamiliar with its use are referred to "Taming Triangle Diagrams" by Ken L. Kosanke, which appeared in *Pyrotechnica VIII*.) The triangle diagram allows one to see where research is headed, where it has been and where it is, all at a glance. This type of record keeping is essential, as the refinement of an existing formula may take 10-20 trials: If one does not keep careful track of previous experiments it is possible that they may be inadvertently repeated, or may have to be repeated. There are certainly enough variables to contend with in even the simplest of experiments, without introducing another: human error. The triangle diagram solves these problems; its use, while not being the only way to do this, is encouraged.

The triangle diagram, being an actual triangle,

only has three sides and so only three variables can be manipulated at a time. Compositions containing more than three components can be used, but the other components must be held constant during the trials where the three listed on the triangle diagram are being manipulated. These other components may be manipulated in another set of trials where they become the components listed on the triangle diagram and the other components are now the ones being held constant. There may be a considerable amount of give and take between these two groups of components to get the final product to exhibit the desired characteristics. This being so, it is best to begin ones initiation into the use of triangle diagrams by selecting a composition that has at most three or four components.

### Pitfalls of the Triangle Diagram

If a black powder type composition is selected for illustration, assume that 5% binder will be added and this component will be kept constant while the others are manipulated. In this case the formula will not contain 5% binder, but +5%. The other ingredients will add up to 100% and +5% binder will be added to them. The "+" stands for "additional percent". The final product will no longer contain the proportions listed on the triangle diagram because it has been "diluted" by the addition of 5% binder. If meal powder was being made with proportions of: potassium nitrate 75%, sulfur 10%, charcoal 15% and +5% wheat paste, the actual formula in percentages would be: potassium nitrate 71.43%, sulfur 9.52%, charcoal 14.29% and wheat paste 4.76%. This is arrived at by adding up the total in percents (in this case 105) and then each percent is divided by this number to reveal the actual percentage. To avoid this slight amount of confusion, we might simply modify the triangle diagram so that the percentages on each side only go up to 95%. The actual percentages of ingredients can then be read directly from the triangle diagram, without the need to recalculate each ingredient to compensate for the 5% binder being held constant.



## Why Experiment With Known Formulas?

In the case of the above "known" formula, we would not have to run many trials of slight variations on the percentages to find that the existing formula is quite usable as is. Indeed, most people probably have never even bothered to attempt this, as the formula's effectiveness is well known and generally agreed on. The +5% addition of some type of binder does not detract very much from the burning speed and ignitability of the classic black powder formula. It does however, detract from it somewhat; after all, carbon based binders do not burn as fast as black powder! So, to compensate for this small percentage of slow burning fuel, what would be the quickest way to go about it?

The above is a typical example of what needs to be done with nearly any formula that will vary from known standards. There can be many reasons why a formula will vary or be altered. In the above example, it was to be altered by the addition of a binder, perhaps to provide better adhesiveness when the composition was wetted and made into grains or pasted on rice hulls. Most formulas however, will be altered due to the unavailability of listed ingredients. In these cases it may be necessary to run some trials to determine if the additional or substituted ingredient will produce (or how much it will alter) the desired effect.

## Specific Methods of Using Triangle Diagrams

The way the author goes about these tests is to find the known formulas position on the triangle diagram and draw a circle around it. The circle is usually about 5% in radius/ingredients around the known formulas point. Dots are made on the edge of the circle at four equidistant locations. These four dots are the first four trial formulas. If one of these four formulas produces a satisfactory result, or at least a promising one, another circle is drawn around this dot and the same process is repeated. (It is not necessary to repeat the formula that intersects the original starting point.) Eventually, perhaps after repeating this process several more times, the most satisfactory formula will be found. Finally, the best formula

is "experimented around" until a zone of the best effect is found. This will be the zone to stay inside of when making this formula with these particular ingredients. If one of the ingredients happens to be expensively priced or is troublesome to work with, the area of the zone that contains the least amount of this ingredient would be the best choice to use. This is one reason why the zone of best effect is determined, instead of stopping when the best formula is found.

On the other hand, if in the first set of trials a satisfactory formula was not found, another circle would be drawn around the first one. This circle would be 10% (in ingredients) larger in diameter than the first circle. Instead of four dots equidistantly spaced on the edge of the circle, eight would now be made. If one of these proves hopeful, it is narrowed in on as before. If not, another eight dots are made in-between the previous eight on the same circle and these trials are run. This process of drawing circles and marking dots on their edges is repeated until a promising result is found. This is then narrowed in on until the best effect is found. Finally, the best effect is skirted until the zone of the best effect is found. Circles are drawn and dots are marked so that new formulas are no more than 5% in ingredients apart from the previous ones. However, as the zone of best effect is being determined, it is sometimes useful to use a finer scale or distance between formulas.

## Concluding Remarks

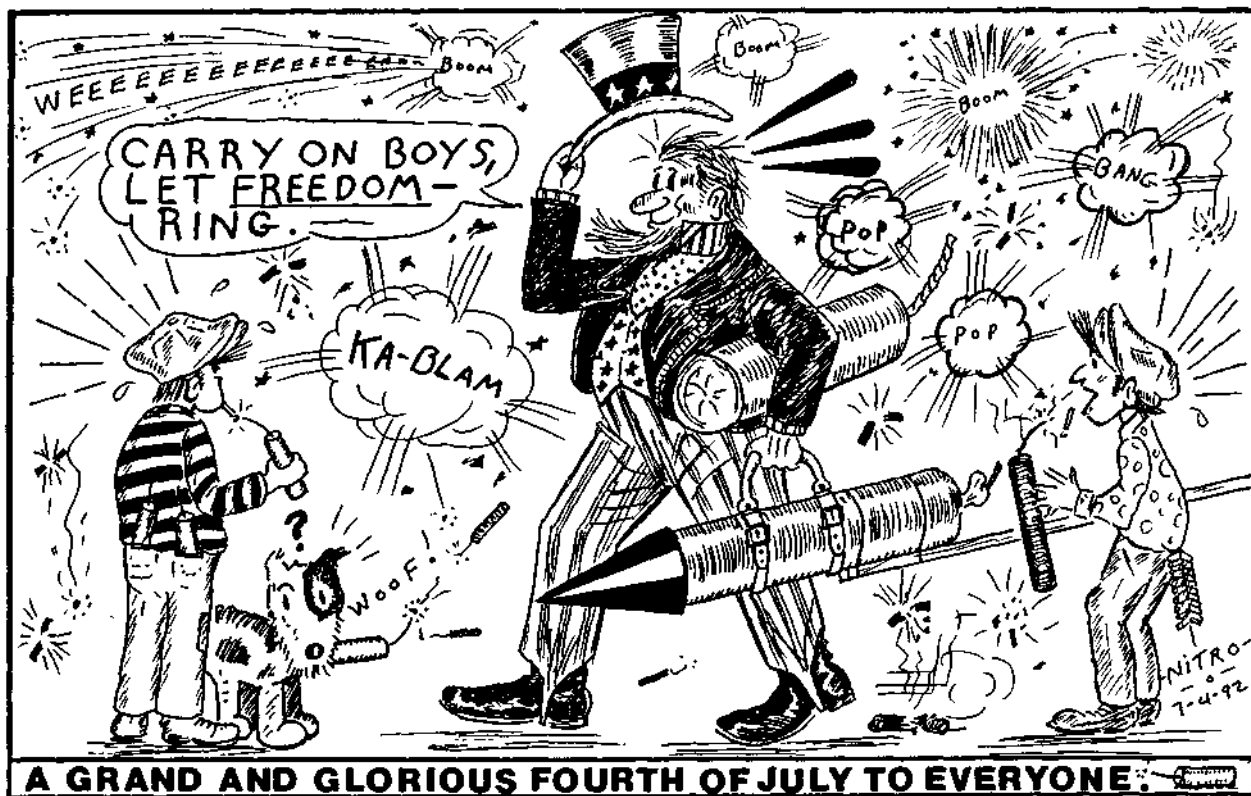
The author has used the above procedures on several occasions and has found them to be extremely helpful. The main advantage seems to be the immediate visual feedback the triangle diagram provides. Successful or promising results of experiments take on a new meaning when seen as part of the whole picture. But, it should be borne in mind that the above process is only the way the author does it - it is certainly not carved in stone. The reader will probably develop his or her own personal touches to this process, and that is how it should be.

There are some tips about using the triangle diagram that bear mentioning:

- experimenter's knowledge) as to render the tests invalid. 10 - 100 gram test batches weighed out on a name brand triple beam scale are what most people seem to use with satisfactory results. SAR

## ROUND STARS TIP

Round Stars... Did you ever have them form little bumps and no matter how you try to correct the situation, it just gets worse? I've found something that seems to really solve the problem. Try using a 50/50 mix of Sta Flo starch and water in your spray bottle and reduce the dextrin content of whatever star composition that you are coating your stars with. It seems that when the starch is sprayed on the stars instead of being in the mix, the composition is picked up much more evenly. It also helps to add a small amount of alcohol to the solution. This liquid starch works well in match and as a star binder also. SW



## THE QUEST FOR FAST POWDER

Ever since my early pyro days I have pursued that elusive dream: homemade black powder that burns like the real thing.

My early high school years were filled with tales of incredible explosions made by mixes of "equal parts" of saltpeter, sulfur and charcoal. A little bit of research on my part soon convinced me that most of these claims were ludicrous. The "real" formula, I soon discovered, was the 75:10:15 ratio by *weight*. All the alleged claims to fame came from BP made with equal parts by *volume*.

My own experiments convinced me of another myth-dispelling fact. Big bangs did not come from just simply buying the ingredients and mixing them together. One had to first grind each component to a fine powder. The gift of my first pestle and mortar thus led me to believe I was on my way. Alas, I got closer to my goal but not nearly close enough.

The closest I actually got was a firecracker that made a dull *POOF* instead of a loud *BANG*. And this was after a couple of hours of both wet and, somewhat dangerous, dry grinding. My hands really ached but that ecstatic moment when I actually created an explosion was worth it.

Ironically, looking back on those teenage years, I now realize that a bit more knowledge then would have got me to my goal quite easily. My true goal was to be able to actually produce a loud bang, and black powder was just a means to an end. At that time I did have the right stuff: potassium permanganate and aluminum powder.

The potassium permanganate I had bought for another of its wonderful pyro properties. This was its peculiar ability to spontaneously ignite when mixed with glycerin. The aluminum powder I inherited from my pyro father. Somehow this stuff had escaped the authorities when they confiscated his pyro stuff a number of years earlier.

Many years later my passion for all things pyro was revived and I again started thinking

seriously about making black powder.

This time I had a different need for the stuff. Gone were the wild passions of puberty that hankered for the power found in creating large bangs. Now I needed it for Roman candles and similar devices.

In my neck of the woods one cannot just go out and order GOEX (or equivalent) by the ton. Here even one kilo of sporting powder is difficult to obtain and often only through devious means. So one is usually forced to home brew or do without. I decided I did not want to do without.

For a long time a fellow pyro and I toyed with the idea of making a ball mill. This was primarily for making meal powder but I reckoned that this was only one step away from making granulated BP I could use for a propellant. Then I found out about the CIA method.

Finally the CIA booklet arrived in the mail and once again I thought I was on my way. Alas, another one of life's great disappointments. The CIA method could not break the 15 cm/second speed barrier. Batch after batch could not get past the 15 cm hurdle.

I used my slow CIA stuff as meal powder substitute and turned my attention back to ball milling. I made a small ball mill and milled a charcoal/sulfur mix for about ten hours. Progress! The next CIA batch made with the milled stuff burnt at about 30 cm/second. Half of this batch went into a pasta maker with the thought of producing granules. This was a complete failure but it did produce a form of meal cake.

I dried my pasta-maker meal cake and did some speed tests. This stuff burned at about 33 cm/second, about 10% faster than the uncompressed powder. It also had the advantage of producing fairly hard granules.

At this stage I was corresponding with some readers of AFN and picked up a number of good tips. The most important of these is that one



must ball mill and preferably for a long time. Another tip was the importance of compressing the meal cake. Ball milling was not a problem; compressing the meal cake was.

I knew that I could get a nominal 10% improvement with my pasta maker press so I decided to press ahead (pun intended) with my experiments. I ball milled for a fanatical 60 hours and adopted changes to the CIA method which would, I hoped, improve the process. Finally I was ready to test my ball mill *cum* CIA *cum* spaghetti press powder.

A finger-burning sneak preview suggested that I had some hot stuff. The day before the powder was dried, granulated and ready for testing, I had lit some waste powder that had fallen on the ground. This stuff was still damp and I expected a slow sputtering ignition when I applied the burning match. Instead I got a sudden *WHOOSH* which literally made me fall over backwards with fright. I also had some very sore fingers.

I timed my latest batch at 90 cm/second! I couldn't believe it and ran two more tests. Similar results. Since then I have made two more batches using the same method with repeatable fast speeds.

The BP does a great job in Roman candles. I used a bit too much in one of my experiments and it shot each star with a bang. Music to the ears of one whose BP "firecrackers" could only produce a dull *POOF*.

To get a BP which approached the right stuff I focused my attention on:

- Charcoal: here I used homemade willow charcoal.
- Ball milling: here I ball mill for 60 hours.
- Fast cooling: here I use the alcohol to both dehydrate the mix and to cool it down.

I feel that this last point is of particular importance. Some of the BP making methods I have heard about add a small quantity of alcohol to the hot mix. I believe in drowning the hot mix in

cold alcohol. A simple application of physics suggests that the colder the alcohol, and the more there is of it, the faster the hot BP will cool down. The faster the BP cools down, the faster the potassium nitrate will crystallize out and the smaller the crystals. The smaller the crystals the faster the powder.

Using more alcohol naturally makes the process more expensive and this is probably one of the reasons why some pyros prefer to add a smaller quantity of alcohol to the mix. To me the extra cost is well worth it.

Here's the method I used for a 500g batch of BP:

1. I grind 75g. homemade willow charcoal to about 100 mesh, then mix with 50g sulfur.
2. Then I ball mill the charcoal/sulfur mix for 60 hours.
3. I mix 375g potassium nitrate with 300ml water in a pot and heat to boiling point on a hot plate.
4. I add charcoal/sulfur mix and stir well until the C/S is thoroughly wetted and mixed with the potassium nitrate. This takes a while. I have noticed a rather weird surface tension effect with the saturated potassium nitrate solution which makes it difficult to mix in the dry C/S.
5. I bring the mix to a boil, stirring quickly.
6. I remove the pot from the heat and let it stand for half an hour.
7. I again heat up the mix and bring to a boil, stirring quickly.
8. Removing the pot from the heat, I empty the contents into 750ml of chilled denatured alcohol.
9. Rapid stirring of the mix/alcohol ensures that they are thoroughly mixed.
10. Now I sieve through a cloth, squeezing out excess moisture.

11. I place some of the mix in a pasta maker.
12. Cranking the handle, I squeeze out as much of the remaining moisture as possible.
13. Taking the nozzle off the pasta maker, I remove the "cake" of compressed powder mix.
14. I repeat steps 11 to 13 until all the mix has been converted into cakes.
15. I dry the cakes in the shade for 24 hours.
16. I dry the cakes in the sun for about 6 hours (or until thoroughly dry).
17. I place a dry cake between two pieces of paper on a wooden board and crush with a rolling pin.
18. I repeat step 17 until all the cakes are crushed.
19. Finally I sieve the crushed cakes and recrush where necessary.

My method uses denatured alcohol, commonly known as methylated spirits in my part of the world. I use this because it is the cheapest form of alcohol available here.

To date I have made three batches and achieved burning speeds of approximately 90 cm/second in each. This speed is frighteningly fast and I am thus extra careful in the final stages of preparation, even in the stages when the powder is still damp.

My quest for fast powder has basically come to an end; my latest batches of BP are certainly more than fast enough for my needs. Attaining faster speeds would just be an intellectual exercise from now on. My latest challenge is to determine how little of the stuff I actually need to send those Roman candle balls into the air without blasting them into orbit. IvM.

## MATCH WARNING

The October issue of the New Hampshire Pyrotechnic Association newsletter carried a warning about very sensitive quickmatch believed to be of Chinese origin.

Under SHOOTERS' NOTES, the newsletter reports that a premature ignition occurred when the operator tried to insert a piece of black match into a length of quickmatch. The report said that apparently the friction caused by the black match rubbing against the quickmatch caused the ignition. The report did not describe any injury resulting from this unexpected ignition.

The article ended by stating that "it is thought that some of the recent match from China uses a more sensitive blend of black powder."

## BALL MILLING TIP

For more mixing and faster cleanup, I sometimes put two pounds of composition in a gallon ZIPLOK bag, along with a handful of 1/2" lead balls. I zip it up and throw it in the ball mill. The mix should contain a small percentage of water to facilitate consolidation and minimize static hazard.

The result is more mixing as the bag tumbles faster than the mill, and the saving in clean up is more than welcome. SW



## SUPER POLVERONE

The man who developed "Super Polverone" tells me that one is not technically supposed to call this stuff "black powder". "Super Polverone" however, can be used as a substitute for commercial powder in many applications. In tests it has been used successfully to lift shells, break shells, and make dandy end-burning rocket motors that go like bats out of Hell.

In a nutshell, the process uses a pre-mixed, ball-milled charcoal/sulfur mixture wetted with alcohol into which a hot saturated solution of potassium nitrate is introduced. The method worked like this:

First, a mixture of willow charcoal and sulfur were ball milled together in a rock tumbler with ceramic balls - since we knew we weren't going to introduce an oxidizer during this stage, we could have used practically any heavy, hard grinding medium. The ratio of the components was 3 to 2 charcoal to sulfur, in this case 30 grams & 20 grams respectively. We added 9% denatured ethyl alcohol to the mixture to aid the milling process, keep the dust down, and help to precipitate out the nitrate later on. We milled the charcoal/sulfur mixture overnight.

The following day, we prepared a saturated solution of the requisite 150 grams of potassium nitrate in very hot water in a beaker on an electric hot plate. The stuff we use is a prilled nitrate from the farm supply place down the road a piece. It costs next to nothing in 50 pound bags - enough to last the likes of us a long time. The solubility of potassium nitrate at 100 degrees C is 247 grams per 100 cc of water - ideal for our purposes. It took about 61 grams of distilled water to dissolve our nitrate. We placed a large plastic mixing bowl in an ice water bath in an automotive oil changing pan, and into this emptied the charcoal/sulfur mixture already dampened with alcohol. We poured in the saturated nitrate solution and mixed thoroughly with an electric cake mixer borrowed from the wife. The saturated nitrate solution quickly cooled and simultaneously mixed with the alcohol already thoroughly dispersed within the charcoal/sulfur mixture. Now, alcohol and water mix together

very well, but the resulting solution does not hold nitrate in solution for beans. So, the nitrate begins immediately to crystallize out of solution. Since we are agitating the process with the mixer and keeping things cool with the ice-water bath, the process generates many small, mostly microscopic nitrate crystals that permeate even the tiny particles of charcoal.

The immediate result is a damp, crumbly mixture with a texture resembling a very dry pastry or bread dough. After agitating thoroughly for several minutes while the nitrate drops out of solution, the resulting material was easily grated through a coarse screen and set aside to dry. When completely dried, the result was the raw "Super Polverone" suitable for many pyrotechnic uses. AJS

### FURTHER ON SUPER POLVERONE

Polverone is an excellent substitute for black powder and the method described in the article looks very good. However, the one thing that concerns me is the suggestion to use fertilizer grade potassium nitrate. Fertilizer grade nitrate is a very cheap source of this oxidizer but it doesn't come without problems. Although it may vary from one manufacturer to another, a 50kg bag I bought some time ago, which came from Israel, was not only hygroscopic, but was quite alkaline. This can lead to problems if it is left in a damp place; shells lifted with polverone made from it may fail to attain a safe height.

Another problem, and one that caused me a lot of confusion, is the pH. When used to make glitter stars or glitter fountains, even incorporating boric acid into the mix will not overcome the effect of the residual alkali attacking the powdered aluminum. There can be as much as 2% alkali (potassium hydroxide?) in the fertilizer which can easily be neutralized with nitric acid by dissolving up the fertilizer and adding the dilute acid drop by drop until the fizzing stops. pH indicator paper may be used to show when the end point is reached. I would not add too much acid since add/-chlorate reactions may result if the polverone is used next to them.

If anyone doubts the speed with which fertilizer grade potassium nitrate can attack aluminum, leave a little damp nitrate to dry on a sheet of aluminum foil for a day or so. It will almost certainly corrode through the foil in that time. PS

### **MORE ON FERTILIZER-GRADE POTASSIUM NITRATE**

After reading these articles, my first impression was, "Eureka, a cheap, plentiful source of a commonly used chemical. I must have some". At \$17.00 per 50 lb. bag, it was an apparent bonanza. What I purchased was K-Power brand  $\text{KNO}_3$ , manufactured by Cedar Chemical Corp. Their analysis was: nitrogen 13.75%, potash 44.50%. In my excitement, I didn't consider what the other 41.75% might be.

I produced a fine-working batch of polverone using a modified method of the original technique. "Cool", I thought, "Let's try it in a star formula". The star I decided upon was a purple glitter comp using - you guessed it - powdered aluminum.

The various chemicals were weighed out, milled as needed (the potassium nitrate was quite granular), and mixed in prescribed manner. The comp was a water-moistened formula. Upon adding water to the mix, something evil was set in motion. As I was kneading the mixture, I noticed almost immediately that the comp was spontaneously heating up. The dough began to rise like bread, followed quickly by vapor emission. All the while the comp was getting hotter and hotter. My initial thoughts of "What the hey?" were soon changed to panic mode. Given the rapidity and intensity of heat production, I felt sure I had only a short time before spontaneous ignition could be reached. Although safely outdoors, a pound of purple glitter star comp blazing away did not stir my pyrotechnic interests.

Immediately I flew to my water hose outlet and flushed the mixture with copious quantities. And while doing so, I wondered that if just a small amount of water had precipitated this near-

disaster, is the addition of more water going to increase the problem? No.

I have yet to analyze my fertilizer-turned-rocket-fuel for pH. But based on P.S.'s experiences and his observation of its reaction on sheet aluminum, I have little doubt now as to the culprit in my mixture where powdered aluminum was involved.

Presumably there is quality fertilizer-grade potassium nitrate available at the considerable saving we seek. However, no amount of savings can offset the potential disaster such un-prettested substances could produce. So for now, I have my chemical grade potassium nitrate for pyrotechnic use, and 50 pounds of nitrogen-rich fertilizer for my lawn. These will allow us both to "stay green". DMcI

### **STILL MORE ON FERTILIZER-GRADE BLACK POWDER**

My experience with this stuff was covered in the January '93 issue, and I found my error - what I thought to be only aluminum powder was, in fact, a 80/20 Al/Mg 400 mesh mix, and I added water. What temerity. Other than that near-disaster, I have found the mix to be very adequate thus far.

After finding such a copious quantity of potassium nitrate for the price, I decided to use the Green Acres idea for all the accouterments; with another visit to Ye Olde Feede & Grain Shoppe. A 50 lb. bag of dusting sulfur set me back all of \$9.00 (98% pure, 2% inert, 95% -325 mesh, silky and very few lumps).

The charcoal took more than a few calls to find, and the price differential isn't worth the effort in small amounts. I contacted some water-purifying companies, and my best price quote was \$1.90 per lb., in 50 lb. lots for coconut-shell charcoal.

I have been using the two garden-variety items regularly now in formulas calling for either or both items, and have found there to be a negligible difference in performance over the higher-priced chemistry. DMcI



## CHLORINE DONORS - AN UPDATE

Halogenated compounds have long been used as color intensifiers in pyrotechnic compositions. Excess halogens (i.e., chlorine, fluorine, bromine, and iodine) in the flame envelopes of burning color compositions help promote the formation of metal mono-halides which generally produce the best (purist) colors, along with the desired spectrum. They also discourage the formation of poorer quality color emitters, such as oxides and hydroxides (exceptions include orange where calcium hydroxide is the desired entity, and yellow, wherein sodium itself is the color emitter on an atomic level).

Chlorine has traditionally been the "halogen of choice", primarily due to the lower cost and better availability of chlorinated compounds. Since chlorine in its pure form is gaseous, a suitable solid form must be found to be of practical application in fireworks compositions. Important characteristics to consider are toxicity, availability, stability, cost, and, of course, effectiveness. Since toxicity is a relative term (any material can be considered toxic, given the proper circumstances, even oxygen!), it makes sense to choose the least toxic compound for the job at hand.

Cost and availability factors become major considerations for the amateur pyrotechnician since one cannot work with something one cannot obtain. However, a good selection of reasonably priced chlorinated compounds is currently available from the various pyro suppliers.

Stability concerns for useful chlorine donors include degree of hygroscopicity (moisture absorption), solubilities in various solvents, and possibly resistance to sublimation.

Although chlorine percentage by molecular weight is the most commonly used measure of a given donor's effectiveness, other factors should also be considered, such as fuel function capacity, ease of ignition, and critical wind resistance.

Table 1 affords easy reference to the relative amounts of chlorine available from today's most popular compounds. These data, coupled with

some additional information, can assist the pyrotechnist in choosing the best chlorine donor for his purpose. Mercurous chloride (an old standby ala' Weingart) can essentially be eliminated due to its cost, mild toxicity, and low chlorine capacity. At first glance it would seem that Dechlorane™ (also marketed under the brand name Mirex™ as an insecticide and, of all things, a fire retardant!) would be the best choice since it offers the highest percentage of chlorine-by-weight. However, it is also a listed carcinogen.

Hexachlorobenzene also carries a high percentage of chlorine but is suspected of being both teratogenic and carcinogenic. These two compounds, in spite of their obvious toxicities, may still find use in some color formulations where it is desirable to eliminate all endogenous hydrocarbons (neither contains hydrogen nor oxygen and can more appropriately be termed "halocarbons"). The remaining compounds are all hydrocarbons which have found good use in pyrotechnic application.

Chlorowax, though yielding an excellent percentage of chlorine and exhibiting low toxicity, appears to have a lower fuel value than its peers. Parlon™, PVC, and Saran™ resin all have useful fuel function capacities as well as acceptable toxicity profiles. Saran resin has the highest percentage of chlorine of the three; preliminary ex-

<b>Table 1      AVAILABLE CHLORINE</b>	
Chlorinated rubber (Parlon) $C_6H_6Cl_4$	68% chlorine
Chlorowax (Chlor-Ezz) Variable	70% chlorine
Dechlorane (Mirex) $C_{10}Cl_{12}$	78% chlorine
Hexachlorobenzene $C_6Cl_6$	75% chlorine
Mercurous chloride (calomel) $Hg_2Cl_2$	15% chlorine
Polyvinylchloride (PVC) $C_2H_3Cl$	57% chlorine
Polyvinylidene chloride (Saran) $C_2H_2Cl_2$	73% chlorine

*(Continued on next page)*

periments seem to indicate a slight edge over PVC and Parlon in wind resistance, as well as ease of ignition.

In conclusion, it would appear that Saran resin is presently the better overall choice of chlorine donors for most non-commercial pyrotechnic color applications. Exceptions would include situations where extreme moisture resistance and/or castability is desired, and here Parlon would be the primary choice. Dechlorane and hexachlorobenzene might also be #1 choices for color sensitive formulae requiring hydrocarbon-free constituents.

#### References:

- 1) Kosanke, K.L. "The Physics, Chemistry, and Perception of Colored Flames, Part II"; *Pyrotechnica IX*, 1984.
- 2) Kosanke, K.L. "Saran Resin - Its Properties & Uses"; *American Fireworks News*, April, 1991, #115.
- 3) The Merck Index; Tenth Edition, 1983.
- 4) Kosanke, K.L. et al. "The Chemistry of Fireworks"; 1991 PGI convention seminar.

## MAKE YOUR OWN DEXTRIN

MP in Florida makes his own dextrin. He takes 1 lb. of high-quality pure corn starch, spreads it evenly in a 12x14" baking pan, then bakes it at 400° for 75 minutes, stirring every 25 minutes. After cooling, the stuff is sieved through a 30 mesh screen. His research and testing show this product to be the exact quality of commercial dextrin.

Speaking of things from the kitchen...Do you suppose a Vega-Matic would work as a method for quickly producing cut stars? Do you still use your electric coffee-grinder for coffee? I get the canned stuff, and use my grinder as a sort of "instant ball-mill" for selected chemicals. The high speed blades turn just about anything you put in it into talc in a matter of seconds. Chunky charcoal doesn't do so well; it can get messy and sounds as if you just ground up the kitchen table. DMcI



## PRIMER FOR MAKING CUT STARS

### INTRODUCTION

Cut stars have been employed in pyrotechnics nearly as long as pyrotechnics has existed. Various methods have been adopted over the years by different manufacturers to produce these items. Since stars tend to be small and the quantities needed are large, manufacturers have attempted to develop mass production techniques. These methods, by their very virtue, cause a large quantity of composition to be on hand at any one time and are consequently dangerous. Accordingly, production of stars has evolved to a state where it employs mass production techniques to a small quantity of material. The economics of survival in the fireworks industry preclude the use of complex and costly machines for manufacturing. Consequently, most mass production techniques are really manual techniques that have been refined, over the years, to the most efficient operation.

The hobbyist working on a small scale is faced with the same problem as the manufacturer - to produce a large number of identical sized cubic or cut stars with as little labor as possible. One method for accomplishing this is the "block" method, as described in *Pyrotechnica I*. Essentially, a 3 - 5 lb. block of composition is made into a "loaf shape". Slices of the loaf are cut (like slices of bread), primed, cut into cubes, and then primed again.

Another method, made popular in the Lancaster's book *Fireworks, Principles and Practice* and in Weingart's *Pyrotechnics*, is to make a slab of composition. The slab is made into the desired thickness of the stars and is then primed and scored into cubes. The entire mass is left intact and allowed to dry, at which point it is broken up into the cubes. The author would not recommend this method when making nitrate/aluminum stars, buffer or not. Indeed, Lancaster and Weingart both recommend making these into "pill-box" stars, so that a piece of black match may be alongside this difficult-to-light mixture. Pill-box stars are extremely labor intensive and unnecessary as well, as will be seen later.

Shimizu's method of making cut stars (or cores for round stars) is the method currently employed by the author. It works well for batches from 100 gms. to a couple of pounds. It is the method we will explore further in this article.

### THE DOUGH

The most important technique to master in making cut stars is the consistency (water content) of the composition. It is impossible to teach this in a book or an article; it only comes through experience. No one, to the author's knowledge, has been born into this earth with the ability to make a correct dough the first time. One simply has to practice, and hopefully do it wrong; the newcomer almost has to do it wrong before he/she will know how it should come out.

Generally speaking though, the dough should be the consistency of "playdough" or "sillyputty": hard, yet pliable. Ideally, one should be able to mash a ball of it flat without its cracking (too dry) or sticking to one's hand (too wet). This is a tough balance to achieve. It will be found that water can be added in increments for some time without hardly any effect, then suddenly the next increment turns the once damp powder into rubber cement. Eventually, one becomes aware of the subtle signs that signal when the composition is nearing saturation.

The binder plays a role in achieving the perfect dough-state too. It takes a certain quantity of water to activate the binder; below this point the composition has nothing to hold it together but its own adhesive qualities, which in most cases are minimal. Dextrin is the binder most often used, but the author prefers wheat paste, especially for stars containing a large proportion of charcoal. Wheat paste requires more water to activate it than dextrin does, and this can become a problem when working with glitter mixes, which will not function well when more than 10% water is added.

Alcohol is used frequently to speed up the drying characteristics of the composition. It also will af-

# THE BEST OF AFN III

feet the consistency of the dough: it tends to cause the dough to not hold together well. The reduced surface tension of alcohol is the culprit and is an extreme problem in mixes with high charcoal percentages. Alcohol will make the dough less dense and a larger volume of stars will be produced with it than with plain water alone. These stars will be lighter, structurally weaker and burn faster than those made with plain water. In the author's opinion, alcohol is a problem in producing a correct dough. Star compositions, especially charcoal types, are very hard to work into a cohesive dough when alcohol is used. That being said, it is still desirable and sometimes even mandatory that some alcohol be used. In the case of charcoal stars, alcohol is used to speed the drying process, otherwise drying times of 3 - 4 weeks are required. In the case of aluminum mixes, they are impossible to wet unless some alcohol is added. 10-30% alcohol is what the author generally uses in the above two compositions.

## MAKING THE DOUGH

Once a formula is chosen, the next step is weighing out and mixing the ingredients. Weighing should be done on a reliable scale. Mixing will be determined by the type of composition.

Generally, the particle sizes of the components should be only as fine as is necessary. This alleviates some of the work. Black powder type compositions may be ball milled to improve the density of the sparks produced. If the black powder composition has a metallic powder added to it, the composition should be ball milled before the metal is added. Compositions containing potassium perchlorate should have the perchlorate component finer than 100 mesh. Non-black powder potassium nitrate and barium nitrate compositions need only be screened, as the water added will dissolve them, making ball milling unnecessary. A good rule of thumb I go by is to ball mill all black powder compositions, and the oxidizers in all other compositions that are not water soluble. The other components in the composition should already be fine enough for use if they have been purchased from the usual fireworks chemical suppliers. If not, they will need to be reduced to at least 40-80 mesh.

The apprentice should remember to thoroughly clean the ball mill or mortar and pestle before using them for a different composition or chemical. I would never ball mill any compositions other than black powder types. Indeed, even these are dangerous and should be done away from people and property.

Black powder type compositions, once ball milled, are ready to be wetted. Other compositions should be screened first to thoroughly mix the various components. Two or three times through a 40 mesh brass sieve will usually suffice. If a coarse metal or charcoal is being employed in the mix, they can be added after the other components are screened, and simply mixed in by hand. Water or water/alcohol is now added in small increments and mixed in well until the desired consistency is reached. When using wheat paste as a binder there is a distinct delay between when the correct amount of water is added and when the final consistency of the dough develops. Thorough mixing or kneading is required between increments of water to allow this tendency to surface before the next increment of water is added. Otherwise, the mix will be over-watered and more dry mix will need to be added. I always have some dry mix set aside.

## FORMING THE STARS

The next step is to form it into cubes. A movable surface is preferred to form the stars on; I use a sheet of Plexiglas. Waxed paper or another non-stick type of paper is taped to the Plexiglas. At this point the surface is dusted with prime. If the stars being made do not require an intermediate prime layer, meal powder would be the logical choice. If an intermediate prime is required, then that composition would be dusted on the waxed paper. The dough is now placed in the center of the paper and also dusted with prime. Two square strips of wood or plastic are now placed on either side of the dough (one on each side). The thickness of these strips will determine the thickness of the stars, so the operator would select the appropriate size; W strips for W stars, etc. [See *Table for Cutting Stars* elsewhere in this volume]. Another sheet of waxed paper is laid on top of the dough. A rolling pin or other similar device is pressed into the dough until it contacts



the strips of wood on either side. The rolling pin is carefully rolled over the entire surface of the dough, while contacting the wood strips, until all of the dough has been reduced to the thickness of the wood strips. The rolling pin is removed and the waxed paper is carefully peeled away. We now have a sheet of composition that is a uniform thickness.

The sheet of dough is now ready to be cut into cubes. A method for marking the dough and insuring nearly perfect cube sizing is as follows. I use a sheet of hardware cloth the mesh of which is the same as the size of the stars being made. The hardware cloth, formed into a "U" shape and starting at one end of the sheet of dough, is pressed and rolled over the dough, leaving perfect squares over the entire sheet. These squares will be the operator's cutting guide.

The dough is now dusted with prime again. A thin, long cutting blade that is not sharp is needed now. A cake icing spatula works well, although they can be expensive. Any device may be used as long as it is thin, straight and its edge is true and not sharp. It is helpful to coat the surface of the cutting tool with wax; this helps to prevent the composition from sticking to it. The operator now cuts the first strip of dough (using the marks from the hardware cloth as a guide), and before removing the cutter, slides this strip away from the sheet of dough and rolls it onto its side. This is done with several strips, which are placed next to each other. This group of strips is now dusted with prime.

A lot of prime is used at this stage and when cutting the strips to ensure that they do not stick to each other. When sliding the strips away from the rest of the sheet of dough, it is desirable to have them come to rest on an area that has fresh prime on it. Or, the strips may be rolled away from the sheet across fresh prime, so that each strip is thoroughly covered with prime.

With several strips arranged next to each other, one end of the group is brought into alignment with the cutting tool by tapping its flat edge against this end. Hopefully, the marks made by the hardware cloth are still visible at this point. A vague mark on one or two strips is all that is

required to begin dicing the strips. After a while, judging the thickness of the cross cuts becomes second nature. The operator dices the strips into cubes now, and when one group of strips is diced they are slid across the cutting board with the cutting tool into a drying tray. This cutting of strips, priming and dicing is repeated until the sheet of composition is depleted.

At this time it may be necessary, depending on the composition, to apply more prime. If an intermediate prime layer is being used, they will definitely need more. This is accomplished by transferring a portion of the stars into a bowl. The bowl is set into motion, as if making round stars (which is what you may end up with, depending on the thickness of prime required). The stars are misted with an alcohol/water solution and then dusted with prime. This is repeated until the prime or intermediate prime layer is the required thickness. Then the plain prime layer is applied (if necessary) in the same fashion and finally the finished stars are dumped into a drying tray to dry.

The above process may also serve as a good introduction into making round stars. As mentioned, the cubic stars will tend to become rounded or even nearly round, depending on the thickness/layers of prime required. The fact that they are soft, wet cores tends to help this naturally occur.

## CONCLUSIONS

The process described, although somewhat tricky to master, enables the pyrotechnician to turn out batches of stars with good size uniformity and ignition characteristics. After some practice, the process becomes much faster than other methods the author has tried. Indeed, it completely supplants the tedious pill box star construction method by borrowing the round star manufacturing technique of applying intermediate prime layers. Round star construction seems to be faster using this method rather than the typical process of starting with an inert core material. The center or core of the round star is the slowest part of the round star to make, so starting with a cut star would remove that part of the process. This, I believe, is part of what Shimizu had in mind. SAR



## YELLOW POWDER

In Tenny L. Davis's book *The Chemistry of Powder and Explosives* on page 31, a small text of a certain Samuel Gurtie writing to a certain Benjamin Silliman discusses "Yellow Powder".

The text describes how the powder is made, by melting together a mix of potassium nitrate, potassium carbonate, and sulfur. When heated to a certain point, the mix melts and should then be kneaded and cooled down again. The resulting solid can be used as a priming agent for firing arms. But...this heating isn't without risk, because when the mix melts, it can produce, besides an expected flash, a considerable loud explosion. Note that there occurs an explosion without the material being confined!

Explosions in open air, when a small quantity is lighted by fuse, is in fact a property of a material which has a small critical mass. This means that this material is capable of transforming from the ordinary burning process into a liberation of gases with velocities above the speed of sound (throughout a very high speed burning process, or by a detonation process).

At first when I read the text I didn't pay any specific attention to it. Even Weingart made a mistake in his book by writing in his introduction on page ix that ordinary blackpowder explodes when a lighted match is brought in contact with it. It could have been that he meant that the blackpowder produces a quick "whoosh" when lit. So I figured that in Davis's book had similarly slipped.

Secondly, I could recall that the only pyrotechnic mix which does explode in open air is a 4:1:1 potassium perchlorate/aluminum/sulfur mix (see McLain's *Pyrotechnics*, page 186). I believed this right away because I had seen a demonstration on German TV with this type of mix. So, okay,

maybe it would have been possible with extremely finely powdered potassium perchlorate. This oxidizer is known to be very powerful, but potassium nitrate does not have that reputation.

Then I started to experiment with this mix, because I simply was too curious. With some crude, and not finely powdered chemicals I made this mix. And my first attempts to let this material produce a bang were unsuccessful. Later on I found out that when I let the flames, used to heat the mix, strike the mix it simply burned like a Bengal fire mix. This also happened when I heated up the mix too quickly. But after some attempts I did produce a bang! The explosion was considerable, noting that I used an extremely small quantity. The secret of success was that the mix had to be heated up very slowly. The initial color yellow soon changed to bright orange, and then to dark red/brown.

Some time later I repeated the experiment together with a friend with a bigger quantity. The results were absolutely spectacular. The explosions were very loud indeed!

I didn't try to apply this extraordinary property of the mix. But I thought it could be used for some pyrotechnic effects, such as Cracker Stars (as described in AFN No.117 by Dave Bleser).

For someone thinking of experimenting with Yellow Powder, I defer to Davis's book, and think about how I always: 1) work with small quantities, and 2) wear safety glasses, and gloves, along with all the usual precautions. RW

[Questions concerning Yellow Powder were addressed in PGI Bulletin No.79, March, 1992. The author says little is known of Yellow Powder and he invites readers to respond with additional information. See page 36].



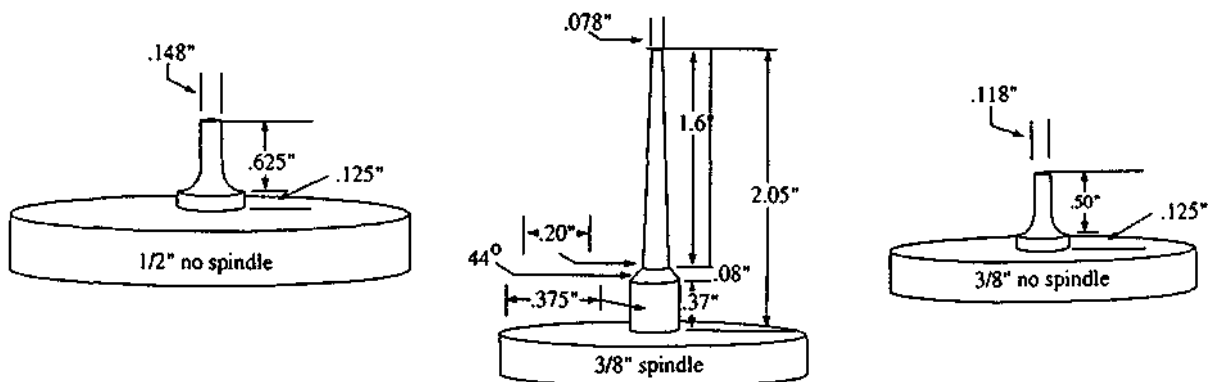
## PASS THE GROG

The last shoot was beautiful and the cleanup revealed the usual quota of interesting items to study. The rocket nozzles that we recovered were particularly interesting to me as the openings were larger by two to three times and sometimes off center, which could contribute to an erratic flight. I did not know how to fix this problem immediately but tried using some silica sand mixed in the bentonite clay to form a fireproof nozzle. This produced a better nozzle but not one I was happy with. About this time - isn't it wonderful how this works out - a friend gave me a few of the standard, factory made, model engines; being curious, I put one on a stick to see what it could do. The result was a straight flight up and a quick fall right next to where it was launched. If they can do it, so can I.

On closer inspection I noticed that the nozzle was not even enlarged! Wow, no wonder it flies true. A little thought and some research, and Viola! The answer is *GROG*. Not the kind that does not mix with fireworks, but the material from the potters' supply. I got a few of my friends to go in with me, as it comes in a 50 pound sack, and that makes a lot of nozzles. This I mixed in a ratio of one to two parts bentonite to one grog. This makes a nozzle that will perform with excellence! The cost is about \$15 for a sack of medium fine grog. The cost of the bentonite is very cheap, and the mixture makes the best nozzles around. I sure like the difference for my fountains, drivers, and rockets!

A motor that I have been playing with in sizes from 3/8" up to 3/4" is based on the technique of the Estes model rocket engine in that it flies with no spindle. I use a short spindle that is just tall enough to form a nozzle in the clay and a hot fuel is rammed or pressed to make a rocket or driver that puts out a lot of horsepower. I have been using Meal D, home made black powder from the CIA method, or sodium benzoate/potassium perchlorate whistle mix. These also work with a couple percent of titanium for a pretty tail. Of course, I use precautions in the form of a blast shield, absolute minimum of fuel exposed, and safety glasses whenever I use ANY titanium. [Experience has shown that pressing titanium metal powder in whistle mix has caused tragic accidents; hand ramming is even worse - Ed.] Since I have been using Grog the flights are straight and true as long as the rocket is balanced properly.

I like to machine my own tools and fortunately have access to the necessary equipment. The 3/8" spindle shown here is another tool that I have experimented with. A rocket made on it is an incredible flyer, using a miserly amount of fuel. This engine is fueled by whistle mix - 30/70% sodium benzoate and potassium perchlorate. It is very important to consolidate the fuel carefully and evenly for consistent flight repetition. When flown with no choke, a high decibel impulse noise screams its way skyward. When used with a grog choke, it is nearly silent and very fast. DA



## MODELING CLAY AND THE PYRO

It's amazing what can be learned by just keeping our ears open when listening to other people. Sometimes one or two words will allow us to make that ever elusive mental leap. One such event took place the other day. A couple of very dear friends stopped by for a little socializing after work. C. (who is the purchasing agent for the best art store in the valley) was showing us some figures that the people at work made out of a product called FIMO. This is a modeling clay that can be cured in an oven at 275° F. Sometime during the conversation she mentioned that the FIMO was plasticized PVC mixed with some bulking agents. Hummm. Well that little light went on over my head. This could have some potential, I thought. After pressing her for some more details it was obvious that I had to get some of this stuff to see if it had any pyrotechnical use. The next day I made a stop at the art store to check out this FIMO. Unfortunately the FIMO was kind of hard and seemed like it would not mix well with oxidizers. BUT, they did have another product called Sculpy which had the same base material and was much softer as well as cheaper (about seven dollars for two pounds). I could hardly wait to get back to the lab to try it.

The first experiment was a batch of potassium perchlorate 80% and Sculpy 20%. The two components had to be mixed by rolling with a roller, much like making pie crust. The composition was then pressed into 3/4" stars with a star pump. Now for the moment of truth. Would it light? Did it ever! That star burned with a large orange-red flame and left spots in front of my eyes! It turns out that one of the bulking agents was calcium carbonate and it imparted color to the flame. Other experiments were made with proportions of 70/30 and 75/25. Different additives were also tried, 1% additional red iron oxide sped up the burning rate a bit, 10% additional American dark aluminum washed out the color some but also ejected white dancing sparks when burnt in the fume hood. This stuff had to be tried as rocket fuel.

That night I received a call from an Illinois pyro. After relating my experiences he got some Sculpy from his local art supply store and went to work.

It turns out that a 3/8"x3" casing with 1/8" nozzle and 2" core will fly to around 500-600 feet, accelerating the whole time. Very impressive. I tried a 1/4"x3" casing with similar nozzle and core but did not get the performance from my rocket that he got from his. The difference was that he ignited his with thermolite and I used visco. His formula is:

### Pyrofish Sculpy Rocket Formula

Potassium Perchlorate	75
Sculpy	25
Mg/Al (50/50, 200-400)	5
Red Iron Oxide	2.5
Copper Chromite	3

There are still a lot of experiments to be done with Sculpy and other related compounds. The way to identify a likely brand is that they all are curable at around 250-275° F. I don't think plasticene will work but who knows unless someone tries it. Caution is urged when experimenting with plasticized PVC products; we don't know all the ingredients in each individual brand. CV

## DON'T THROW AWAY FAX TUBES

Core tubes from rolls of FAX paper are 8 1/2" long, i.d. of about 5/8", and o.d. of about 3/4". One type I've seen has a wall thickness of 1/16" and another was about twice as thick. These cheap sources of cardboard tubes have many applications. MS



## SCULPY REVISITED

Some months ago AFN published an interesting article about using Sculpy modeling clay as a binder (AFN #138, Mar.'93). The plasticizer PVC is really what is known as PVC PLASTISOL, and consists of high molecular weight dispersion grade PVC resins mixed with large quantities of liquid plasticizers (dioctyl adipate, sebacate, azelate, etc.) and have infinite pot life at room temperature. Craig doesn't say if he cures his composition, but the PVC won't develop good binder properties until cured at 275-350° F for a few minutes. The PVC dissolves and gels in the plasticizer at that temperature. If not cured, all you have is a good putty (useful in its own right).

These plastisols were developed by Atlantic Research in 1950 as ammonium perchlorate filled castable and extrudeable propellants for many tactical missiles. The fireworks maker would be better off to get some plastisol from the manufacturer and use oxidizer and fuel as the "bulking agent" instead of the Sculpy. He could then load up the comp, with much more solids and get better performance for less dollars! KB

### HEALTH WARNING TOO

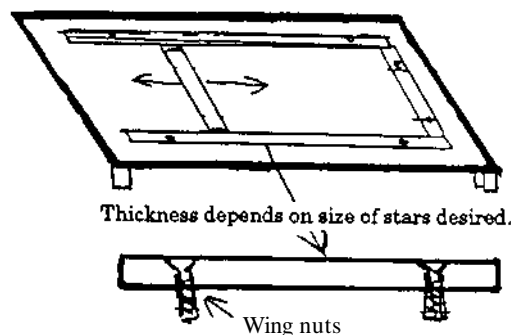
From the editor of *ACTS FACTS*, comes the warning that when PVC burns it forms vinyl chloride monomer, a carcinogen, and phosgene, a poison gas, along with other "highly toxic chemicals". She also points out that the copper chromite in the Pyrofish Sculpy formulation will emit toxic chrome compounds, and that the plasticizer in Sculpy may be a health hazard for the workers.

*ACTS FACTS* is a monthly newsletter from ARTS, CRAFTS AND THEATER SAFETY. Interested readers may contact them at 181 Thompson St., #23, New York, NY 10012.

## TABLE FOR CUTTING STARS

One method for making cut stars led me to construct a table that makes the procedure easy. This table lends itself to making any size cut star and will accommodate various batch sizes. Another advantage is that the star comp is formed into a rectangle so that when the stars are cut, the cubes all come out the same size.

As you can see from the sketch, the table does not have any dimensions shown. That's because the table and forming rails can be made to the size that best suits your batch size and cut star size.



To use the table, after I dampen the star mix and put it on the table, I work it into a flat cake with a wooden spatula and then slide the free end rail forward or backward, depending upon the amount of comp. When finished working the comp into a rectangular cake of uniform thickness, the side rails can be carefully removed and then the comp can be cut into cubes. If I put a sheet of kraft paper on the table before the star comp, the paper with the stars can be slid off onto a drying screen.

The table and side rails should be painted with two or three coats of varnish so that they can be easily washed after each use. JR

## DRYING STARS & GRINDING CHEMICALS

Recently I was asked about statements I had made in previous articles in AFN. The first question dealt with stars containing high amounts of charcoal, which I said should not be dried in the sun because the water may be "driven" into the stars. I was asked: "What are the alternatives? I have understood that spider stars just take weeks to dry under normal drying conditions. I can't afford to tie up drying screens for weeks in the shade. What else can I do?"

The second question concerned grinding: "Some of the lesser-used salts tend to come in crystal-line form. Often they take considerable time to crush to powder, even in a large mortar/pestle. Are there any tricks?"

These questions are probably asked by everyone at one time or another. Drying any kind of star rapidly creates a new problem at it solves another, and grinding is essential to pyrotechnics.

Charcoal stars are black, and they absorb a lot of heat from sun drying. This can cause the interior to heat up, and cause an efflorescence of nitrate/water to evaporate on the surface. If this happens, the star will appear dry, but will flash over the surface when ignited, and leave the core smoldering afterwards. I saw this happen to several different types of charcoal and lampblack stars back in the late 70's when I operated Green Dragon fireworks. I had made them before, and on that particular day, they were sun-dried, and all made useless by being dried too rapidly.

For charcoal stars, if it is inconvenient to tie up expensive drying screens for the weeks it may take to dry these stars, the pyro might simply transfer them to shallow trays as soon as they can be handled without deforming. Cut-down cardboard boxes or soda can "flats" would suggest themselves, since they are free, and disposable.

It should be kept in mind that good ventilation is better than heat alone. A breezy, partly cloudy day in the spring or fall can be excellent for that first day of drying. A little alcohol in the dampening water, around ten percent, will also help. It is

also important to be careful to use as little water as possible, and not over-dampen the stars.

Regarding the second question, grinding with a mortar and pestle is inefficient at best. Even large mortars do not hold very much material. The extra space is filled up by the ground material as it is moved around with the pestle. One must also grind like hell - no wimps here! It is best to frequently run the material through a screen of the desired particle size, and it is expedient to tolerate as large a particle size as is feasible.

Big Bruce has advocated the use of a kitchen blender for years, which works as long as it is not overloaded. Soft materials work better in a blender, hard ones not so well, and metal powders are taboo! Titanium, for example, will ignite if "ground" in a blender!

I have found that the best alternative is the ball mill. They are remarkably efficient at their purpose, and are not particularly expensive. I simply load it - about 1/2 to 2/3 full, set it to run for an hour or two (a timer is convenient) and then strain out the grinding media with a coarse-mesh screen. JHB

## PYRO HINT

Nitrocellulose lacquer will shrink less and will retain flexibility if 2% to 5% camphor is added.

## BRILLIANT ORANGE/TITANIUM STARS

The new "Orange Illuminating Star" by Peter Budarick (*Pyrotechnica XIII*, p.35) caught my attention as it can be thought of as a combination of the Robert Veline orange ( $\text{KClO}_4$ /- $\text{CaCO}_3$ /Parlon/Accroides/Magnalium/Dextrin) and the Jennings-White/-Wilson orange ( $\text{NH}_4\text{ClO}_4$  instead of the  $\text{KClO}_4$ /Parlon; PGI Bulletin No.71, p.32) with the exceptions that calcium oxalate is used instead of calcium carbonate and the magnalium content is much higher. I didn't happen to have any calcium oxalate on hand so I tried it with calcium carbonate. In this modification it was inferior in both color and brilliance to my own "Brilliant Orange". Nevertheless, I thought it would be worth trying with the addition of titanium for an effect along the same lines as my "Brilliant Red/Titanium Star" (WPA Newsletter, Jul.'90). This worked very well, better in fact than the brilliant orange/titanium star that I had previously been using. Here is the new formulation:

### BRILLIANT ORANGE/TITANIUM STAR

Ammonium Perchlorate	20
Potassium Perchlorate	20
Calcium Carbonate	15
Magnalium (100-200 mesh)	15
Titanium (10-20 mesh, flake)	15
Parlon	10
Accroides Resin (Red Gum)	5
Dampen with alcohol	

This formulation includes some changes from the original Budarick formulation other than the addition of titanium and the use of calcium carbonate. Budarick uses 4% potassium dichromate which I have omitted. It is unclear whether this was used as a burning rate enhancer or to protect the magnalium from corrosion. To be on the safe side concerning corrosion, I opted for non-aqueous binding, utilizing the accroides resin content as an alcohol mediated binder.

It is ironic that the commentary "He [Budarick] prefers not to use chlorates for safety reasons" is immediately preceded by a description of ball-milling potassium perchlorate with potassium dichromate. No mention is made of the stringent precautions required to avoid breathing in, or skin contact with, the resulting carcinogenic dust.

Jack Drewes comments "Experienced operators have found that the use of solvents with explosive vapors adds an unusual degree of risk in fireworks formulations". (AFN No. 110, p.3). However, I would always choose to use alcohol mediated binding if by so doing one can avoid the use of potassium dichromate. In general it is easier to utilize flammable solvents "safely" than it is to utilize carcinogens "safely". I write as one who has handled both classes of material professionally on a daily basis for many years.

Relevant literature: K.L. Kosanke, "The Use of Titanium in Pyrotechnics", PGI Bulletin No.67.

CJW

## DRAGON EGG WARNING

Here is a warning for people shooting Dragon Eggs fireworks: If exploding Dragon Eggs come in contact with glass, i.e., auto wind-shields, the lead oxide tends to meld into the surface of the glass, making it very hard, if not impossible, to remove. We have notice the same effect on painted aluminum siding and painted concrete. With an increasing number of Chinese items using this crackling effect, shooters should be concerned about the type of surface that will be exposed to the exploding particles, eeh

## USING KEROSENE?

A pyro writes: "I hope one of the AFN readers can answer this question. Is there any danger in adding kerosene to compositions such as gerbes, wheel drivers, or Niagara Falls? For instance, the waterfalls mix contains 50% aluminum which is very light and hard to compress in the tube; if it could be dampened with kerosene it would be much easier to work with. I saw kerosene being used once in making cone fountains but I don't know what the mix contained."

Well, we know that many military formulations used to employ kerosene, and we seem to recall seeing red fusee formulations in Weingart which used it.

## USING KEROSENE IN FIREWORKS

Paraffin oil [kerosene in the U.S.] in some form is widely used in the manufacture of fireworks, where it has a variety of uses. I suppose that the biggest consideration would be that it keeps down the dust and makes fluffy compositions rather denser to handle when charging. Quite a lot of commercial fireworks are damped with a small amount, perhaps half a percent, and this does make it much easier for people to handle compositions in large quantities. However, a good deal depends on the grade of the oil that is used; if the rather smelly commercial kerosenes are used then this is not quite so good. In the first place, you have to contend with the smell which you either hate or probably do not mind very much, and secondly, workers do tend to complain that it gets up their nose and really is rather unpleasant.

As a result of the various problems we decided to use the low viscosity type of pharmaceutical paraffin oil which is virtually odorless and tasteless and, of course, quite pure. This is considerably more expensive than commercial kerosene but, on the other hand, it is used in comparatively small amounts and a twenty-five litre drum lasts us quite a long time.

Another reason for using this material is probably to phlegmatise any compositions which contain sensitive materials and, in this case, for example, we tend to put it into compositions which contain titanium flake. It certainly can be used with aluminum powder for, after all, many commercial grades of aluminum powder are prepared with stearic acid or, some form of paraffin oil and therefore, it really would not only help the manufacturing process for aluminum but it would presumably prevent it from corroding too quickly.

I suppose that one disadvantage of adding paraffin oil could be that it does tend to make compositions slightly more smoky, but again, that depends very much on the nature of the material. We are all prepared to put up with smoke in fireworks at the best of times. One of the compositions in which paraffin oil is frequently used is in the ammonium chloride/potassium chlorate smoke composition which still features from time to time in commercial products largely because it is comparatively innocuous in these days while worrying about dangers to health.

Ammonium chloride is still used considerably in medicine and so one can, presumably, assume that it is still fairly safe to make into smoke. The chemical reaction between potassium chlorate and ammonium chloride ought to be really quite a hazard but, to the best of my knowledge, there has never been any accidents associated with this mixture, a fact that is really quite remarkable. The paraffin oil, presumably, has been put into such mixtures to possibly slow it down but also, I suppose, the theory might be to inhibit the reactivity between the chlorate and ammonium ions which may be present in these mixtures.

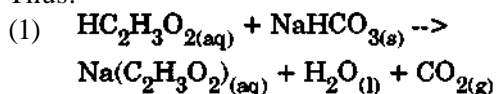
You are quite right that paraffin oil has certainly been used in a large number of flare formulations and I suppose the general assumption is that it was used to make it easier to charge and to slow down the burning rate of the composition. However, the paraffin oil also makes it much easier to press materials and so there is a considerable advantage in consolidation of material when used in hydraulic presses. RL

## PRODUCTION OF BENZOATE COLOR AGENTS

The use of copper(II)benzoate as a blue color agent was discussed by Bleser(1). In large part, the endorsement for its use is based on its ability to serve as both color agent (copper) and fuel (benzoate). There is something to be said for this approach. For example, consider a color agent such as copper(II)carbonate ( $\text{CuCO}_3$ ); it is only the copper that is useful in producing color. (See Reference 2 for a more complete description of colored flame production.) What is more, energy is required to free copper from its carbonate ion. Consequently, flame temperature is lowered, which in turn results in less colored light output. It would be preferred if the copper could be made available without having to pay the full energy cost of freeing it from the carbonate ion. One way to do this is to chemically combine copper with a fuel such as the benzoate ion. Then, when the fuel is consumed, copper will be left over and ready to make the blue color-generating molecule, copper monochloride ( $\text{CuCl}$ ). Because copper benzoate is not commonly available, Bleser described one way to produce it. There is, however, another way to produce copper benzoate. This process is a little more complicated, but the basic process can also be used to make many other interesting pyro-chemicals, only one class of which is benzoates.

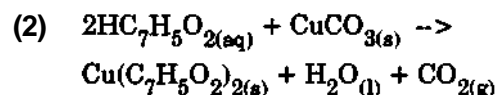
When an acid is mixed with a carbonate or bicarbonate in the presence of water, the resulting chemical reaction produces carbon dioxide [soda water gas,  $\text{CO}_2$ ] and water [ $\text{H}_2\text{O}$ ], plus the metal salt of the acid. One familiar example of the process is that observed when vinegar [a dilute solution of acetic acid,  $\text{HC}_2\text{H}_3\text{O}_2$ ] is added to baking soda [sodium bicarbonate,  $\text{NaHCO}_3$ ] producing the sodium salt of acetic acid [sodium acetate,  $\text{Na}(\text{C}_2\text{H}_3\text{O}_2)$ ] with much frothing and fizzing as gaseous carbon dioxide escapes.

Thus:



The physical states of the substances are indicated by (s) for solid, (l) for liquid, (g) for gas, and (aq) for aqueous or dissolved in water.

In a manner similar to Equation 1, the reaction of a benzoic acid solution [ $\text{HC}_7\text{H}_5\text{O}_2$ ] with copper(II)carbonate [ $\text{CuCO}_3$ ] yields the color agent and fuel, copper(II)benzoate [ $\text{Cu}(\text{C}_7\text{H}_5\text{O}_2)_2$ ]. This is shown in Equation 2.



Since benzoic acid comes as a solid (much like boric acid or stearic acid, which are more familiar to pyrotechnists), it must be dissolved before it will react in this way. In addition, because benzoic acid is not very soluble, the water must be heated to encourage more of the benzoic acid to go into solution and thus allow the reaction to proceed. After the reaction is completed, recovery of the benzoate is easy; the carbon dioxide by-product is lost to the atmosphere, and the water by-product is removed by drying.

In Equation 2, if the copper(II)-carbonate is replaced with strontium carbonate, strontium benzoate can be produced. Similarly, the use of barium carbonate produces barium benzoate, and calcium carbonate produces calcium benzoate.

Listed below is a simple procedure to produce these unusual, but potentially effective color agents. See Table 1 at top of next page.

### PROCEDURE:

A) Place no more than about 50 parts by weight of water into a glass container. (It is desirable to use a minimum amount of water. With experience, it will often be found that less water can be used.) The container should be generously oversized so that when the reaction proceeds with the evolution of carbon dioxide, and the mixture froths-up, none will be spilled.

B) Using the information in Table 1, weigh out the ingredients to make the desired metal benzoate; for example, to make barium benzoate, weigh out 12 parts benzoic acid and 11 parts barium carbonate.

C) Add all of the benzoic acid and about 1/4 of

**Table 1. Production of Benzoate Color Agents**

Reactant	Parts by weight(a)	Product	Parts by weight(b)
Benzoic Acid	12	-	-
<b>Metal Carbonates:</b>		<b>Metal Benzoates:</b>	
Barium carbonate	11	Barium benzoate	19
Calcium carbonate	5.5	Calcium benzoate	14
Copper(II)carbonate	6	Copper(II)benzoate	15
Strontium carbonate	8	Strontium benzoate	17

(a) These amounts include a slight excess of carbonate to assure the complete reaction of the benzoic acid.

(b) These are the theoretical amounts that can be produced. In actual practice, the amount produced depends on the exact procedure followed. However, generally only about 80% of these amounts will be recovered for use.

(c) Note that copper(II)carbonate as used in fireworks is more accurately basic copper(II) carbonate, which is  $\text{CuCO}_3 \cdot \text{Cu(OH)}_2$ . The weight shown in the table correctly reflects this fact.

the metal carbonate to the water and stir. The mixture may be a fairly thick slurry.

D) Begin warming the mixture until bubbles of carbon dioxide are observed. Stir the mixture to help break-up the froth of gas bubbles.

E) When the production of  $\text{CO}_2$  is essentially complete, add another increment of carbonate. Repeat until all the remaining carbonate has been added.

F) When all the carbonate has been added and no bubbling is observed, heat a little further and continue to stir to ensure a complete reaction.

G) Before proceeding to the next step it is useful (and sometimes, important, depending on the solubility of the product benzoate) to boil off most of the excess water. Heat the mixture slowly until no significant amount of water remains visible. (This will assure a good yield even for benzoates that are highly soluble in water.)

H) Allow the mixture to cool and then dump the product (the metal benzoate) onto a mat of paper towels to absorb most of the remaining water.

I) Air dry the material for several days or place in an oven, at 225° F, with air circulation until dry.

J) Pass the dried material through a screen to break up any lumps.

#### CAUTIONS:

Essentially all copper, strontium and barium salts are somewhat toxic. For example, the J.T. Baker Saf-T-Data health and contact ratings for these metal carbonates range from 1 (slight) to 2 (moderate). Because of the increased solubility of benzoates, their ratings will probably all be at least 2 (moderate). [As a point of reference, note that barium nitrate has a health rating of 3 (severe).] Accordingly, some degree of caution is appropriate when working with these materials. Certainly any glassware used to make these benzoates, and any oven used to dry them, should not be used to prepare food.

The authors have produced metal benzoates using this method, but have not developed formulations for them, nor have they tested the sensitivity of any formulations using them.

#### REFERENCES :

- 1) D. Bleser, *New Electric Purple*, American Fireworks News No. 89 (1989).
- 2) KL. Kosanke, *The Physics, Chemistry and Perception of Colored Flame, Part II*, Pvrotechnica No. 9(1989). KL&BJK

## CHARCOAL

A couple of weeks ago I went to a local winery and picked up a load of fresh grape vine prunings which I converted to charcoal on Saturday. I used a very simple, yet effective method to make the charcoal which consisted of a 32-gallon steel drum with removable lid (furnace), a 5-gallon steel bucket with lid (retort can) and a welded steel grate.

I cut a 5x8" hole in the bottom side of the large drum. This allows me to feed scrap wood into the fire which is burning in the bottom of the drum. The grate sits in the bottom of the large drum and allows the 5-gal. can a solid resting spot, with enough room for a fire underneath (about 8").

The 5-gal. can is first burned in the furnace to remove any paint, asphalt roofing cement, plating or other undesirable contaminants. Of course, the gasket in the lid is also burned up in the process. A couple of 1/4" holes were drilled in the bottom of the can and then it was loaded with grape vine. The lid was held in place by using about six of the securing tabs.

The 5-gal. can was placed on the grate and the 32-gal. lid was used as a damper and to help hold the heat in. More wood was loaded into the fire. After about 45 minutes the grape started breaking down, in the absence of oxygen, and the steam and flammable gases began to escape from the vent holes in the bottom of the can. This gas jet was directed at the hot coals/flames and really added to the intensity of the fire with a very noticeable blow-torch sound which lasted about 10 minutes. Flames were also present around the lid. After the escaping gases/flames stopped, I continued the cooking for another five minutes, just to be sure all the wood was converted to charcoal.

The 5-gal can was removed, cooled down and then opened - perfect black, hard grapevine sticks. These crush much easier than mesquite.

I weighed out 3,632 grams of grapevine, which yielded 709 grams of charcoal in one 5-gal. bucket. The volume in the bucket decreased by about 30%. After five loads, I ended up with a 5-

gal. can of moderately crushed grapevine charcoal. There were no traces of ash or uncarbonized wood in any of the five batches.

I suppose that some people will think that it's a little wacky to be making your own charcoal, but I think that charcoal is a larger variable in most compositions that people think, and that there is an uncertainty about what is the makeup of a bag of commercial charcoal. It's only after experimenting with different charcoals that one notices that there really is a difference. This new "tool" will allow me a way to easily make inexpensive charcoal from various types of wood. A smaller version could easily be made by using 1- and 5-gal. cans.

### SOME EXPERIMENTS WITH HOMEMADE CHARCOAL

So far I have made charcoal from willow, grapevine, pine (Monterey) and oleander. I already had some mesquite and coconut shell.

The retort method is the only way to make quality charcoal, and this method turns out amazingly beautiful charcoal. It is actually much cleaner than the partial burning of sticks in a 55-gal. drum. A friend does his charcoal in this manner and there is always some uncarbonized wood and ash left over.

I have ball-milled four different batches of 75/15/10 black powder, using mesquite, coconut, grapevine and willow charcoals. The only variable changed was the type of charcoal. Five grams of each were weighed out and poured into a line about six inches long. The results of a test burn were:

1. Mesquite: about half as fast as grape and coconut.
2. Grape and coconut were about the same and twice as fast as mesquite.
3. Willow was about twice as fast as grape and coconut.

I know that speed is not the only characteristic that is important and I do have other tests

planned. I did moisten some of the willow black powder and pressed it into a cylindrical shape about 1" diameter by about 1" tall. This was dried and then broken and screened. The "fines" were then poured into a line and ignited. Poof! I then took some commercial GOEX (4Fg) and poured some in the same configuration. Poof! I could not tell which was faster/slower, so it will require something like a video camera to help me time each event.

The material that did not pass through a 10 mesh screen was put into a paper towel with a piece of quickmatch and placed in the bottom of a 1 3/4" dia. tube. A cylindrical piece of wood then was put into the tube and the fuse was lit. Kwhoomph! and the wood shot a couple hundred feet into the air. I think that's a satisfactory lift!

I have many more experiments to conduct with the various types of charcoals, but I can assure you that charcoals are not all the same. Now every time I look at a published formula containing charcoal, I always wonder what types of charcoal they were using. Life was so much simpler before I started studying charcoals. Then, charcoal was charcoal. GL



MAKING CRACKERS

## MAKING CHARCOAL IN SMALL QUANTITIES

Having always loved fireworks but becoming a neophyte pyro at the tender age of 38, I have been trying to absorb every scrap of fireworks material I come across. While digesting every word of **Best of AFN II**, I found some articles about charcoal. Realizing that charcoal is the building block of fire-works, I decided to relate the following to AFN's readers.

I love good smoked sausage, and the only way to have it is to make it yourself. I built a cold smoke smokehouse to do just that, and I used an old dishwasher to make it. Then my father-in-law came to the rescue with a source of the needed cold smoke.

The by-product of that smoke source is an excellent quality charcoal, made in small quantities in an easy-to-control process. Here's how I did it.

I obtained a 3-lb. coffee can which I wrapped in several layers of fiberglass cloth (such as is used to patch boats). The cloth was secured with wire. I used a piece of metal roof flashing to form a cone to fit the can, using pop rivets to hold it together. In use it is inverted over the can. Then I cut off the point to leave an opening about 3/4" diameter. A cheap single burner electric hot plate provided the heat source.

I fill the can with wood chunks, shove on the cone, and turn on the heat. By regulating the heat I can get wonderful dense white smoke for the sausage. When the smoke has stopped (and the sausage is finished) I plug the hole with a piece of wood dowel cut to fit, then let the can cool. Guess what is in the can when it's cool: great charcoal. LN





## MORE ABOUT CHARCOAL

Charcoal - an amorphous form of carbon produced by partially burning or oxidizing wood or other organic matter.

Amorphous - 1. Without definite form. 2. Without definite type. 3. Without definite chemical composition.

The definition of charcoal and the first two definition's of amorphous are from Webster's dictionary. By combining the definitions you can see that the third definition applies to charcoal.

The question that needs to be addressed is how much does the indefinite chemical composition affect the performance of charcoal when added to pyrotechnic compositions.

Charcoal is apparently a compound of the chemicals in the wood or matter, along with the carbon produced by reducing the matter through oxidation. Some of the chemicals may be removed during burning, depending on the temperature that they react at. However, not all the chemicals will be removed and the ones that are left will affect your pyrotechnic compositions.

Where do these chemicals come from? Well, ask the gardener and he'll tell you that nearly every tree and plant requires different chemicals and pH to grow. These chemicals are stored in the fibers of the tree or matter and are just lying there waiting to affect your pyro-comp.

This is not the only difference. The size and shape of the fibers also affect the way that the charcoal combines with other chemical structures. The fiber size and shape seem to affect the speed and temperature of the charcoal, while the additional chemicals seem to have a greater effect on the color that is produced when burning.

We have learned more about charcoal by talking to some of the old timers who still burn wood for

heat. They can tell you which woods burn slow and hot and which woods burn slow and cold, fast and hot, etc. It seems that the burning characteristics of the wood carry over to the charcoal. Woods that burn hot and fast, such as willow, are best for mixes that require speed.

This held true in the three charcoals that we have tested so far: willow, red cedar, and hackberry. Using a 15-9-2-2 Spider Web mix, we found that the hackberry produced a charcoal tail on the stars 4 to 5 times longer than the ones from either the willow or the red cedar.

Although the faster charcoals worked well in blackpowder mixes and speed regulation of color compositions, they did not perform well in high charcoal mixes.

When using charcoals with high sodium content, you can expect poor color purity, especially in blues. The yellow of the sodium will wash them out.

What we are saying at this point is that there are many unknowns about charcoal that we need to lend heed to. If you are using an exact formula and it requires charcoal, you have just added an unknown to your formula.

One way this could be resolved is to identify the different characteristics of the different types of charcoal, either through chemical analysis or by experimenting to find the best charcoal for a particular effect.

It seems we have only scratched the surface of a lot of information.

The only thing I'm absolutely sure of at this point, is that when making charcoal you had better clean up before coming in the house and it'll keep you out of a heap of trouble. VT



## IN PRAISE OF CUPRIC OCTOATE

The "New Blue" of David Bleser<sup>1</sup>, utilizing cupric benzoate in combination with ammonium perchlorate, is now getting old. It remains one of the best published blue star formulations with regard to both color and burning speed, however. In addition, I found that cupric benzoate was the only commonly used copper compound that did not produce a detectable exotherm upon dampening with water, when used in combination with ammonium perchlorate and magnalium.<sup>2</sup>

Are these properties specific to the benzoate or are there other such materials? I had a chance to answer this question upon acquisition of some cupric octoate, also known as cupric caprylate or copper (II) octanoate. The sample was a very fine, but slightly greasy, powder with a beautiful deep blue-green color.

A quick calculation of the fuel content relative to cupric benzoate indicated that the level of cupric octoate should be around 15% (85% ammonium perchlorate). When tested as a lance, this composition gave a burning speed of 8.6 sees/inch, compared with 9.4 sees/inch for Bleser's composition or 13.0 sees/inch for an equivalent cuprous chloride/ammonium perchlorate composition. Compared with the benzoate composition, the smoke production was less (extremely low in fact), the flame size was smaller, and the colors were indistinguishable.

Nicely functioning stars can be made by using nitrocellulose/amyl acetate for binding, but I thought an aqueous system would work too, so next I added dextrin. The addition of the cool burning, flame expanding fuel at the expense of oxidizer enabled the flame size to equal that of the benzoate composition while maintaining indistinguishable color, and a burning speed of 9.0 sees/inch. The aqueous binding system works without problem and the stars have excellent color, ignitability and burning speed.

Ammonium perchlorate stars must not be primed with compositions containing potassium nitrate, on account of the formation of hygroscopic ammonium nitrate.

### NEW BLUE

Ammonium perchlorate	80%
Cupric octoate	15%
Dextrin	5%

These stars have advantages over the cuprous chloride composition mentioned earlier, in that there is no deterioration of color at low relative wind velocities, and the ignition properties are superior.

When I tested cupric octoate in the ammonium perchlorate/magnalium system that I had used previously, I found that it too produced no detectable exotherm upon dampening with water. Thus, it appears to share all of the favorable properties of the benzoate. It also shares what, until recently, had been the principal disadvantage of the benzoate, its lack of availability. I have suggested how to overcome this problem for the benzoate, by utilizing a combination of benzoic acid and cupric oxide. Unfortunately this strategy will not work for cupric octoate because octanoic acid is a liquid.

Clearly, this is only a preliminary study, but I thought it worthwhile to communicate my results with cupric octoate as it appears to hold much promise. There is probably nothing special about the octoate, and good results might be obtained with carboxylates comprising from six to nine carbon atoms, with slight adjustment of the formulation.

### Literature Cited

1. D. Bleser, "A New Blue", AFN No. 64, 1987.
2. C. Jennings-White, "Ammonium Perchlorate/Magnalium Blue Star Systems", WPA Newsletter, Vol.2, No.6, 1990.
3. C. Jennings-White, "Cuprous Chloride, Part II", PGI Bulletin No. 71, 1990.
4. C. Jennings-White, "I've Got the Acid Blues", WPA Newsletter, Vol.2, No.3, 1990. CJW



## BUILDING A SPIKING HORSE

Shell building season is upon us once again, as pyros prepare to use the result of winter experimentation to fill the summer skies. Whether one uses stars, comets, inserts, or other effects, a necessary step in cylinder shell construction is *spiking*.

The spiking horse described here is the type used by professionals, yet its simple design makes it just as practical for amateur pyro hobbyists. This horse eliminates the need for long, pre-cut lengths of twine, and even the largest shells can be spiked in a small work area.

### Construction Notes:

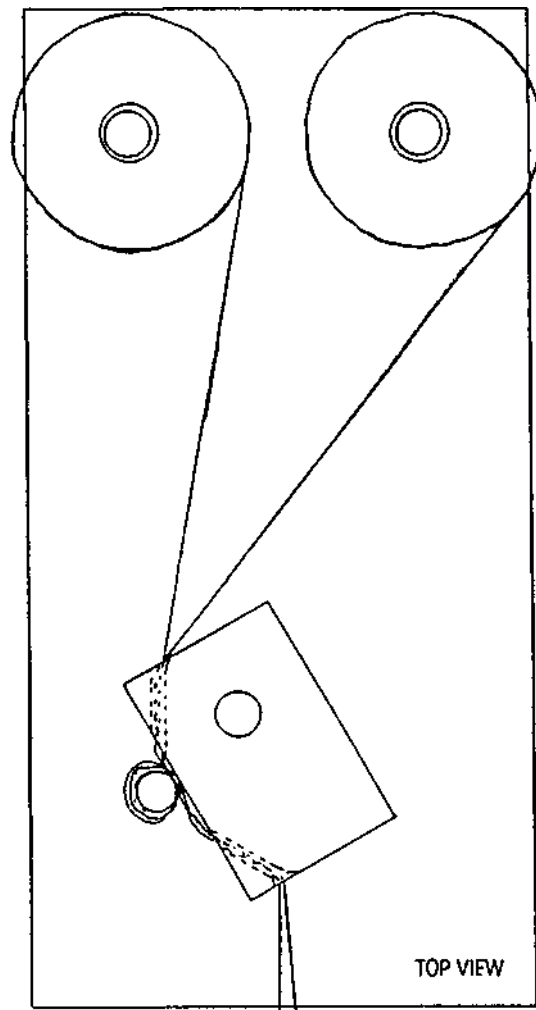
1. Dimensions given are guidelines and can be altered to suit the user's own needs.
2. Base should be hardwood or good quality plywood.
3. Dowels can be hardwood, although it may be best to make the tension pin and swivel block pin out of steel or aluminum rod. Dowels and pins must fit tightly into the base and should be glued.
4. The swivel block should be made from a hard material such as aluminum or nylon. A piece of old nylon cutting board works well. The twine holes must be very smooth and slightly widened at the edges to reduce twine wear. The block does not have to swivel very far to work properly. In the tension position, the tension pin must hit the block between the twine holes.
5. The horse can be used with one or two spools of twine; pictured is the two-spool setup.
6. The horse may be permanently mounted or just clamped to the work bench.

To use the horse, the operator loads one or two spools of twine onto the dowels. The twine is threaded through the first hole in the swivel block and wrapped one turn clockwise around the tension pin. Then it is threaded through the second hole and is ready for use.

When spiking a shell, the operator pulls to the right to release tension and to pull out enough twine for a turn or two. Then he pulls to the left. The twine will be gripped between the tension pin and swivel block, and the operator can work back toward the horse.

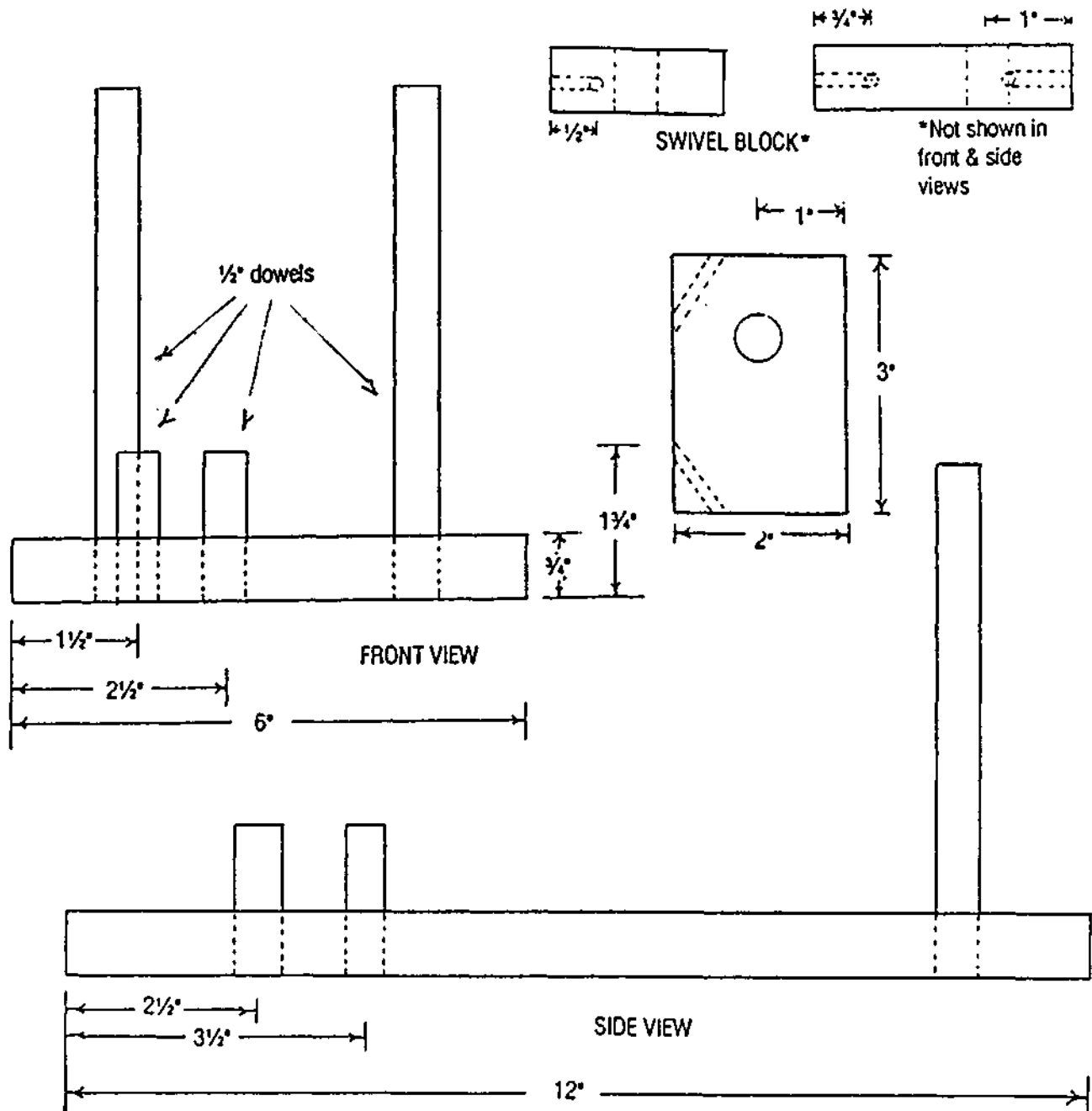
Information on spiking techniques can be found in *Best of AFN II* and *Pyrotechnica IX* and *XI*.

RS/HS





# THE BEST OF AFN III





## EASILY MADE ROUND SHELL CASINGS

In this article I will try to describe my first efforts at making 2 1/2" round shells. There are plenty of excellent articles already published on making shells, so I'll try to leave out the obvious.

### THE HEMISPHERICAL CUPS

For molding four hemi halves I use a method that is quick, but uses a bit more paper than eventually ends up in the half. Materials: a wooden ball, pieces of 10x10" Kraft paper, wood glue.

The first step is to wrap a precut piece of Kraft paper around the ball in such a way as to form a ball with a "stem". See drawing #1.

The second step is to paste the wrapped ball with glue over the "equator" (e). Now I mold a second precut piece of paper around the pasted ball, taking special care to squeeze out all air bubbles and ripples.

The third step is exactly like the previous. The wall thickness is now three layers of paper.

The fourth step is to cut a hemi at the equator (e) of this "ball with stem", with a sharp knife. The third and fourth cup will have to be molded using the ball with the first two paper cups around it. However, care must be taken not to cut into your first two hemis when cutting the third and fourth cup of the ball with stem. If the four cups are neatly cut, they should dry. If the edges of the cups do not appear to be well pasted, it is possible to give them some extra glue. The cups will get a somewhat flat-round form because of non-symmetrical shrinking, but this is of no real significance.

### TIME FUSE

For time fuse I use a 2" piece of 3/32" visco fuse. I paste this securely in a piece of 1.2" x 3.2" Kraft paper, which is then rolled tightly around the fuse. See drawing #2. After they are dry I mark them at a predetermined point, which through trial and error I have found to be 1-1/16".

### LOADING THE SHELL

Now I take cup #1 and make a hole 0.1" in the center of the cup and put in a piece of time fuse, then glue it securely. I make two or three knots with thin Italian twine around the outside end of the fuse, in order to prevent the lift charge gasses from entering. See drawing #3. When the fuse is dry, I place the fused cup on a small cardboard ring, see drawing #4, which will hold the cup firmly in place during further assembly. Now I carefully place my stars against the inside of the cup. When the cup is filled with stars, I pour my burst powder in. I apply some pressure to exclude excessive air pockets. This burst is simple "Super Polverone" type.

The other cup is also filled with stars and burst charge, taking care to fill both up to the edge. Now I take a piece of thin (but strong) metal and press against the cup that does not have the time fuse. See drawing #5. If I apply enough pressure the cup seals hermetically so I can turn it around and place it on top of the other half, then quickly withdraw the plate. The metal plate must be highly polished and not easily deformed. For example, when using a piece of cardboard for this step, the stars will be pressing against the cardboard, and when it is withdrawn, the stars will move with it. (I had this happen once and I can assure you that it is very irritating.)

Now the cups are pressed against each other until the seam is tightly closed. A strip of paper is glued over this seam, taking care to press out any air bubbles. I do not use tape because generally it does not adhere very well to glued paper, and besides, it's no sport!

Now I cut a small piece out of the edge of the third and fourth cups, which serves to receive the fuse. See drawing #6, detail a. These cups are glued from their inside, and the ball is also glued in heavily. Then the cups are squeezed over the ball, at right angles to the first seam. It is very important that the cups make good contact over all the surface.



# THE BEST OF AFN III



The ball is dried completely. The wall thickness at this point is very small, but the bigger part of the strength of the wall must be contributed by the layers which are glued on from this point.

I won't go into detail about which way is best to paste shells because enough techniques have already been described. But here are some tips:

In general, it is essential to make a case which is equally strong at every spot, as this will determine the symmetry of the break.

I take extra care to squeeze out any air bubbles.

I use a good glue which sticks right away (unlike most types of methylcellulose-based wallpaper glues, for example).

I use two different colored types of Kraft paper, which helps observing your progress; I use relatively small rectangular pieces, approximately 3x1".

## FINISHING THE SHELL

After the shell has completely dried I use a very sharp knife to split the time fuse to the marked predetermined point. I dip this fuse in a solution of red gum/alcohol, and then into meal powder. This will help to assure ignition. See drawing #7. When the alcohol is dried I attach a small lift-charge cup. I use a 4/5" length of spiral wound thin walled tube of 4/5" diameter. This cup is attached by gluing some layers of Kraft paper over the lift cup and onto the base of the shell. See drawing #8. Since I use polverone as a lift charge, I take care to firmly attach the cup to the shell. After the cup has dried, I pierce a hole through the side of the cup for the quickmatch.

After inserting the quickmatch, I fold the bare blackmatch around the meal-coated time fuse. See drawing #9. Now I fill the cup with polverone lift. Because it is not near the quality of commercial black powder, I use quite a bit more. For this shell I would use about 90 grams. Then I close the cup with a thin cardboard disc, glued on with Kraft paper and glue. When dry, the shell is ready for use. See drawing #10.

## DISCUSSION

I use polverone bursting charge because it doesn't have the tendency to detonate if used in larger quantities under high confinement. I think H3-type burst and whistle-type comps do, certainly if they are applied in high density, i.e., if not coated on rice hulls but granulated. And I feel no need to have a too shattering burst for the propulsion of my stars since they could be blown blind, or the prime coating could be peeled off, or the stars broken.

The use of rice hulls brings up another interesting point. Rice hull powders, compared to granulated powders, have little or no crush strength. When thinking about the tremendous setback the stars receive when the shell is projected out of the mortar, I predict that the stars located in the upper half of the shell must be forced down onto the burst charge. So if a burst charge is used that has a low crush strength, the stars will end up in a non-concentric location. This conclusion is based on my personal ideas and I have never seen proof of this occurrence.

I do not use a thin bag for separating the stars and the burst charge, for example, the Kozo paper suggested by Shimizu. I suspect that if the burst charge is lighted, this thin paper will be torn into little pieces which could obstruct flames from reaching all the stars. I believe this will be less of a problem in commercial round shells, but their burst powders are better and their stars will be stronger (higher crush strength), and will catch fire more easily.

However, if a burst charge is used which would become a (more) friction sensitive combination with the stars, a separating bag would be essential.

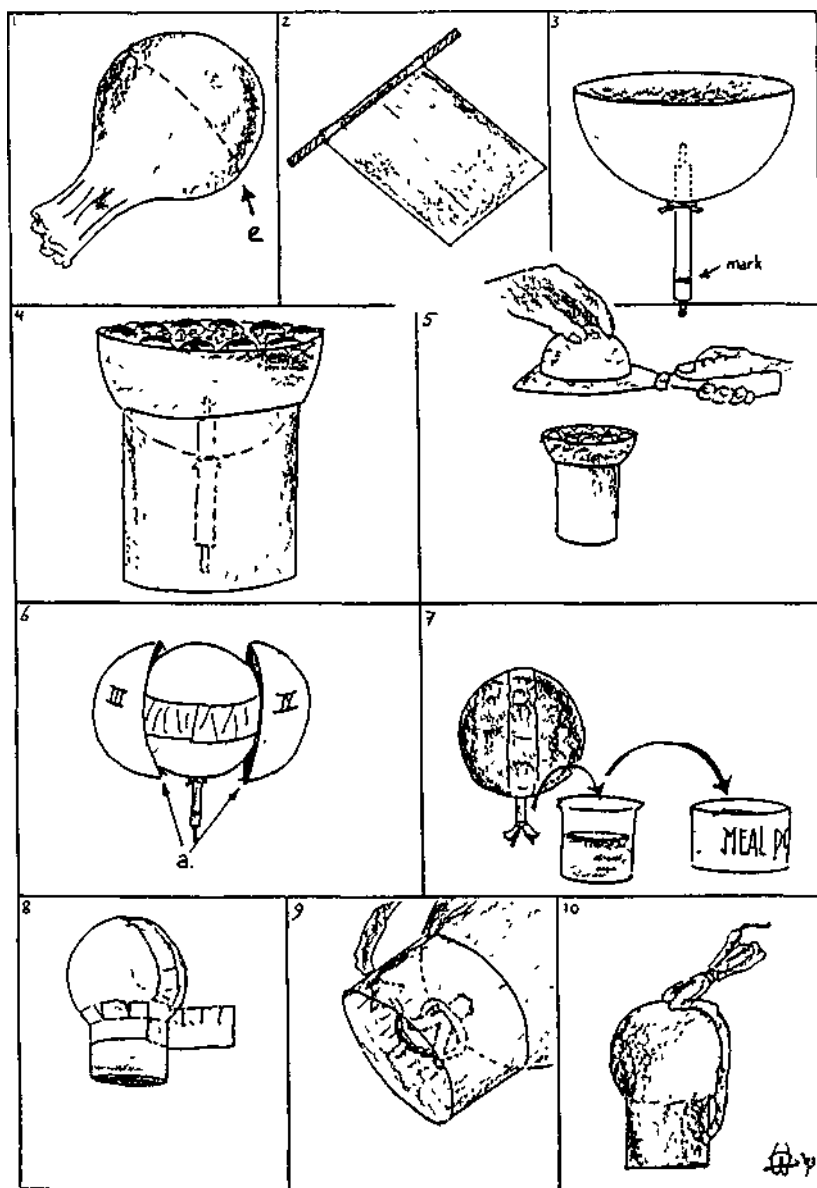
With regard to symmetrical strength of the inner casings, I actually should have used six hemispherical cups instead of four, because then all three dimensions (and their seams would be well covered with a cup. However, I found this too elaborate, and wouldn't expect noticeably different performance.

Because I use polverone as a lift charge, the lift

# **THE BEST OF AFN III**

charge cup is a relatively strong container. This will cause a better expulsion of the shell from the mortar, and therefor it will explode at a higher altitude. (My shells burst at approximately 25 meters, which is still fairly low.)

The best artistic quality is, in my opinion, attained with bright, deeply colored stars which do not burn too long. RW



*Drawings by author. Not to scale.*

## RICE HULLS - IS THERE AN ALTERNATIVE?

When reading the firework literature it is apparent that the use of rice hulls as cores upon which to coat bursting charge composition is a standard technique in the construction of a wide variety of shell styles. This may range from the traditional Japanese method of pasting their H3 composition onto rice hulls in the production of burst charge for their round shells, to the use of meal coated rice hulls, in conjunction with smaller quantities of either flash or whistle composition, as the burst charge of say round plastic shells or in canister shell flash bags. Although the idea of using coated rice hulls as a granular burst charge is most likely Oriental in origin, its use is more widespread. Many U.S. shell makers apply the technique and in Europe commercial shells from Spain commonly employ coated rice hulls as a burst charge component. The use of rice hulls in a burst charge is often evident from the glowing mass of debris which is sometimes seen hanging at the centre of a shell burst. This is often the case with hulls that have been too thickly coated with meal gunpowder.

Clearly rice hulls are an essential component in many shell designs and herein lies my question, which I have never seen considered. Rice hulls tend only to be available in countries where rice is cultivated as a crop. They are essentially an agricultural waste product with no export value and, therefore, will be virtually unobtainable where rice is not domestically grown. This would include northern and central European countries, including the U.K. Consequently, any amateur or manufacturer in these places who wishes to duplicate Oriental shell design, or employ some of the less traditional approaches to shell construction which have appeared in the U.S. literature, is faced with the problem of locating an alternative to rice hulls.

This is not as trivial a problem as it might appear. For example, in the case of the Japanese Warimono style, the use of rice hulls to form burst charge granules (partly) determines the burning rate of the burst charge which, when

used in conjunction with the correct shell wall thickness, enables the shell to burst with the required radial symmetry. If a large core were to replace the rice hulls, the burning speed of the burst charge would be reduced and adjustments would have to be made to the strength of the shell wall in order to maintain a radial break. Clearly the use of core material of inappropriate particle size and surface area would lead to deviation in the performance of the shell if "conventional" (i.e., as applied to a shell made using rice hull cored burst) shell construction techniques were otherwise followed.

Thus, is there a suitable alternative to replace rice hulls where they are not available? Alternatives which have been suggested are sunflower seed husks (too large and messy to produce), lavender seeds (expensive), wheat chaff, and bran (inappropriate size and shape, also tricky to coat). Does anyone have any better suggestions?

CTB

## TEDIUM RELIEVER

If you would like to make more paper ball shells, but just can't bring yourself to the tedium of those thin pasted strips, try this: After the shell is loaded, sealed and spiked, smear a thin layer of paste all over, and instead of using long thin strips, use 2" by 3" "patches" for pasting. The shell comes out more wrinkled, but just as effective and not nearly so time consuming. SW



## THE BEAUTIFUL 4" SPIDER WEB SHELL

One of the most spectacular yet simple to make fireworks bombshells is the Spider Web. It is also one of the most inexpensive shells. Some companies call this shell an Octopus, but the effect is the same. This shell packs a dramatic punch when it bursts. Exploding with a bang, it instantly fills the sky with golden tentacles spreading radially in straight lines and in all directions from the center. The gold stripes are formed from the burning powdered charcoal trail left behind as the stars are hurled at high speed. The pattern just hangs in the sky for many seconds before fading. A 4" canister Spider Web shell, when made properly, looks like a 6" chrysanthemum. Fire five of these in a salvo or flight and an awesome checkerboard spider web fills the sky! Here's how I have refined the Spider Web to perform better than any others I have ever seen:

### THE SECRET IS THE STAR

Stars are cut 5/8" or 3/4" (large) square. The formula:

#### FORMULA 1

Commercial Meal D	10.0 lbs.
Potassium nitrate	7.5
Air Float Charcoal	7.5
Sulfur	1.0
Dextrin	2.0

#### FORMULA 2

Potassium nitrate	15.0 lbs.
Air Float Charcoal	9.0
Sulfur	2.0
Dextrin	2.0

While the formulae are given in pounds, smaller batches can be made by substituting grams, ounces, etc. for the lbs. or by multiplying or dividing all the quantities by the same number, keeping ratio relationships the same. For example, Formula 1 can be weighed out in ounces with each quantity multiplied by two to make enough stars for 3 or 4 shells. Formula 1 is a very fast burning star because it is 50% commercial Meal D black powder. It will ignite 100% from the strongest flash bag. The stronger, the better! Formula 2 needs to be ball milled for at least ten hours to be almost as fast, yet just as ignitable as

Formula 1. Because it burns slightly slower than Formula 1 (after ball milling), these stars achieve a larger spread in the sky. Ball milling also serves another purpose. It reduces the amount of ash and shortens the charcoal glow time. Without ball milling, some of the sparks may glow all the way to the ground. With ball milling, the golden stripes are more uniform and more beautiful, fading in unison. Formula 1 (less the Meal D) can also be ball milled to achieve uniformity and less ash. The Meal D is added after ball milling the rest of the chemicals. Very slight dampening with a volume mix of 80% water with 20% denatured alcohol is helpful during ball milling. By slight I mean just enough to settle the dust but the mass still feels dry and flows freely as a powder.

Commercial quantities can be ball milled in an electric cement mixer that has been modified. I did this by removing the blades and reinstalling the bolts to prevent leakage of powder out the bolt holes. I also removed the motor and replaced it with a totally enclosed (sealed) motor and thoroughly electrically grounded the machine. Ball milling of a mixer charge of 28 lbs. of Spider Web mix, was done with a set of inexpensive Bache Balls! The mouth of the mixer was sealed with a sheet of heavy plastic cut in a circle larger than the opening of the mixer vessel. The plastic cover was held in place with bungee cords. After 10 hours, the powder was absolutely beautiful and the stars it made performed exquisitely.

If one tries to burn the star composition after mixing and ball milling, one will be disappointed. It appears to be smoldering and slow as if something were done wrong. This is normal. After the stars are made by thoroughly dampening with water, forming loaves in a frame, slicing, dicing, dusting and drying, the stars perform quite differently! Burn time for a 3/4" star is less than 1 second. The star is very sensitive to low temperature incandescent heat ignition, yet is very stable and insensitive to friction or impact. This makes the star ideal for hard breaking flash bag bursts!

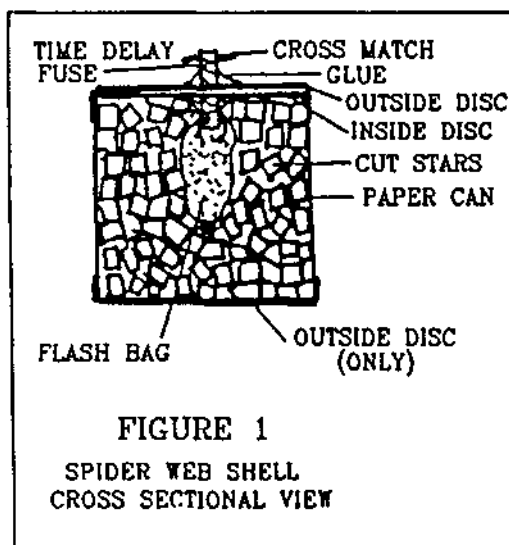
Once the stars are made, I use the following materials to assemble a 4" Spider Web Shell:

## SHELL MATERIALS

- Paper Can with end caps, 3 1/2" dia. x 4" long.
- 3 Chipboard discs, 1/8" thick x 3 1/2" dia.
- Japanese 1/4" Time Fuse, 3 seconds between cross match.
- Dime size Coin Wrapper for making Flash
- Wooden Dowel, 5/8" x 4" for making Flash
- Masking Tape.
- Spool of 12 ply Cotton Twine or equal shell twine.
- Enough good Flash Powder to fill a dime wrapper.
- Igniter Cord for cross matching time fuse.
- White Glue and/or Hot Melt Glue & gun.
- Home made granulated black powder.
- Wallpaper wheat paste.
- Kraft Paper, 70 lb. and 20 or 30 lb. grades.
- Quickmatch fuse.
- 2FA Black Powder for Lift, 2 oz.

## PUTTING IT ALL TOGETHER

Assembly is as follows; refer to Fig 1.



The shells can be made the traditional way of rolling a paper casing but my way (with paper cans) is easier to assemble and performs equally as well.

Two of the chipboard end discs should have center holes to receive the 1/4" time delay fuse. With Elmer's white glue, I fasten a disc inside the loose end cap of the paper can (the can bottom end cap should already be glued in place). A weight is then placed on this disc and set aside to dry. Next, I slide the dowel inside the dime size coin wrapper almost the full length of the wrapper. I then crimp the end of the wrapper over the end of the dowel to close off the dime wrapper and forming a bottom. A short piece of masking tape is then placed over this crimped end to seal the bottom of this soon to be flash bag. Using a hot salute flash powder, I fill the flash bag 3/4 full. Next, the time delay fuse, cut to the correct length and cross matched with igniter cord, is inserted (with cross match) into the flash bag. The bag is gathered around the time fuse and tied with twine just above the cross match.

Being sure to center the flash bag among the stars, I next load the stars and flash bag into the paper can. The spaces between the stars can be filled in with pulverone or granulated home-made black powder. The pulverone filler is necessary with hand rolled casings but optional if using a paper can. This type of shell functions equally well without pulverone. The top edge of the flash bag where it is gathered around the time fuse must be kept even with the top edge of the paper can. Next, I smear a generous portion of white glue around the inside circumference of the paper can end cap that was previously set aside. Holding the time fuse centered, I lower the paper can end cap with chipboard disc (glued inside cap) onto the fuse and paper can. Once the end cap is seated onto the paper can and while applying hand pressure to keep the cap from springing back up, I apply masking tape around the circumference of the cap where it meets the can wall. The bottom end cap of the paper can is also taped and sealed.

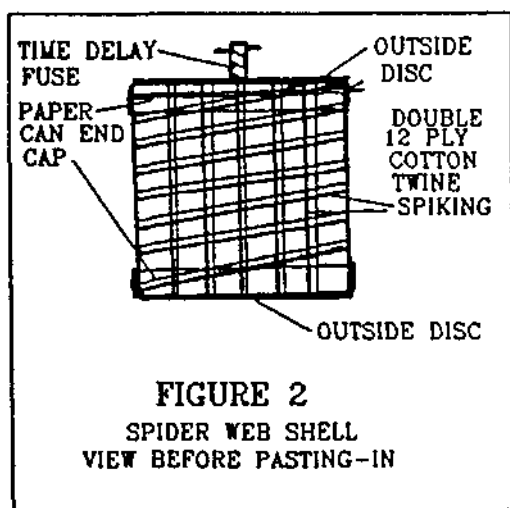
I next gently pull up on the time delay fuse to assure that the top of the flash bag is against the inside disc. A generous portion of Elmer's glue is smeared on the outside of the top end cap and around the time fuse to seal against lift flame entry. I then assemble another chipboard disc with center hole over the fuse and down against the paper can end cap. This disc is taped down in

four locations 90° apart to hold it in place while the glue dries. The third solid chipboard disc is glued to the bottom of the shell in an identical manner. Next, I glue a generous fillet of Elmers around the time delay fuse to complete the double seal against lift flame. The shell is now set aside for the glue to dry overnight.

The next step is spiking the shell with twine. Two parallel lines of twine are applied simultaneously to give a strong hard break and symmetrical pattern.

I start by looping the free end of the twine around the time fuse, holding the end down, as twine is fed out and laid down against the shell wall, crossing over the top of the free end. The spiking pattern follows the sketch in Fig. 2, and is tied off with a clove hitch knot around the entire circumference of the shell, after spiraling up the side.

The strength of the spiking will be greatly enhanced by running cotton twine through a wheat paste slurry and wiping off the excess as it is applied to the shell.



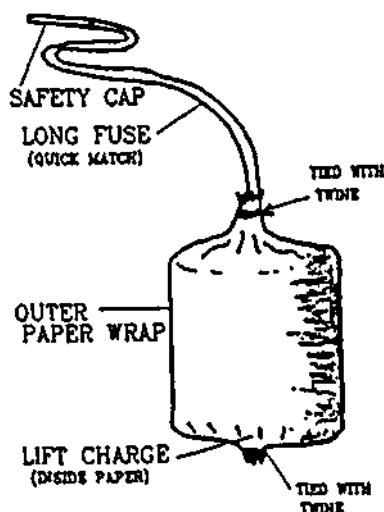
After spiking, the shell is ready for pasting. Kraft paper (70 lb. rating) is cut so the paper grain will lie parallel to the shell length. The width of the paper is cut so that it will cover the full length of the shell, and fold over to cover 2/3 the diameter of the shell at each end. The length of the paper should be 48 inches. Each shell gets pasted with a sheet this size. A slurry of wheat

paste is prepared and generously brushed on both sides of the paper. The paper must be thoroughly soaked. The paper is folded like a bellows and squeezed with the hands to make the paste penetrate the fibers of the paper and to soften the paper. I then smooth out the paper on a formica table top and roll the shell tightly, centering the shell in the paper while working out any air bubbles. The paper that extends over the ends of the shell is torn in strips about an inch wide. The tear is made from the end of the paper to the end of the shell. These strips are laid down over the end of the shell and smoothed tight against the spiking, working out air bubbles. On the fuse end, I keep all the strips on the same side of the fuse as I rotate the shell and laying down each strip. I make sure there is a good tight seal around the time delay fuse. When finished, the shell is set aside to dry in the air stream of a fan or out in the sun.

The shell can be finished as any shell. The final cross match hole is punched in the fuse and a piece of igniter cord is inserted. I have also split and primed the time fuse with nitrocellulose lacquer and black powder when out of igniter cord (igniter cord can be purchased from Coonies Explosives, Hobbs, NM). Some shell makers finish the shell with the time fuse up and a pass fire quickmatch connecting the top of the shell with the lift powder at the bottom. The quickmatch long fuse is introduced to the top of the shell where the time fuse and pass fire are connected. I prefer to invert the shell, putting the time delay fuse directly into the lift powder. However, I wouldn't do this if I were using a spoolette time fuse. Spoolette fused shells have to be fired fuse end up or the spoolette core will blow through on lift.

## FINISHING IT

For final assembly, I roll the shell with a quickmatch long fuse, in 3 turns of 20 or 30 lb. dry kraft paper. The long fuse lays parallel to the shell. The paper should be wide enough to cover the length of the shell plus cover the full diameter of each end of the shell. The end of the quickmatch has the paper trimmed back 1/2" to expose the black match. This end is bent over the end of the shell where the lift charge will be in-



**FIGURE 3**  
**FINISHED SPIDER WEB SHELL**

roduced. Two ounces of FFA commercial black powder is poured into this end of the shell covering the bare end of the quickmatch and surrounding the time delay fuse. The paper, starting with the inside rolled layer, is laid down over the black powder. The final turn of paper is gathered and tied off. I then trim off any excess paper beyond the clove hitch knot. The final touch is to install a mopoline or safety cover on the end of the long fuse to be ignited. The long fuse is then folded and secured with a rubber band and labels placed on the shell. WO

## MAKING HOMEMADE WHEAT PASTE\*

A good old fashioned wheat paste mixed with warm water is used for pasting kraft paper on aerial shells. Wheat paste is also called wall paper paste and can be obtained in paint stores or hardware stores. If wheat paste is unavailable in packaged powder form, it can be easily made in the kitchen.

1. A cup of sifted flour is blended into 3 cups of cold water.
2. In a separate saucepan, 3 cups of plain water are brought to a boil; heat remains on.
3. The cold water/flour mix is slowly added, in small increments, with constant stirring to prevent sticking to the bottom of the pan. This is continued until the cooked paste is of the desired viscosity. The cooking mixture is stirred for a few minutes between adding the flour/water mix. If the paste is not thick enough, a mix of 1 cup flour to 2 cups cold water is slowly added to the cooking paste, same as above.
4. After the paste has cooled, it is ready for use. As the paste cools, it will continue to thicken. If it becomes too thick, additional water is added to thin it. The paste can be preserved for storage in a closed container by adding a few ounces of sodium salicylate. This will give the paste a slight pinkish color. Paste that does not have sodium salicylate added will require discarding within a day or two as it will sour and smell bad. Sodium salicylate also is used to make whistles when mixed with potassium perchlorate. WO

\* Excerpted from Bill Ofca's *Technique in Fire, Vol. 1, All About Aluminum, Flash Powder, And Aerial Salutes*.



## GOLD FERRO-ALUMINUM FLITTER

If you're like me, you bought a pound or so of ferro-aluminum a while ago and couldn't seem to find a formula that it works well in. Well, maybe this is just the thing.

It is my personal opinion that not enough shells containing flitter stars are seen in displays anymore. One reason for this may be that most of the old formulas used German black aluminum for the fuel, and nowadays that's cost-prohibitive. This formula uses American dark pyro aluminum as the main fuel, which makes it a lot less expensive. Barium nitrate is used as the main oxidizer; the potassium nitrate and charcoal improve ignitibility. The sulfur is a catalyst, cryolite the color donor, the boric acid a buffer (because of the large amount of aluminum).

Barium nitrate	24
Potassium nitrate	14
Sulfur	8
Charcoal, air-float	3
Cryolite	3
Dextrin	7
Boric acid	+1
Aluminum, Amer. dark pyro	19
Ferro-Aluminum, 35:65, -60 mesh	22

These stars burn fiercely, throwing off a thick tail of golden sparks. Adding a comet (same formula) to the shell would produce a *Palm Tree* effect. Because of the fast burning rate, the stars must be cut large (no less than 5/8"), and the shell must have a hard break, like a spider-web.

When mixing, I first screen everything, except the metals, and mix well. Then I add the metals and dampen the mix with 90:10 water/alcohol. More than 10% alcohol may cause the stars not to hold together very well. [This formulation has a spontaneous combustion potential. Consult Aluminum-Nitrate Reactions, *BEST OF AFN II*, page 178].

When the stars are dry, I prime them well with a mixture of star crumbs and polverone or 4Fg. I even add a small amount of pyro-flake titanium to the prime to ensure ignition. DB

## ROUND SHELL CONSTRUCTION USING INNER & OUTER SHELL CASINGS

This type of round shell construction uses an inner round spherical shell casing nested inside another shell casing. This allows the manufacturer to spend less labor on pasting in a round shell. Pasting labor is the most time consuming and expensive item in the assembly of round shells. The pasting in of the shell is almost eliminated by using this method.

Here are some of advantages:

Biodegradable; easy assembly; consistent breaks; quick assembly time; readily adjustable breaks; great for parachute and Poka shell types; even better to make chrysanthemum type breaks; easily taught shell assembly with consistent results; considerably easier to obtain nicer looking finished products; allows for more productive manufacturing treatise to be established; component shells can be made and tested with minimum of time and expense; fast.

Inner and outer nesting shell casings consist of building a round shell as it is normally done using Japanese paper spheres. The builder then surrounds this with another round shell casing that fits tightly over it. The result is a shell encased in another shell casing, thus making the casing wall twice as thick. This eliminates most of the pasting. It is easy to imagine that this type of shell assembly is quite fast and less labor intensive.

Precocious Pyrotechnics is now stocking four sizes of sets consisting of one inner and one outer sphere paper casing. 3" sets are \$1.20; 4" = \$2.50; 5" = \$3.30; 6" = \$5.20. Precocious also stocks the regular Japanese-made paper casings from 2" thru 24". Minimum order is \$50 (plus shipping); with a \$100 or more order, they will include a free booklet that tells how to construct perfect performing shells using these methods. The booklet sells separately for \$14.95, postpaid in U.S.

GH



## BRIGHT STAR COMPOSITIONS WITH HIGH MAGNALIUM CONTENT

In an encyclopedia<sup>1</sup> I found that magnalium powders are used in bright star compositions, but could not find any details concerning components and their respective quantities.

Troy Fish mentions star compositions containing magnalium powders in *Pyrotechnica VII*<sup>2</sup>.

Today I want to present such a composition that I have used successfully.

The composition is suitable for cut stars, as well as for round stars. For both techniques the composition is wetted using a mixture of equal parts of water and denatured alcohol.

The stars required two layers of prime. After complete drying of the star, the first fire composition is applied and then it is completely dried again. Then the final layer is added.

I have also included an alternate first fire composition from Ellern's Formula #166 (page 379). This should be used for fast-ejected stars. The binder is nitrocellulose lacquer. The final layer is the same as mentioned above.

Some modifications are possible. Red gum can be replaced partially or totally with other natural resins like shellac, gum dammar, colophony and Vinsol resin. Shellac shows the best flame color, but the best ignition will be achieved by Red gum. Dammar, colophony and Vinsol show lower burning rates and whiten the flame color.

Strontium carbonate can be replaced by an identical quantity of calcium carbonate. The former yields a vermilion color, the latter is crimson. Instead of strontium carbonate, strontium oxalate can be used, but the color is less intense.

To achieve a satisfactory green star composition, it is necessary to replace strontium carbonate with the same amount of barium carbonate. Barium chromate can be used as well but cannot be recommended because of its toxicity.

For bright yellow stars, I replace 20% of strontium carbonate with 12% of ultramarine blue. For orange colored stars, mixtures of both are suitable.

To improve ignition and burning rate of the stars, it is possible to add red iron oxide, black iron oxide or cupric oxide in concentrations of about 2%. Both iron oxides whiten the flame color slightly; cupric oxide gives the stars a bluish tint. The addition of potassium dichromate in concentrations of 2 - 4% apparently improves combustibility, but cannot be recommended because of the enormous toxicity and carcinogenicity.

For extremely hard stars, the dextrin content can be increased or may be substituted by glutinous rice starch.

### References:

- (1) *Ullmarm's Encyclopedia of Industrial Chemistry*, 5th ed., 1992, Vol. A 22, Pyrotechnics.
- (2) *PYROTECHNICA VII*, 1981, pg 25 - 37.
- (3) Ellem, *Military & Civilian Pyrotechnics*, (1968).
- (4) T. Shimizu, *Fireworks, The Art, Science^ & Technique*, Maruzen, 1981, pg 148. HWW

### BRIGHT STARS WITH HIGH MAGNALIUM

Potassium perchlorate	30%
Parlon	12
Red gum	4
Magnalium 50/50,100 mesh, 150u	30
Strontium carbonate	19.5
Boric acid	0.5
Dextrin	4

FIRST FIRE COM.		FINAL LAYER	
Potassium perchlorate	73%	Meal powder	93%
Red gum	12	Charcoal, fine powder	5
Charcoal, fine powder	5	Dextrin	2
Cupric oxide	1	ALTERNATE FIRST FIRE (bind with N/C lacquer)	
Iron oxide, black	1	Potassium nitrate	54%
Pyro aluminum	4	Silicon	40
Dextrin	4	Charcoal, fine powder	6



## MAG/55 ENHANCES AERIAL SALUTES

There are almost as many formulations for flash powder and salute construction as there are pyros. Nonetheless, I thought it worth the time to formulate my own version that would provide most of what I view as essential salute elements: a loud, bright flash with a huge spread of titanium sparks. At the same time, I wanted to maintain the highest level of personal safety in both the mixing and construction phases as well as the latter stages of storage, handling and firing.

### GENERAL CONSTRUCTION

Most published formulas call for the addition of 8 - 15% by weight of titanium sponge to create the ball or shower of sparks from a salute. Two things bothered me about simply mixing in the titanium with the finished flash powder. First, adding titanium directly to flash composition significantly increases the risk of accidental ignition. (One NEVER screens such mixtures.) Second, assuming a uniformly mixed flash/ti composition, when the salute detonates, only those titanium particles furthest from the center of the salute will be propelled any significant distance and be distinguishable from the central core flash. Essentially, the titanium near the center of the salute is wasted.

To address both these issues, I construct 3" double-walled salutes by inserting a 2" diameter tube inside a 2 1/2" diameter tube. The inner tube, or core tube, is filled with flash, while the outer ring of space is filled with mostly titanium (8% potassium perchlorate, 3% bright aluminum flake and 89% titanium turnings). This negates the need to intimately mix the titanium with the flash powder, and also provides a very wide break to all the titanium particles. This technique also allows me to use the less expensive titanium turnings versus sponge.

To insure a generally round, symmetrical break of titanium in larger salutes, an additional modification is needed. First, I load some titanium in the core tube to a depth of about 1/4" and cover with a single ply of tissue paper pressed down around the fuse. Next, I add the

flash comp to within 1/4" of the top of the core tube. Then this is followed by another ply of tissue and a second thin layer of titanium to top off the core tube. I sometimes use different mesh sizes of titanium and add some zirconium to create different and interesting effects.

When it comes to commercial construction, salutes are the Rodney Dangerfield of shells. Too often, only star shells receive the kind of meticulous attention to detail which ALL aerial shells should get. All things being equal, overall shell construction plays a major role in salute performance.

From a safety standpoint, the last thing you need is a 'gas blow through' resulting in a gun detonation. Therefore, I spend a good deal of time and material constructing the end plugs/caps and fuse entry points. The second to last thing you need is a salute that goes up and then comes down; I use two fuses cross-matched with Thermolite and dipped in a nitrocellulose lacquer/black powder slurry. Overdoing it? Maybe, but for 5 cents and 5 minutes work, I buy an awful lot of peace of mind.

In terms of sound level, the stronger the casing wall, the louder and sharper the report. I therefore use a heavy walled outer tube, and then wrap it with two layers of 30 lb. kraft paper, string it in, and finish off with several more layers of kraft. Considering the expense of raw materials, the potential danger, and normal desire to get the most bang for the buck, I sometimes have to wonder why there are so many 3" commercial salutes that are not that much louder than an old fashioned M-80. Shell integrity plays a major role.

### THE FLASH

Next, I wanted a flash formula that yielded the loudest and brightest sound and light per unit weight, yet remained relatively 'safe' ...a true oxymoron if ever there was one. From all the formulas reviewed, it seemed that magnesium had to be included to create the intensity of light and concussion I was looking for. For example, a 50%

# THE BEST OF AFN III

perchlorate, 45% magnesium and 5% potassium dichromate mix is well known for its immense power. However, I wanted to keep the amount of magnesium to a minimum to negate moisture issues from arising (especially in storage) as well as the toxicity issues with dichromate. In addition, although potassium chlorate is widely believed to be the best noise producing oxidizer (speed of detonation is higher with the chlorate versus the perchlorate), it is also very dangerous to handle, so I restricted myself to the perchlorate and ruled out the use of sulfur.

Since I did not want to use potassium chlorate or sulfur, I needed a way to increase the detonation velocity. There is considerable literature supporting the idea that large variations in aluminum particle size may increase the detonation speed and resulting concussion produced. Also, providing air spaces within the composition also seemed like an effective way to maximize the velocity of detonation or *brissance*. This manufacturing technique is widely used in the production of many high explosives to increase the velocity of detonation. To effect this characteristic, I decided to add Cab-O-Sil and wood flour to the formulation. Adding bird seed or some other inert and harmless material may do as well or better.

After testing eight different formulations, the following was subjectively (but clearly) determined to produce the loudest noise possible along with a very intense flash:

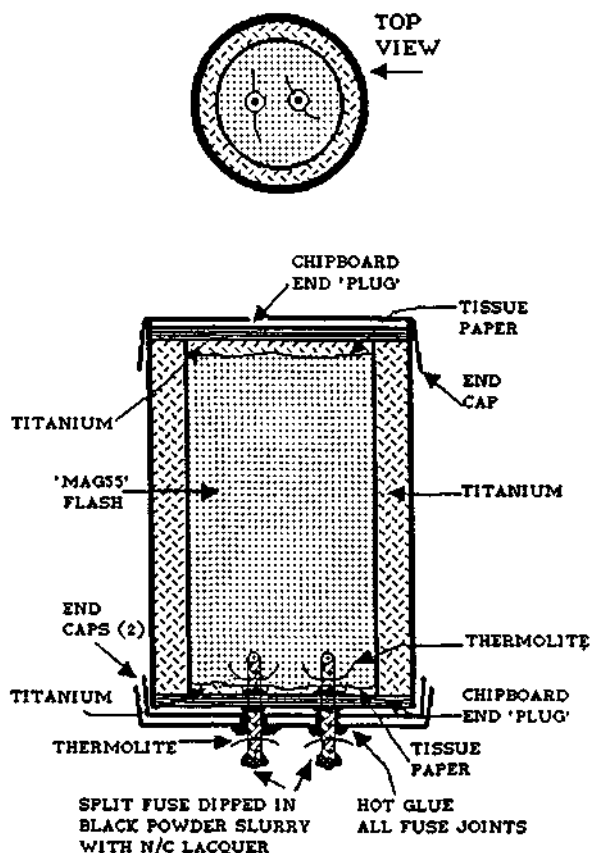
## MAG-55

Potassium perchlorate	64.0%
German Black aluminum	15.0%
American Dark aluminum	5.0%
Bright aluminum flake	5.0%
Atomized aluminum	1.0%
Magnesium 400 mesh	5.0%
Magnesium 200 mesh	5.0%
Cab-O-Sil	+ 2
Wood Meal	+ 2
Potassium dichromate	+ 1

I first mix all the metals together, then separately mix the oxidizers, Cab-O-Sil and wood meal. Then using a long broom handle to which

I've attached a camel's hair brush, I mix the oxidizers and metals on a large sheet of kraft paper laid out on the ground. I never mix more flash than I plan to use immediately, which in my case is typically 120 grams (for 2 salutes).

Using the above construction technique, a 3" salute requires only 60 grams of flash comp. The resulting air blast is considerably louder than all 3" commercial salutes and most 4". By increasing the magnesium content to 20% (and reducing the oxidizer to 60% while eliminating the American dark aluminum) the brilliance of the flash becomes truly awesome, although there is no appreciable difference in sound level. AP





## MICROSTAR BURSTS - WITHOUT MICROSTARS

I'm developing my skill at making gerbs. I'd especially like to duplicate an effect seen in several commercial Class C fountains and sparklers, wherein parent sparks break or branch with an audible fizz, pop, or crackle into daughter sparks. I'm aware of disagreement as to the name of such effects, but I expect to be understood in referring, to at least some of these as microstar breaks or bursts. I was referred to published procedures for making microstars, which appeared daunting to this novice who'd just started making *any* stars (for prismatic gerbs). So instead of dabbling with magnalium and antimony trisulfide, I got lucky.

Typical of my simple work is the following composition:

Strontium nitrate	3
Potassium perchlorate	2
Red gum	1

mass proportions, mixed dry. This I tamp (not ram) into a 3/8" diameter unchoked case rolled from brown bag paper and Elmer's Glue-All, with an end plug of Durham's water putty (the late Al Lesser's favorite). A cardboard base is added if necessary, and may be stuck directly onto the wet putty, but holds better if glued. Lit with visco fuse, this slow red flame mix looks like a road flare, although the mouth of the case intermittently catches fire, diluting the lance color effect. Months of storage of the powder of prepared item don't seem to hurt its performance.

To add to the effect of simple case items like the above, I usually experiment with added coarse metals: steel, aluminum, or titanium. I expect, and usually get, simply, sparks. But when I added 20-40 mesh flake titanium to the above red flame mix just before or as I charged the case, the resulting effect was surprising. Above the red flame, each of the rising sparks audibly broke,

with lots of gray dross left on the ground. The mass ratio of red flame powder to titanium could vary from 5:1 to 75:1, and probably beyond in both directions, without a qualitative change in this burst effect.

Maybe this effect has been seen before. 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 mealed powder or whistle compos gave just "plain" sparks. Nor were microstar 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 compo. Presumably the incandescent titanium flake, without benefit of a cast microstar around it, rises thru the flame and develops a crust derived at least in part from the powders or combustion products. Gas within this crust then explodes thru. It's a pretty effect, simply produced. Following is from the booklet

FORMULAS by Ed Moore.

### BLUE STEEL FOUNTAIN

Ammonium perchlorate	65
Hexamine	10
Stearic acid	7
Copper carbonate <i>OR</i>	
Copper oxychloride	6
Steel fine powder	12

Composition is tamped lightly into a choked case 1/2" i.d. with 1/4" wall. If small amount of titanium is added to a portion of the mix and that mix is charged into the tube first, then the regular comp next, the effect is to change from a delicate steel to a crackling titanium fountain. RG

## MICROJET STARS

After competing in the 1990 PGI aerial competition, I've been asked by some of my friends to explain the principles and how-to's of a micro-jet star. After many hours testing, failing, and retesting, I finally came up with an idea based on the popular go-getter. The first time I saw one of these, I was overwhelmed with excitement and headed back to the lab to try to make my own. Making a standard cylinder shell loaded with go-getters was quite simple since they lined up neatly against the shell wall, but you are limited as to how many rows will fit per shell. Thus came the birth of the micro-jet. Using a different construction method, I cut down the overall size by 80% with burn time almost equal to a full size go-getter. The void I felt created by a go-getter shell was suddenly gone, and a full, almost symmetrical pattern was achieved by tripling the amount of stars in a shell. Still not completely satisfied, I thought a little more enhancement might be needed for a more interesting effect. Since the size of the jet is so small, it could be used as a core in a round star. Here's how I do it.

First I roll some 3/8" diameter tubes with 2 turns of 40 lb. Kraft, about 8" long. After drying them, I cut them into 3/8" lengths. Next I cut a few 1 foot pieces of medium speed thermolite and dip them in a thin slurry consisting of nitrocellulose lacquer, Meal D, and acetone to put a nice thin coat to keep it from crumbling when being cut. I then cut the thermolite in lengths slightly longer than the 3/8" tubes to be used later. Next I mix my composition in a small air-tight container and knead it into a tennis ball size dough ball. Since the formula I use is so Parlon rich, it is easy to mold and press into the pre-cut tubes. After pressing 15 or 20 tubes (with forefinger and thumb) I insert a piece of thermolite in the center, repeating the process until done. Drying time is usually 1 or 2 days, depending on the weather. When they're dry, I gather them into a tight bunch with the thermolite end up, and using a paint brush, smear a hot igniter slurry over the tops. When dry I turn them over and coat the under side with a thick jelly of N/C in

acetone to slow or stop the ignition of the bottom side of the jet. Now I mix a batch of White Aluminum Streamer comp., and in a large round bottom bowl I start coating the jets with the streamer composition. Stars were rolled 1/2" in diameter and primed with a hot mix, Meal D prime. The end result is a star which leaves a long silver/white tail, and at the end, zips across the sky in a different color. Here are some formulas I've used.

NOTE: When rolling stars, I use a non-aqueous system. No water should touch the jets due to the presence of magnesium. [Latex gloves, face shield, and respiratory protection are minimum personal protection. Flash point of acetone is -4°F., with very high evaporation rate, factors which favor the likelihood of dangerous vapors around the work area].

### RED MICROJET

Potassium perchlorate	25
Strontium nitrate	25
Parlon	30
Magnesium 100 mesh	17
Red gum	3

### ALUMINUM STREAMER

Potassium nitrate	51
Aluminum, spheroid. 325 mesh	12
Magnalium 50/50	8
Titanium 20-40 mesh	8
Charcoal, air float	5
Red gum	5

### HOT IGNITER

Potassium perchlorate	65
Silicon	20
Red gum	10
Sulfur	5
Charcoal, air float	2
(I mix 2 to 1 with Meal D)	

RSNJ



## CRACKLE STARS

Crackle stars are commonly found in Oriental shells but are slowly finding their way into shells of the west. A crackle star is nothing more than a star which explodes at the end of its burning. Since the explosion noise at ground level is no greater than that of a small firecracker, the noise at the ground level is sensed as a flurry of crackles.

The central exploding core must of necessity be a very sensitive composition, for it must explode without the assist of any confinement. The Orientals employ a mixture of potassium chlorate and realgar which is far too sensitive to be mixed in a dry state. It is prepared as a wet slurry which is applied to long strands of a type of twine, not unlike the method of making quickmatch. The damp cord is cut into small pieces before drying, and a safer mix is applied over it by rolling in a pan. Only when completely covered by a non-sensitive mix are the cores safe to handle.

Realgar is difficult to obtain in the U.S. I can't resist relating that I bought a crystal specimen of realgar at the Denver mineral show for around \$100. It was a rock covered with beautiful thumbnail-sized transparent red spade-shaped crystals. Needless to say, I have no intention of grinding them up. I will need to keep the specimen in the dark as light causes the crystals to form cracks as it slowly degrades to the more stable orpiment.

So where does one go to find a sensitive composition safely encased in a small container suitable for rolling into stars? Just walk into any gun shop and pick up a box of pistol primers and you'll find the perfect device!

Pistol primers have a very shiny and smooth outer surface which presents some problems with getting star compositions to adhere. Compositions that adhere best to smooth surfaces are those which have a very fine particle size. One of

the best is a mixture of equal parts of potassium perchlorate and fine aluminum. Water cannot be allowed to soak into the primer or it will be rendered inactive, so I use a solution of 10% nitrocellulose in acetone.

Moving outdoors. I dump the primers in a smooth metal pan and spray them with the solvent mixture until they are uniformly damp. A very small amount, about 1/2 teaspoon of aluminum/perchlorate is sprinkled on while the primers are in rapid motion. I keep sprinkling until the composition begins to accumulate on the bottom of the pan. At this point there will still be incomplete coverage of the cores so it will be necessary to repeat the spraying and sprinkling until the cores are completely covered. I watch for any build up of sludge or scum on the pan; as it develops, I wipe it off with an acetone-soaked towel.

When complete coverage is obtained, the star cores can be allowed to dry. After drying, the cores will be relatively impervious to water and other compositions using water soluble binders, like glitter, charcoal star mixes, color mixes, etc., which can be layered over them. A slow burning aluminum flitter mix could also be used; it gives a very nice effect, for when the core ignites and explodes, there often are pieces of unburned flitter blasting off the star and giving the effect of a shell breaking into a few hundred mini-crossettes.

Yes, the addition of a couple hundred primers as star cores will add about \$2 to the cost of the shell but the results are certainly worth the trouble. I would strongly discourage pyrotechnists from using the very sensitive, difficult to ignite, and toxic lead-containing Hells-A-Poppin'-type compositions which have been discussed in a recent issue of AFN. In the quest for more exciting stars, we need not venture into unsafe and untested compositions. DB

## CRACKLING MICRO STARS

*[This material has been produced from notes taken during a seminar at a PGI convention.]*

**Warning:** The crackling formula shown in this article uses lead compounds that are toxic. I take adequate precautions against inhalation, ingestion, and skin contact. Whenever working with this mix or the microstars, I am sure to wear a quality face mask and rubber gloves.

**Warning:** The crackling formula is sensitive to impact and will explode from a moderate blow. Sensitivity varies and seems to be relative to the amount of metal powder in the formula; the larger the metal content, the more sensitive the mix seems. I always keep my test batches small, keeping in mind that *any* amount of this formula may detonate unconfined when ignited.

These microstars are commonly found in the Class C item "Dragon Eggs". A 1mm cube will explode with a sharp crack and flash shortly after lighting. A technical article discussing this phenomenon appeared in *Pyrotechnica XIII*.

Lead tetroxide	81.8%
Magnalium 50/50%, 100-200 mesh	9.1%
Copper Oxide	9.1%
Nitrocellulose lacquer (binder)	10.0% V

Lead tetroxide is red lead, also known as Minium. It is toxic, especially if the user should breathe or eat it. The copper oxide used is the black oxide. I purchased it at a ceramic supply store. Red (anhydrous) copper oxide also worked fine. The magnalium was 50/50% alloy, 100-200 mesh granular. I found that the atomized 50/50%, 200-400 mesh would also work well, but the finer the magnalium, the faster is the reaction to explosion. The N/C lacquer was 10% in acetone. Curiously, I found that the addition of some antimony sulfide or sulfur caused the microstars to flash brightly, but explosion did not occur.

To make the microstars, I use the smallest amount of the previous formula as possible, putting it in a paper container. Then while stirring with a wooden dowel, I slowly add enough N/C

lacquer to make the consistency similar to window putty. I then place it on a 3/16" screen, and using a pressing and scraping motion, pass it through. Many microstars will be formed, but since the mix is fairly wet, some big globs will also be present. I clean the residue from the screen, using a stiff brush. I wait about a minute and then push the composition through the screen again. This breaks up the lumps. I let them dry until hard. The microstars can now be mixed with some basic meal powder and ignited with visco fuse to test their crackling action.

To be useful, microstars must be sorted for size. I put the dry microstars onto a 30 mesh screen and sieve out the smaller ones. Retained on the screen are the larger ones. I take those that have passed through and put them through a 60 mesh screen. The ones retained on this screen are the small microstars. The material that passed through the screen can be used for sizzling comets or mixed together with a new batch of composition and recompounded. Both the large and small microstars can be used for crackling comets or for cores for cracker stars.

The basic comet formula is Shimizu's tigertail.

Potassium nitrate	44
Charcoal (airfloat)	44
Sulfur	6
Dextrin	6

For a bright gold comet I might add 10% extra titanium (40-100 mesh) or an extra 10% magnalium (atomized 200-400 mesh).

I weigh out 75% microstars and 25% comet formula and mix together. It always seems wrong, but since the microstars are heavy, this is the correct proportion. Taking care not to break up the microstars, I dampen with 50/50% alcohol/water and then press into comets.

To use the microstars for cracker cores for round stars, I roll the above basic comet formula with either the titanium or magnalium added around the microstars. To make into Dragon Eggs, I make the mix a little damper, form a small lump by hand, insert a piece of visco fuse and then let dry, then wrap it in a piece of aluminum foil. AK



## AQUEOUS BINDING OF SODIUM NITRATE STARS

Sodium nitrate is the most hygroscopic oxidizer of general use in fireworks. Consequently many pyrotechnists forgo its use entirely. Its occasional use is usually considered to be dependent on non-aqueous binding, to provide some degree of protection against moisture. While such considerations may be necessary in the commercial setting, the individual pyrotechnist living in a low humidity climate may have more choice in the matter.

The relative humidity above a saturated sodium nitrate solution, at 20°C at equilibrium, is 77% (Shidlovsky, 1964). Approximately, this means that when the ambient relative humidity exceeds 77%, sodium nitrate will begin to absorb moisture from the atmosphere. Conversely, when the ambient relative humidity is below 77%, sodium nitrate should cause no problem. The conditions of use in an unprotected situation therefore require that the ambient relative humidity not exceed 77%. While this condition is hard to meet in many parts of the world, the United States has several such areas. Table 1 lists selected U.S. cities wherein the average morning relative humidity of the most humid month is less than 75%. In such locations the use of unprotected sodium nitrate should be quite feasible. In addition, many places experience low humidity conditions for much of the year. For example, the average morning relative humidity in July (as in July 4th) in Salt Lake City is 52%. The average morning relative humidity in November (as in November 5th) in Los Angeles is 61%. Such possibilities are not limited only to the Western United States. For example, the average morning relative humidity in New York City in December (as in New Year's Eve) is 69%. Also bear in mind that heating a workplace in winter will decrease the relative humidity, while not affecting the dew point. In addition, the use of plastic shell casings helps keep the moisture level about the same as when sealed.

The use of sodium nitrate in stars with aqueous binding has a long history. For example, the amber star given in Table 2 is not original, but is of historic origin. It is simply the old 6:1:1

formula for gunpowder, with sodium nitrate replacing potassium nitrate, together with the addition of dextrin for binding. It is an example of an excellent colored star that would have been available prior to the introduction of chlorates to pyrotechnics. There is no problem with the preparation, storage, and use of these stars in a reasonably dry climate, such as in much of the Western U.S.

The replacement of charcoal with magnalium, together with the addition of parlon (which decreases continuous emission from metal oxides), and other minor adjustments, allows the production of analogous "brilliant" yellow stars, as in Table 2. Barium nitrate shifts the color more toward yellow from the amber produced by sodium nitrate alone.

Shidlovsky (1964) has warned about the mixture of sodium nitrate with aluminum: "The  $\text{NaNO}_3 + \text{Al}$  mixture has a low chemical stability and can be used only if it is effectively protected from atmospheric moisture by greasing additives or by sealing the product." Shimizu (1989) has found that magnalium is much less reactive than aluminum toward moist sodium nitrate. This is expected since the nitrate decomposition produces alkali, to which aluminum is sensitive, whereas magnalium is stable in this circumstance, being more prone to decomposition in an acidic environment. Therefore the addition of boric acid to our brilliant yellow should theoretically increase the hazard of decomposition, rather than decrease it as would have been the case with aluminum. In order to check this prediction we added 0.5g - 200 mesh magnalium to each of two petri dishes, one containing 20 ml saturated sodium nitrate solution, the other containing the same also saturated with boric acid. With the plain sodium nitrate solution the reaction was zero to barely perceptible. By contrast, when boric acid was also present, a vigorous effervescence together with an exothermic reaction immediately ensued. Consequently we do not add boric acid to such mixtures, and we consider the practice to be unduly hazardous.

*Continued on next page*

# **THE BEST OF AFN III**

A common test to differentiate between magnesium and aluminum is to subject the metal in question to a weak acid, such as acetic (white household vinegar), wherein aluminum has no reaction, magnalium a slow reaction, and magnesium a vigorous reaction. Note that magnesium is even more sensitive to decomposition in acidic media than is magnalium. Shimizu (1989) has demonstrated that boric acid promotes the aqueous decomposition of magnesium. Our experiments indicate that this is also true for magnalium.

Conclusions:

Sodium nitrate may be sensibly used in stars with aqueous binding, provided this is done in a climate of sufficiently low ambient humidity. Active metal fuel may be used in such stars, provided due thought is given to the nature of the reactivities involved.

Literature Cited:

Shidlovsky, A.A. 1964. *Principles of Pyrotechnics*, Third edition. English translation available from NTIS.

Shimizu, T. 1989. *Fireworks from a Physical Standpoint*, Part IV. English translation available from Pyrotechnica Publications.

**Table 1. Selected Low Humidity U.S. Cities**  
(Data from National Climatic Data Center, Ashville, NC)

City	State	Most Humid Month	Average Morning RH of this Month
Phoenix	AZ	December	67%
Tucson	AZ	August	65%
Yuma	AZ	December	59%
Colorado Springs	CO	August	69%
Denver	CO	May	70%
Pueblo	CO	November	73%
Billings	MT	June	71%
Great Falls	MT	June	69%
Helena	MT	November	74%
Eiy	NV	February	73%
Las Vegas	NV	December	55%
Albuquerque	NM	December	71%
El Paso	TX	September	66%
Cheyenne	WY	May	70%
Lander	WY	November	69%
Inyokern	CA	December	65%
Edwards AFB	CA	December	71%
Sandberg	CA	April	67%
Victorville	CA	January	65%

**Table 2. Star Formulations**

Ingredient	Amber	Brilliant Yellow
Sodium nitrate	73	55
Barium nitrate	-	5
Sulfur	12	10
Charcoal (Airfloat)	12	-
Magnalium (50:50, -200 mesh)	-	15
Parlon	-	15
Dextrin	3	+4

CJ-W&SM



## CUT STARS - - - WITHOUT CUTTING

In the past, the majority of stars I have made have been round stars. Though they have their merits, they are time consuming to make. This is especially true if you want to put together 100 or so 6-inch shells for a party out in the desert, as we frequently do out here in Las Vegas.

Lampblack stars in particular are absolutely no fun whatsoever to roll. The dry lampblack powder contaminates everything and eventually is tracked into your house by some means or other. Making cut lampblack stars presents new problems. Drying, is one, and the pasty goo that doesn't exactly cut the way it should, is another. Adding alcohol does speed drying to some extent, however adding more than 30% alcohol will affect the binding capacity of dextrin-bound stars. Of course, one could use 100% alcohol and replace the dextrin with red gum for binding.

**Enter the fluorescent light grid.** Sheets of plastic with various textures and levels of transparency are used to diffuse the light from fluorescent fixtures in suspended ceilings. One style is a grid with square holes that measure  $1/2 \times 1/2 \times 3/8$ " thick. These are available in almost all hardware or home improvement stores and come in sheets measuring two by four feet, for about \$4.00. Cutting one in half will give two 2-foot square sheets to use to make cut stars.

To make cut stars from these sheets, I start with the right putty knife, the kind used to spackle drywall with. There are two types: stiff and flexible. I have found that a 2-inch wide flexible one is perfect.

I lay some waxed paper on the table and put the grid on top. Then I mix up a batch of star comp, and moisten it to the consistency of a smooth plastic spackle. Using the putty knife, I simply push the comp, into, and spread it over, the plastic grid. Unlike cutting stars with a blade, the amount of water added is not critical. Adding too much water and attempting to cut with a knife can be messy.

When all the comp is pressed into the squares, I just flip the grid over and scrape any excess off. No composition is wasted, and any excess is pressed into another set of empty holes.

To dry the sheet I stand it up or hang it from some unused holes. Since each star is totally isolated from the next and air can get to both the top and bottom of each star, they will dry reasonably fast. When dry, I lay some newspaper on the table, hold the grid over it and most of the stars will just fall out. Others may be tapped out with a stick.

In determining what star comp, to use, I keep in mind that it must *shrink when dry*. If it doesn't the stars will never come out of the grid.

I also keep in mind that a  $1/2$ " star is too large for slow burning colored stars, but faster burning types work quite well. The table shows the lampblack comp. I use.

### LAMPBLACK STAR COMP.

Homemade meal powder	396 g
Lampblack	138 g
Sulfur	48 g
Dextrin	18 g

Mix is wet with  $1/2$  water &  $1/2$  isopropyl alcohol (drugstore variety).

Other compositions will work, but this one is the one I use most often. I allow these stars to dry for 3 - 4 days before removing them, and another couple to dry completely. BL

[Editor's note: This light grid system is similar to the old industrial star plate method that is described in the text books. With these plastic grids, it's unnecessary to invest a couple of hundred bucks in aluminum or brass star plate sets.

So are these cut stars or pressed stars? Of course they are pressed, but the resulting star is square, not pill shaped, and thus offers those nice, sharp edges that make for easy ignition.

It's not often that star makers will attempt to press lampblack stars, but the author seems to have hit upon a neat solution. The comp he uses is fast and easy lighting, and must have a great hang time in the air. Few effects can beat a well made lampblack star and this method is certainly worth the learning process. Lampblack takes water reluctantly, and the alcohol will make the difference.]



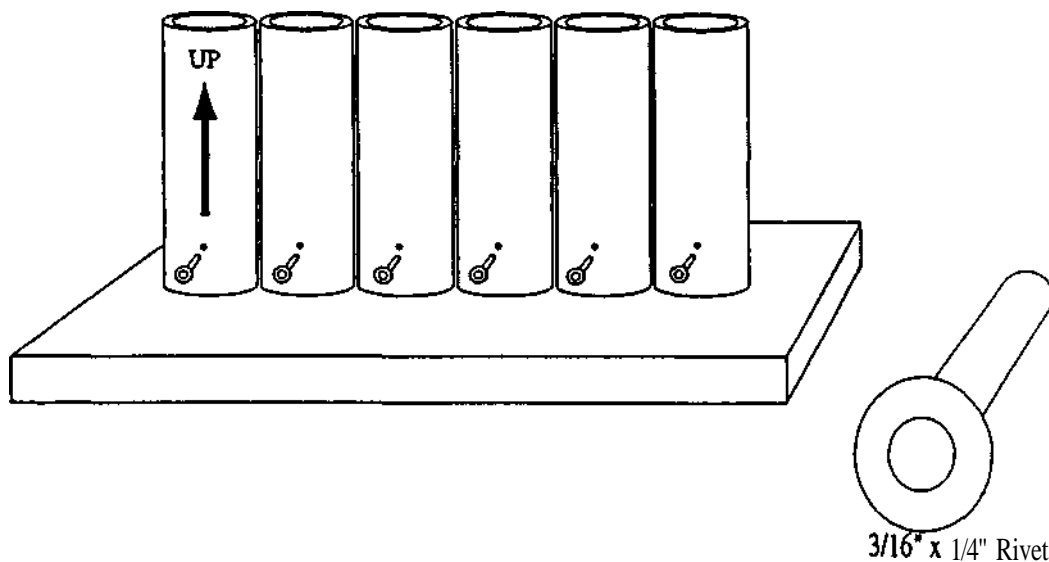
## LONG LASTING PAPER MORTARS

I like to test my new stars by shooting a few into the air to see how they work. This can use up a lot of test mortars, as the fuse hole in the tube grows with each star launched and in a short time the hole is so large that the fuse will fall out. One day I was working with some pop rivets and saw that the rivet part would make a fine fuse hole protector for a paper tube. By taking out the pin part of a 3/16" by 1/4" rivet I was left with a fine hole protector. I plug the tubes with clay or wood and attach to a base of choice. I use a liberal amount of hot-melt for the attachment. The paper tube gets a hole that is slightly undersized for the rivet head so that when it is forced into the tube it will stay. Now I have a recyclable fuse hole that will last much longer than the paper mortar.

To solve the second problem of tube burnout, I mix graphite with lacquer to make a non-burnable coating that is easy to apply and works

well. The proportions of graphite to lacquer are very forgiving. I add several spoonfuls of graphite to a cup or so of lacquer, varathane, urethane, etc. in a can that is labeled mortar coating, shake it up, and pour it into a tube. I am sure to plug the fuse hole with plasticine clay or hold my finger over it to keep the coating in the tube. Now I cover the top of the mortar with a paper disc, hold tightly, and shake or invert several times to coat the inside of the tube. When coated, I empty the excess into a paper cup, original container, or pour into the next tube.

I have done this coating process with all my paper mortars; even the 6" tubes for shells. The graphite-lacquer coating is very fireproof and can extend the life of the tube by forty or more times! This will even work on extending the life of spiral wound tubes. The coating in the small tubes will also help hold in the fuse hole protectors. Now I can make stars instead of replacing tubes! DA





## VISCO TIME-FUSE EXPEDIENT FOR CLASS C

The examination of almost any domestic Class-C aerial shell tube item will show a piece of visco-type safety fuse used as the timing element in the shell. In some cases two pieces are used, no doubt for double dependability. Although visco fuse is adequate for most purposes in commercial fireworks, it has two characteristics that make it difficult to use for precise timing. These characteristics are side-spit and side-ignition.

Side-spit is the spit of the flame through the side of the fuse. It is the burning through of the sidewall of the fuse by the flame front as it progresses down the length of the fuse. Side-spit is essential for lighting difficult-to-ignite compounds such as smoke mixtures.

Side-ignition is the sensitivity of the fuse to ignition through the sidewall rather than the end. It is considered a bad characteristic when fuse is too sensitive to side-ignition. The Consumer Product Safety Commission considers side-ignition a safety hazard and has established criteria for side-ignition by stating that coated (visco) fuse must be able to withstand the glowing end of a cigarette touching the side of the fuse for a specified period of time without igniting the fuse.

Although various makes of fuse burn at different rates, most burn 30 - 45 seconds per foot. This means that a portion of the fuse will be either inside or outside the casing of the shell, and only a small section will be covered where it passes through the shell wall. The flash of the lift charge is supposed to light the end of the fuse, but if side-ignition occurs close to the casing the timing will be spoiled. Also, if side-spit occurs on the portion of the fuse inside the shell, premature ignition will result.

Time fuse, as used in display shells, is constructed in such a way that it produces absolutely no side-spit and is totally immune to side-ignition. Down the center of the fuse is a fairly small core of powder - small in relation to the diameter of the fuse. Around this core of powder are spun one or more layers of cotton or jute twine, then a thick layer of tar, another layer or

two of twine and, in some cases, more tar, then a final wrap of gauze tape finished with a coating of sizing and white clay, or even an extruded plastic jacket.

The tar performs valuable functions, only the least of which is to waterproof the fuse. It completely covers the core so as to prevent side-spit and side-ignition. Just as important, however, is the fact that as the fuse burns, the tar softens, expands and melts, allowing the hot combustion gases to escape readily into the atmosphere. Without this venting quality the gases would build up pressure, expand the core, shoot through, much as in quickmatch, and destroy the effectiveness of the timing.

A slow-burning powder is also essential for consistent results in time-fuse. A powder that burns too fast can also cause pressure build-up. Fuse powders are either special grained powders made with a high ratio of potassium nitrate or a reduced ratio of charcoal, or a mixture of fine-grain powder and other mixed ingredients to slow the burning rate of the black powder. The homogeneous special fuse powders are preferred by blasting-fuse manufacturers, for there is no chance of erratic results resulting from segregation (separating of the ingredients) or mixing errors. Although visco fuse is designed for a specific use, which is the primary ignition of commercial fireworks, it can be used for timing purposes if its characteristics are modified to eliminate side-spit and side-ignition. This can be accomplished as follows:

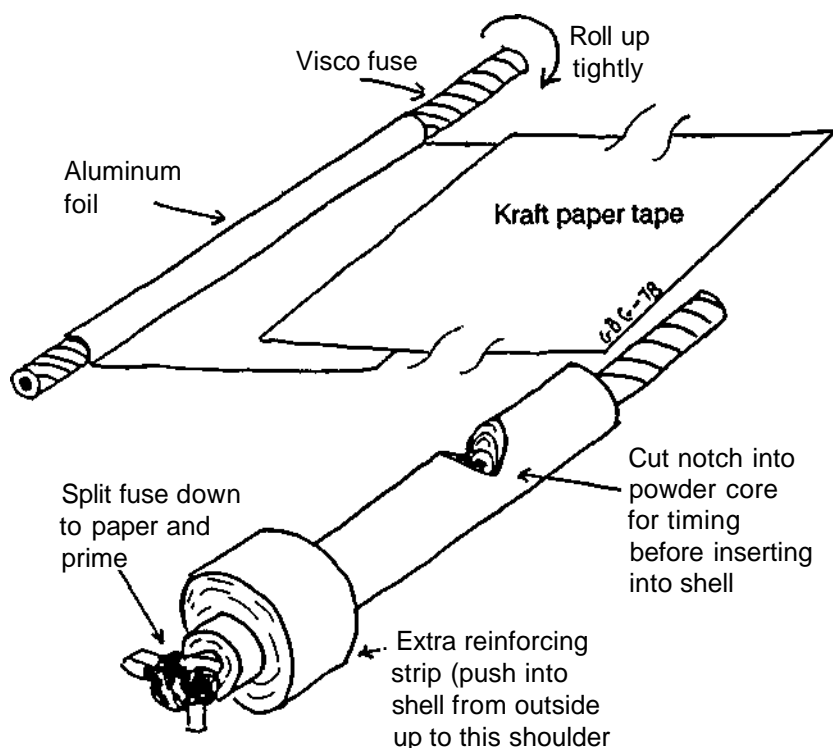
### MATERIALS:

1. Visco fuse, maximum diameter .115 inch (7/64"), burning time, 30-45 seconds per foot, cut into 2 1/2" lengths
2. Lightweight aluminum foil cut into 1 1/2 x 3" strips
3. Kraft paper strips of same dimensions as the aluminum strips

I wind a strip of aluminum foil tightly around a length of pre-cut fuse. I spread adhesive on one of



## THE BEST OF AFN III



the kraft strips, then interleave the first half-inch of it into the last wrap of the foil and wind the rest of the strip up tightly around it and allow to dry.

The function of the aluminum foil is to conform to the irregular exterior of the fuse and so block the flow of gases. 3" gummed paper tape is excellent for the outer wrap and need only be moistened with water, eliminating the use of paste or glue, serving as a binder and providing a good gluing surface for attachment to the shell. Masking tape can also be used, but moistened paper tape shrinks as it dries, which further compresses the foil around the fuse.

After drying, I test a dozen or so of the wrapped fuses, which should burn evenly from end to end when lit, without popping or blowing through. If such malfunction occurs, it is because the fuse is too "hot" - that is, too fast-burning or having too

large a powder core. Note again that fuse with a burning-time of 30-45 seconds per foot is required; if a foot of it burns in only 25-30 seconds, it will not be satisfactory.

I wrap a 3/8" x 3" strip around the end as a reinforcement and gluing-stop for attachment to the shell casing. I split the stub end of the fuse at this end down to the paper wrapping, dip in priming-paste and then in grain powder for positive ignition by the lift charge. For timing, a notch is cut through the paper wrapping and into the powder core at a point experimentally determined to give the desired delay. This should be approximately:

Small shells - 2 to 3 seconds

3" to 6" shells - 4 to 5 seconds

Breaks - 1 to 2 seconds

I punch a hole in the shell just large enough to accept the wrapped fuse but not the reinforced end, which should be securely glued to the casing as the fuse is inserted from the outside. On the inside, I slip a piece of piped match over the notched end and lead it to the center of the shell, securing it with glue.

Note: I do not cut off the stub end of the fuse extending beyond the notch, as this can provide a second-chance source of ignition if the match should fail to take fire from the side-spit at the notch.

I have used several dozen of these assemblies and have yet to have a misfire. I would, however, stick to regular time-fuse or spolettes for the main fuse in large shells and reserve the "Visco Expedient Time-Fuse" for breaks and Class-C shells. GBG

## SHRINK THAT VISCO FOR TIME

My last order for materials contained a quantity of #100 spherical plastic shell casings. Upon their inspection I noticed that the fuse hole was a small 3/32" diameter - oops! I had planned to order these casings with a fuse hole size to accept 1/4" Jap time fuse. OK, so I checked the order blank and sure enough, my mistake! I can't exchange them because that would be admitting to a real dumb mistake...well, you know. An anonymous call to the supplier confirmed that this size hold was for visco fuse.

Upon closer inspection of these shells I found that if I simply hot glued visco through the fuse hole, which is a collar of Vi-inch long, the delay could be between only 1 or 2 seconds. A trial shell was made up and sure enough, it timed to a delay of 1.2 seconds. This was not enough delay to allow the bursting height that I like to attain. So my "there has got to be a better way" mentality went to work!

My stock of visco fuse has grown recently due to my "get it while you can" reaction to the shipping situation scare, and because of a great deal on "3/32" cannon fuse" (excellent quality visco) available from The Sportsman Paradise Co. (1-800-888-3006), part #R6-7948. There were also some good deals at the Summer fireworks Festival last summer. This was a good chance to use up my overstock of fuse.

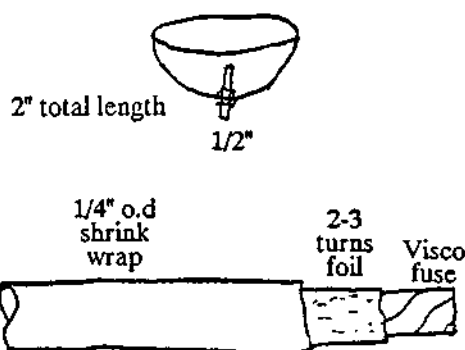
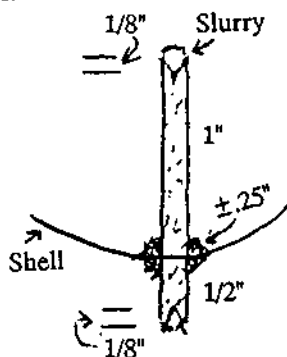
I had to find a way to make a good time fuse using the visco that I had. I did read the "Visco

Time Fuse Expedient for Class C" article on page 41 of *The Best of AFN II*, and I knew that, if properly prepared, visco would time very well. I wanted to achieve this without a great deal of rolling and gluing. The key is to eliminate side-spit and side-ignition. The fuse must also have a covering that will remain intact to keep the fuse in place as it burns through the shell wall and supporting adhesive. The light went off! Ah ha! How about shrink wrap tubing - the stuff that we use to re-insulate electrical wiring connections? I was off to the races.

I had some 1/4" o.d. shrink tubing from Radio Shack left over from a past project, and it fit perfectly. I shrank some over a 6" length of visco and lit it. The fuse burned right through the tubing, so I tried another piece but added three turns of aluminum foil and then put the shrink tubing on. This worked great. Close inspection revealed that the foil moulded right to the rough surface of the fuse and the shrink tube tightened right around the fuse and foil to form quite a consolidated piece of work. It looked great, was easy to make, and one could make and cut a bunch of measured fuses accurately and quickly. Now to try them.

My first concern was to see if the outside of this time fuse would heat up enough to ignite any comp that it was exposed to before reaching the end burn. I poked a hole all the way through a %" i.d. cardboard tube and then hot glued a piece of this fuse through the tube. I cut off the tube W

TIME:  
4 sec.



# THE BEST OF AFN III

below and 1/2" above the fuse, filled the tube with Meal D, and taped the ends. As I expected, the fuse burned right through without igniting the powder. Then I enlarged the 3/32" hold in three of my plastic shells and hot glued fuses in place. I put fillets of hot glue on both sides of the fuse hole. The fuses held solidly in place, enough to withstand a substantial lift charge. On two of these shells I coated the internal part of the fuse, which was 2" long, with a meal powder-N/C slurry, and after drying, they also failed to ignite the coating while burning through. The fuses were not held as firmly in place after this test due to the softening of the hot glue during burn through. A different glue might be used to overcome this.

The last shell was set up with a total fuse length of 2", with 1/2" outside the shell and the remaining 1/2" inside. I split each end with a razor blade

and dipped them into meal/NC slurry. Later, after lighting, the total delay was found to be 4 seconds. The assembly worked fine. Time tests for this fuse were as follows:

1" - 2.4 seconds

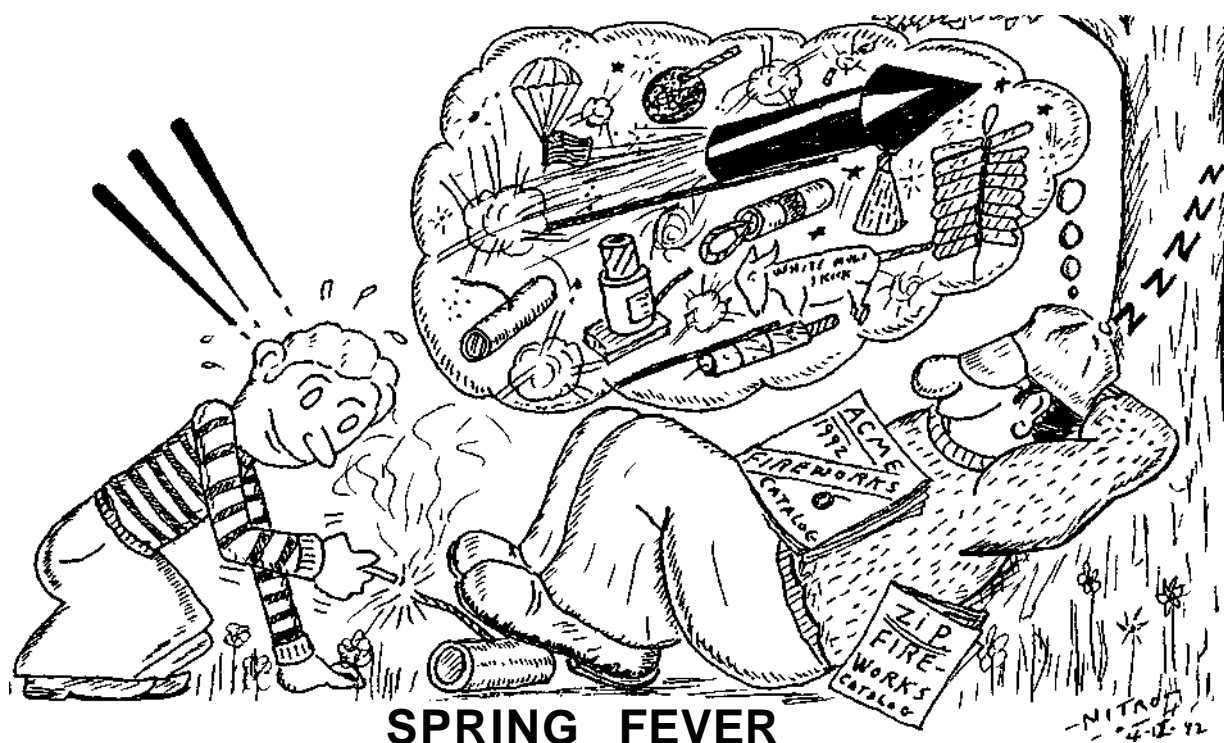
2" - 4.0 seconds

4" - 8.5 seconds

Average burn time: 7 inches divided by 14.9 seconds - 2.13 seconds. Not bad!

Then I made up three simple #100 star shells using 1.75" lengths of my new time fuse. The shells performed perfectly, with no misfires or duds. Further testing is in the works. I now have a number of different time length fuses on the shelf, ready for use. I hope to hear from other pyros who have found a use for this technique.

WGF





## VISCO TIME FUSE

When I first started building aerial shells, I didn't have access to the standard 1/4" or 3/8" time fuse used as the delay for the projected shell. Visco fuse was abundant though and so I developed a process for using it as a substitute for those fuses.

Visco fuse has a fairly reliable burn rate, but it may vary from batch to batch and manufacturer to manufacturer. Because of this, it is important to purchase only high quality visco fuse and to test it often. Once a suitable type/brand has been found, I would stick to that type/brand, at least when making substitutes for time fuse. Furthermore, I would fuse only small shells with visco, with the exception that no aerial salutes of any size would be.

Aside from the above, the only other problem with using visco as a time fuse is its side-spit. This can be overcome by enclosing the fuse with some type of fire-proof covering. The covering should adhere very tightly to the fuse, otherwise the air gap between the fuse and its covering will only serve (like quickmatch piping) to accelerate the burn rate of the fuse. The possibilities for covering the fuse are virtually endless, but what works for me is foil-backed duct tape. The type of foil-backed duct tape I use is designed to protect automobile engine wiring harnesses from high heat conditions. It is distributed by General Motors and the part number is 10184916. However, a suitable substitute could probably be found at a large hardware store.

The tape comes in rolls 2" wide, so I begin by cutting the number of time fuses I need in 2" lengths. A 6" piece of duct tape is removed from the roll and I carefully roll up one piece of fuse in it. The visco has a rather irregular surface and so the tape tends to spiral off to one end.

This is of little consequence as the ends will be trimmed later. It is important though that the tape be rolled very tightly onto the visco. There should be no air gaps or pockets. Once rolled, I further consolidate the tape by rolling it back and forth under pressure between my hands or between two hard surfaces. The end result should be a stiff, dense roll of about 1/4" diameter.

The burn rate of the visco in use will dictate how much of the 2" piece should be trimmed. The visco I am currently using burns at about .43" per second. So, for a 3 second delay I cut the 2" piece down to about 1.3"-1.5". This cut should be made at an angle. This will expose a large cross section of the powder core. This end, when assembled, faces the lift charge and ensures ignition of the fuse. The other end does not need to be trimmed in this fashion, as the visco produces a good "squirt" of flame when it reaches the end, reliably igniting standard burst charges.

I have used the above process for converting visco into time fuse and have found the success rate to be 100% so far. The visco possesses a number of qualities desirable for a shell time fuse, the most notable being its large powder core. This is easily ignited (without priming) by the lift gases and easily ignites (again, without priming), the burst charge. When it is attached to the end disc it should be done so with a synthetic type glue, as Elmers or other water based glues may not stick well to the foil covering. At any rate, if it is allowed to protrude 1/2" - 3/4" from the top of the end disc, it will provide a sturdy point to tie and pivot the spiking onto. Credit for a similar idea for using visco as a time fuse, which was written previous to this article, goes to GG, whose article appeared in *The Best of AFN II* on pages 41-42. SAR

# THE BEST OF AFN III

## ARE YOUR READY BOXES READY?

Ironically, one of the last things pyrotechnicians think about is their ready boxes. Too often the trash can is emptied, hosed out and pressed into service at the last minute.

While many shows, especially the large scale performances, are now fired electronically, most are still done the traditional way with load, fire, reload, fire, reload, fire... For many budgets and even some locations, it's not practical to have all the hardware required. Even in big shows, often the larger caliber shells are still handfired.

The purpose of the ready box is simply to hold the aerial shells close enough to the firing line they serve so reloading is easy; at the same time it protects the shells from the elements and any debris from all the firing lines and other devices.

The process generally begins with shells being unpacked and the match carefully unwrapped. Everything is checked for any cracks, tears or leaks, sorted according to the plan and then placed in the ready boxes. The cardboard packing box the shells come in is the poorest ready box of all. Since the loaded ready boxes may sit around for hours before showtime, cardboard is especially vulnerable to moisture or any errant spark or flame.

Many operators place a canvas tarp under and over them, which is certainly an improvement. But that makes it harder to get in and out of and creates the tendency to have it open more often and longer. Ready boxes should only be open when the line in front is not being fired and it is time to reload!

Too often loaders, especially inexperienced ones, are so caught up in the excitement of the show that they rummage around the box looking for "the right one" while sparks fly around them, or they stand there with the shells unprotected in their hands. Hello there, St. Peter!

Garbage cans are popular because they are cheap, readily available and when the show is over, can be used for something else. They are

improvements over cardboard but present other problems. They are deeper than they are wide, so the tendency is to fill them up. That places a lot of shells in one place at one time and often all jumbled together randomly too.

That presents greater risks in the event of a problem and fewer boxes attracts a crowd of anxious reloaders, all jostling to get their shells. That's when the safety caps come off or the match gets torn.

Any metal can presents a serious shrapnel problem. Plastic ones are somewhat safer in that regard, but they won't stop a mag star that hits it from burning through. The biggest problem with a garbage can is the lid. In order to open it and reach all the way in, it has to be wide open. That increases the chances of loose sparks or ash, possibly even ones not visible to the eye, to drop in uninvited and.....

Again, a canvas tarp helps reduce some of these risks, but that adds to the difficulty in reaching in. And a fully loaded, tarped can is hard to move quickly if the wind shifts suddenly!

The next method, and the preferred one, is to make wooden boxes specifically to be used as ready boxes. You want plenty of them so only one or two loaders are working from each box so they don't get in each other's way.

The best ones I've seen are made out of floor grade 3/4" plywood and are 24" wide, 36" long and 16" tall. They'll hold 12" shells easily. Each is glued together with a floor adhesive and clamped tight so there are no gaps and no nails or screws. It has rope handles on all four sides, so no matter what the angle, you have something to grab so you can move it in a hurry, even by yourself.

The lid is larger than the bottom so there is a 2" overhang all the way around. There are no metal hinges, only five rope strands through the back and into the lid.

A heavy canvas flap is attached to both sides and



the back so when you open it, they are protected. This also prevents it from opening too far and unless you hold it open, it will slam shut quickly.

A new type of ready box is those stackable, plastic storage and recycling bins with lids. They come in many sizes, usually with two lids, one flat on the top and the other at a handy angle for reaching into.

The best are made of our favorite material, High Density Polyethylene (HDPE). You can check for it by looking for the recycling seal. Avoid Low Density Polyethylene (LDPE) or polypropylene (PP) as they aren't as sturdy or resistant to cold weather or abuse and are more likely to let a large spark or star melt through.

With a canvas tarp over and a string tied to the lid so it can't flop open all the way, it makes a quick, light and inexpensive ready box that doubles as a place to put other things in later.

No matter what you use, a couple of chemical light sticks inside will help you see inside without blinding you in the night. Always stack the shells neatly with only one size to a box, have a tender there to manage it so it can be moved quickly and he/she can supervise the loaders, and keep it covered at all times!

One last tip: Just because the firing line is in front of the box, swirling winds above can bring things down from behind. That's why you never want that lid open any more often or longer than you have to! CPW

## CHEAP TOOL AIDS LANCE ASSEMBLY

The lance nail tool is relatively easy to assemble and has many advantages.

It's cheap and can be assembled for under \$2.00, making it available to everyone's tool box. It's easily portable, can be color coded to clarify ownership, keeps lance nails right with your work because it's magnetized, and is easy to use.

Inserting lance nails on the frame in the ship with a hammer is most difficult. In the field, sometimes it get impossible. With this tool, it's even *easy* to install the lance nail when the frame is in an upright position leaning against something, or if re-lancing a set piece and some of your old nails have become rusty or broken off. It's a simple job.

The materials required are:

- 1 - 16d double-headed nail (such as a scaffold nail)
- 2 - Magnets (such as from Radio Shack at 230 each)
- 1 - 4 1/2" long section of mop or broom handle
- 1 - Bicycle handlebar grip

The key component is the double-headed nail which acts to hold your lance nail and must be have a suitable hole drilled into it. This is best done by making a simple jig to hold the nail while it is being drilled. Take a small 2x4" wooden block and drill a 5/32" hole through it, then drive the double-headed nail into the hole. This simple jig will hold the nail tightly enough to keep it from spinning while it is being drilled.

Next, switch to a 1/4" drill and drill into the top of the nailhead only enough to form a funnel-shaped cavity. This will act as a guide for inserting your lance nail when the tool is being used.

Then switch to a 5/64" drill and drill into the funnel to a depth of about 11/16". This will leave about 5/16" of the lance nail exposed for penetration into the rattan or wood. Deeper or shallower depths can be made to accommodate different



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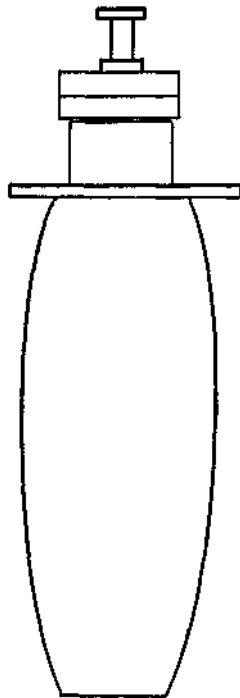


size lance nails, if you are ever using other than the standard 1" nail.

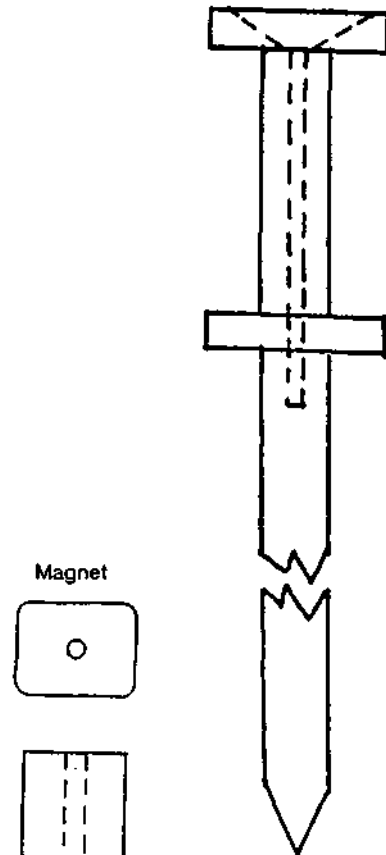
Next, cut a section of broom handle  $4\frac{1}{2}$ " long. Then drill the center, using a  $\frac{5}{32}$ " drill for a tight fit or  $\frac{11}{16}$ " which will require a little glue.

Slip two magnets (found at Radio Shack) onto the double-headed nail and then insert the nail into the broom handle. Depending upon how deep the hole is drilled and which size drill you used, you may find it necessary to turn everything upside down and tap it with a hammer until the magnets are flush to the top of the handle.

To make the tool easier on the hands, insert the wood handle into a bicycle handlebar grip, using furniture polish on the handle and inside the handle grip for ease of installation.



Completed Lance  
Nail Pusher  
showing double-headed nail,  
2 magnets, bicycle handle  
bar grip in place.



16d double-headed  
Scaffold Nail  
Drawn 3 x actual size.

Broom or  
Mop Handle  
 $4\frac{1}{2}$ " long.

Different colored grips may be used to either designate the depth of the tool, or to clarify individual ownership.

The tool is magnetized and will pick up a considerable number of lance nails, making them readily available for insertion into the tool. RFC





## ALTERNATIVE CORES FOR BURST CHARGE IN ROUND SHELLS

Rice hulls. How many times have you seen this item mentioned in the pyro literature? Often, right? But how often have you seen this material available at your local store for a reasonable price? If you are like most American pyros, you probably had to request them as packing material from KSI, Inc., to see for the first time what a rice hull looked like. And when you finally opened the box..oh the mess!

A simple fact of life is that most pyros look for the cheapest materials capable of producing the desired effects. When it comes to chemicals, it is difficult to substitute one chemical for another without changing the effect (e.g., color, intensity, burn time, etc.) in some manner, so most pyros are on common ground. But when it comes to other materials used in the pyro trade (e.g., papers, fillers, glues, string, etc.) numerous materials can be used to achieve the same effects. More times than not, the ultimate choice of material is based on local economic considerations. As time marches on, some of these materials are eventually elevated to the same status as chemicals.

The rice hull is a classic example of a replaceable material which has been elevated to practically the same level as an essential chemical. I have never understood the almost religious devotion to rice hulls as cores for burst charge in small to medium size shells because there are plenty of substitute materials available. Prompted by CTB's plea for a rice hull alternative (AFN, April 1994), below is strategy by which I replaced rice hulls (and cotton seeds) with a more readily available local material - vermiculite.

The key to replacing any core material for burst compositions without extensive trial-and-error testing is to understand the role of the core. Excellent discussions concerning this topic are already available from a number of sources<sup>1,2</sup>, but it is useful to summarize the features desirable in a core. The ideal core should be lightweight, roughly spherical, and relatively nonporous. It should have a relatively uniform size distribution

and it should hold the burst composition well. It should not burn or allow fire to remain in it after the explosion. And ideally, it should be both cheap (i.e., free) and biodegradable. A number of materials are mentioned as cores by Shimizu, but rice hulls and cotton seeds are the materials most often mentioned in the pyro literature.

But what if you don't live near a rice paddy or a cotton plantation and you instead have a virtually inexhaustible supply of some other potentially useful core material? How can this material be made to work without building zillions of test shells? I was faced with this situation several years ago. I had no idea where to get rice hulls or cotton seeds locally, but I did have free access to huge amounts of vermiculite. The "rice hull problem" would be solved forever if I could just find a way to use vermiculite.

Vermiculite is a very common packing material in the retail chemical business. It comes in nearly every shape and size, ranging from fine particles to large (1/4 x 3/4 x 3/4") chunks. The most common material consists of irregularly shaped chunks which usually pass through 3x3 hardware cloth but are retained on 4x4 hardware cloth. This material is too large for use as a burst core in small shells, but it can be broken up by a variety of methods. In my case, I just wait for a box of the finely granulated stuff to appear from time to time. In either case, vermiculite should be sieved before using. Particles which pass through a 4 mm wire mesh and are retained on a 2 mm mesh are best suited for small shells. Particles which pass through 4x4 hardware cloth and are retained on a 4 mm mesh are good substitutes for cotton seeds in larger shells.

The apparent density of loosely packed 2-4 mm particles of vermiculite is 0.194 g/cc, which is significantly greater than the apparent density of the rice hulls I obtained from KSI (0.126 g/cc). This means that each gram of vermiculite has fewer particles than each gram of rice hulls. If the same weight ratio of burst comp-to-core is used to make burst charge, this means each par-

ticle of vermiculite will be coated with more material. The consequences of simply substituting vermiculite for rice hulls without making any other changes are predictable: burst comp is wasted and shells break much too hard.

The key to using vermiculite or any other core material in the place of rice hulls is to make sure that the core material is coated with the "normal" amount of burst charge. This can be done by trial and error, but it is much easier to use Equation 1. The derivation of this simple equation is outside the scope of this article, but this equation should hold for any burst composition coated on nearly any nonporous core.

$$\text{Equation 1: } R_2 = (d_1/d_2) \times R_1$$

where  $d_1$  and  $d_2$  are the densities of core materials #1 and #2, and  $R_1$  and  $R_2$  are the weight ratios of burst comp-to-core used with each core material.

Using this equation is simple:

(1) Calculate the apparent density of core material #1 (e.g., rice hulls) and the apparent density of core material #2 (i.e., the new core material). This can be easily accomplished by determining the weight of cores in one level 8 oz cup of loosely packed cores; the density (in g/cc) is the weight in grams divided by 227.

(2) Calculate the necessary ratio of burst comp-to-core using Equation 1.

(3) Make up your favorite burst charge with your new core material and construct your shells using your standard procedures.

A few minor adjustments will probably have to be made later, such as adding or subtracting a layer or two of paste wrap or changing the burst comp-to-core ratio slightly, but if everything is done properly the new burst charge should perform nearly as well as the old burst charge. This is because the amount of burst composition provided by the new burst charge should be close to the amount provided by the old burst charge.

Before discovering vermiculite, my favorite burst charge for 4" round shells (paper hemis) was

4.5:1 H3 on rice hulls. Using Equation 1 with  $d_1 = 0.126$  g/cc for rice hulls,  $d_2 = 0.194$  g/cc for vermiculite and  $R_1 = 4.5$  for H3 on hulls,  $R_2$  was calculated to be 2.92. I therefore tried using 3:1 H3 on vermiculite to break my 4" shells. To be perfectly honest, the results were not quite as good as 4.5:1 H3 on rice hulls, but it was nothing that two more layers of 50# kraft paper couldn't cure. I now use 3:1 H3 on 2-4 mm vermiculite to break all of my 4" round shells.

I have not experimented with many other core materials, but I suspect that almost any lightweight, nonporous material could be put to good use as a core for burst charge, provided that the burst comp-to-core ratio was properly adjusted. The reason for this optimism stems from a quick analysis of other burst charges reported in the literature. Consider, for example, the compositions listed in Table 21 of Shimizu's book.<sup>1</sup> Rice chaff, cotton seeds, and cork pieces are listed as core materials for shells 5" and bigger, but the burst comp-to-core ratios vary widely. In the case of rice hulls, a 5:1 ratio is needed to accomplish what cotton seeds can do with a 1.4:1 ratio. The ratio for cork pieces is even larger (7:1). Why? The reason is simple if we use Equation 1.

The apparent density of rice hulls is 0.126 g/cc. The density of cotton seeds is approximately 0.45 g/cc.<sup>3</sup> I don't know the density of Shimizu's cork pieces, but the apparent density of finely chopped corks from several wine bottles was approximately 0.1 g/cc. If we use 5:1 rice hulls as the reference point, Equation 1 predicts that the burst comp-to-core ratio for cotton seeds and cork pieces should be 1.4:1 and 6.3:1, respectively. Considering the number of variables involved, the agreement between the calculated ratios and those listed by Shimizu is remarkable.

## References:

1. T. Shimizu, *Fireworks: The Art, Science & Technique, 2nd Ed.* Pyrotechnica Publications, Austin, TX, 1988, pp 207-14.
2. D. Bleser in *The Best of AFN II*, American Fireworks News, Dingmans Ferry, PA, 1990, pp 122-3.
3. Reference 1, pi77. FJF

## MR. CHEAPO AND HIS USED VERMICULITE

I read with great interest the article about "Alternative Core Material". For several years I had wondered if and how vermiculite could be useful. I never thought about using it as core material, but considered it only as a replacement for sawdust in an inert capacity. However, if it works, it's a nice and welcome suggestion.

The reason I never used it was because at that time large and cheap (free!) quantities were available only as used filling material for liquid laboratory chemical bottles. This used material coming from cardboard or wooden boxes is definitely NOT clean, and it may even be hazardous to use because frequently spilled acid and other aggressive chemicals are absorbed and are unnoticed. I presume the author is referring to clean and fresh vermiculite only, and not the waste laboratory product.

Clean vermiculite will probably not be found in giant heaps for free, but rather in closed 40-gal. polyethylene sacks or bags with the brand name on it. And you probably will have to pay for it. But it's better to pay for clean ... than not pay ... by Mr. Cheapo ... who has never since been seen.

RP



CHARGING SHELLS

## ANOTHER CORE FOR ROUND STARS

This article is for the hobbyist - for he alone has the time/patience to do this. We've all heard of the various materials to use for cores to roll stars., i.e., lead shot (my favorite), bird seed, tapioca pearls, micro stars, sand, water droplets, and a new one, molecular sieves. This article is a twist on the micro star.

This year I was introduced to a new consumer item called "Crackling Whip" (Magic Whips). When unrolled, you have a narrow ribbon approximately nine-feet long with a piece of visco at one end. Upon lighting the visco you get treated to 3,000 shots (pops), nothing to scream about, but neat. Well, my first whip stopped shooting after about three feet and, of course, we must investigate what, why and how these things work. What I found was a narrow (3/8") strip of tape with an adhesive on one side and on this adhesive 1/8" round particles, 3,000 of them (that's what the label said), and a piece of twisted paper fuse running the full nine feet. They looked so round and uniform in size that I thought maybe they could be used for cores (crackling).

First, the red tissue paper covering the tape needs to be removed. This is done pretty easily by using/pulling on the paper fuse to cut through the red tissue. Then, by using my fingers, I gently roll the tiny cores off the adhesive tape. Again, the label says 3,000, but when finished, it feels like a zillion. Because some of the cores retain a small amount of adhesive, I thought it would cause a problem. Not so when a 50:50 water: alcohol solution is used to mist the cores. It seems to me that the alcohol causes the adhesive to dissolve, but I'm not sure. Anyway, I did not have any problems rolling them with my star composition. OA



## MAKING QUICKMATCH

Three plastic buckets are needed. For bucket #1 I weigh out 12 lbs. of potassium nitrate, screen with a 16 mesh screen and pour into the bucket. In bucket #2 I weigh 4 lbs. of sulfur and screen empty into the bucket. In bucket #3 I screen 8 lbs. of charcoal dust. The three buckets then are taken to the mixing/milling machine where bucket #1 is poured into the machine, along with 1 pint of water. Then the contents of the other two buckets are added. Next a bowling ball and a bocci ball are put in, the stainless steel cover is locked on, the operator leaves the building and locks the door behind him, then turns the power on from outside.

During this time, additional preparations are accomplished. From the black powder magazine, a 25-lb. bag of GOEX meal D black powder is withdrawn, and a suitable subtraction is made in the inventory log for the BATF inspector. From this point on, all quickmatch is made outdoors, in a 20x20-foot shelter with roof and three sides.

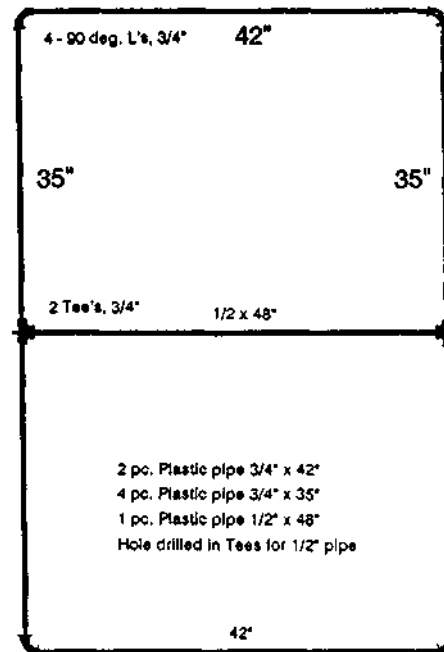
For the next steps I will need the winding frame, and my black powder slurry tank with rollers to pull the string through. I'll use 10 cones of #2 or #3 string, and my dusting box.

After the powder has been milled for two hours I remove the comp and store it in a stainless steel tub. Then I put 7 lbs. into the mixer, along with 25 lbs. of meal D, 1 lb. of dextrin and 1 lb. of starch. After locking the cover on, I'll mix for 15 - 20 minutes.

Then the powder goes into a stainless tub and water is added, mixed with a long handled spatula. Whenever my grandson or one of the workers helps me, they always ask how I know when the powder is the right consistency. My answer is that it comes with experience, but here's a trick. I use an old tea cup, fill it with slurry, and then pour it back into the tub, holding it about 15" high. If it flows freely, it's ready to use. If it is still thick, I'd add more water and stir.

With the string and powder in the string tank (see previous article), I will pull and run the

### QUICKMATCH WINDING FRAME



string (actually, now it's fuse) on 4x6' frame. The frame can take about 105-108 strands. I am careful not to pull the powder off the string when running it onto the frame. When the frame is full with strands, I will place the frame in a dusting box, add two scoops of homemade mill powder, place the cover on the box and then turn it 4 or 5 times. Then I remove the frame and hang it out to dry.

Climate has a lot to do with making quickmatch outdoors. I would never make fuse if the humidity is above 58%, and the temperature above 83°. I would wait for a clear, dry day, with wind, low humidity, and warm.

After the quickmatch job was finished, there would always be a small amount of black powder left in the tub. I would wash out all the equipment and pour out the water in the tub. I would dump the powder from the dusting box, add two more scoops of homemade powder to the water. I would then fill a bucket with rice hulls and mix in the tub of black powder a little at a time, mixing by hand, then placing on a screen to dry. I would use this as a filler for making shells. LJS

## SPlicing PIPed MATCH

When preparing set pieces for a display, the most often-repeated operation is that of joining two pieces of piped match to convey fire from one to the other. Thus, it is one of the first skills the prospective fireworker should learn. Unfortunately, the literature has few, if any, exact descriptions of how this important operation should be done, and the beginner must first learn it on the job. It is hoped that the following instructions will help in preparing him to make fail-safe splices quickly and efficiently at his first display.

Joining Piped match, hereafter referred to under the more commonly-used term "match", divides into two categories: connecting two lengths end-to-end, or splicing a terminal end into another continuous length. The latter operation, known as "cutting-in", required slightly more skill and will be described first. In the illustrations, the piece marked "a" represents the loose end and "b" the length being spliced into.

about 6-inches long and can be hung about waist-high on a piece of twine around the neck, leaving both hands free for other operations. The pipe marked "b" is grasped between thumb and forefinger of the left hand (if the operator is right-handed) and with scissors in the right, a cut is made downward as shown, just to but not into the match, whose position can be felt by the other hand; then the tip of the shears is slanted upward and the cut continued to remove a piece of the pipe about as illustrated and expose the match. With practice, making the cut becomes one smooth operation, with two snips of the shears.

The end "a" is then inserted into "b" as in Figure 2, so that the two pieces of bare match are in contact, and a piece of twine is tied around the pipes just to the left of the notch to secure them, as in Figures 4 & 5, with the excess twine snipped off. Finally, about two inches of 3/4" masking tape is wrapped around the joint, Figure 6.

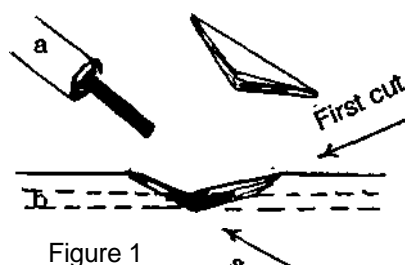


Figure 1

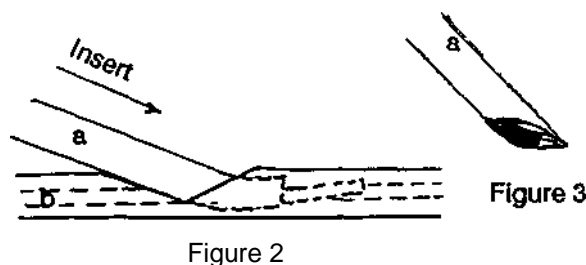


Figure 2

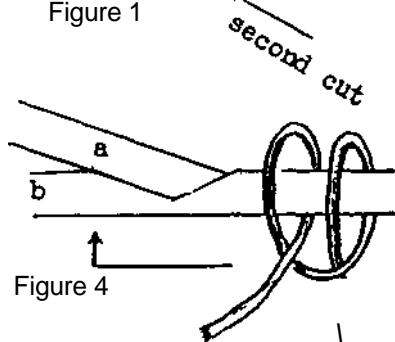


Figure 4

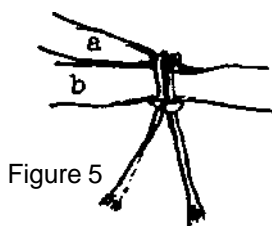


Figure 5

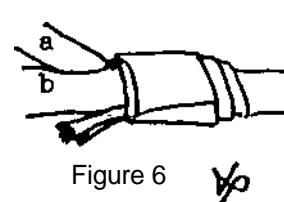


Figure 6

Figure 1 shows the first step; the paper pipe is trimmed back about 1/2" at the end of "a", leaving an intact piece of bare match protruding; then a wide-angled V-shaped cut is made in "b", being careful not to cut into the match itself. For these operations, a small pair of sharp scissors is used, a favorite among fireworks being Wiss electrician's shears, model 175-E. These are only

The knot shown is the traditional fireworker's *Clove Hitch*, probably favored because it can be tied rapidly and almost one-handedly in a single operation. For clarity, it is shown in Figure 4 somewhat to the right of where it is actually tied, the correct position being illustrated in Figure 5. Actually, a simple overhand knot would do the trick if secured by a second knot of the same

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type, but this would involve two tying operations with the risk of slippage between the first and second, as anyone knows who has used it for securing bundles.

It is suggested that the beginner consult Figure 4 and practice tying the clove hitch, at first around a solid rod such as a pencil or dowel, until it becomes second nature. Its advantages will soon become obvious, and once he can do it effortlessly, he will be recognized as a real fireworker. I have seen one operator who does it faster than the eye can follow! No attempt has been made to describe the operation in words, since every operator will discover the way that works best for him, be he right- or left-handed.

The tying cord generally used by the pyrotechnist is a rough brown 3-ply flax of about the same thickness illustrated, known in the trade as "Italian Shell Twine". Because it is not smooth, knots made with it hold firmly, even when not pulled up so tightly so as to choke the tubing. A satisfactory kind is widely sold for tying packages.

Here's another method for cutting-in match. The end of the pipe to be inserted is not trimmed back from the match but merely cut off diagonally as in Figure 3, leaving the match flush with the cut. It is then inserted into the notch in "b", pointed part upward, so that the

match is in contact, or nearly so, with the continuous length running through "b". Quickmatch burns vigorously enough that there is actually little chance that the fire will fail to transfer from one piece to the other in a closed tube, even if slightly separated. Also, in this quicker method, the joint is not tied with twine, but merely wrapped with a few turns of masking tape. In either case, the tape covers the gap between pipes, protecting the match from moisture and stray sparks, but in the latter, it is also depended upon to hold everything together. Perhaps the fairly recent availability of masking tape calls for an updating of traditional splicing methods!

In end-to-end joining of two lengths of match, each will usually have a piece of bare match extending from the pipe as in "a", Figure 1, covered by a protective safety cap slid over it. The cap of one can be removed, cut into a desirable length, replaced and tied securely, while the other cap is discarded. The second length is then slid into the open end of the cap, bringing the ends of bare match together, and another tie made around this end.

These match-splicing operations are essential not only for interconnecting lancework frames, but in preparing other sets and fireworks like wheels, "trees", and finale batteries, and they should be learned early in the game. MPVH



MAKING CATHERINE WHEELS

## MATCH-PIPE MAKING SIMPLIFIED

As most amateur pyrotechnists have discovered, rolling the tubes for piped-match has always been one of the most difficult operations in the making of fireworks, since the tubes are so long and narrow. If you know a couple of tricks, however, rolling these tubes can actually be quite simple. In this article, I will pass along two such tricks.

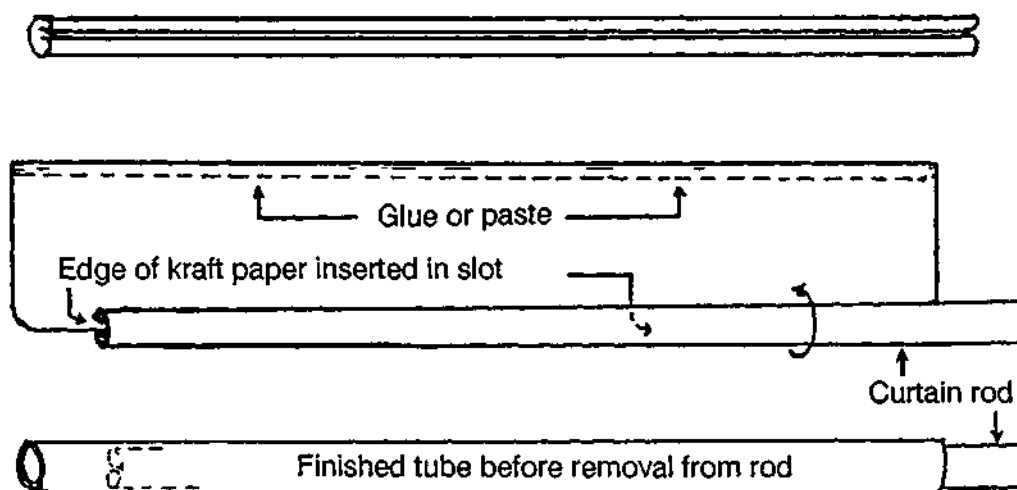
### #1 - FOR PARALLEL-WOUND TUBES

For reasons of durability and uniformity, commercial match-pipes are parallel-wound, generally 1/4" in diameter and several feet long, with the ends of successive tubes slipped and pasted over each other to form the longer pipes needed for matching lancework and other items, and slipped over the longer lengths of black match as the process proceeds. The main problem for the amateur trying to make such tubes is in getting the first turns started so that the following layers are quite parallel and even at the ends, this difficulty arising because the strips of paper used are so long in relation to their width. Weingart suggested the use of 1/4" dia. steel rods as formers for rolling the tubes, but by cheating a bit, I have found that getting those first turns started so that the result is a perfect parallel-wound tube is much easier if the following stratagem is adopted:

I obtain a narrow curtain rod, such as the type sold in hardware and home furnishing stores, packaged complete with mounting hardware, having a slot running its entire length as shown.

Now I cut some lightweight kraft paper, 20#, 30# or 40#, into strips 6" to 8" wide and no longer than the rod. When the lengthwise edge of one of these strips is pushed into the slot, making sure it stays there as you start rolling, it will be gripped by the slot, insuring that the edges of the following turns are parallel. Note that the paper should be inserted so as to leave part of one end of the rod exposed after winding, so that it can be pulled out; then I run a little glue or paste along the upper edge of the paper and wind the remaining turns as illustrated.

Finally, I remove the tube by gripping the end of the curtain rod at one end and the extending paper at the other and pulling the rod out. If it tends to stick, as sometimes happens, it is helpful to grip the end of the rod with a pair of needle-nosed pliers. An added refinement would be to make the tube waterproof by sealing the final turn with a long strip of wide cello-tape instead of gluing or pasting it, although this would be rather more expensive. Alternatively, the first couple of inside turns could be made with waxed





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paper, finishing the tube with kraft, as is done with some commercial quickmatch.

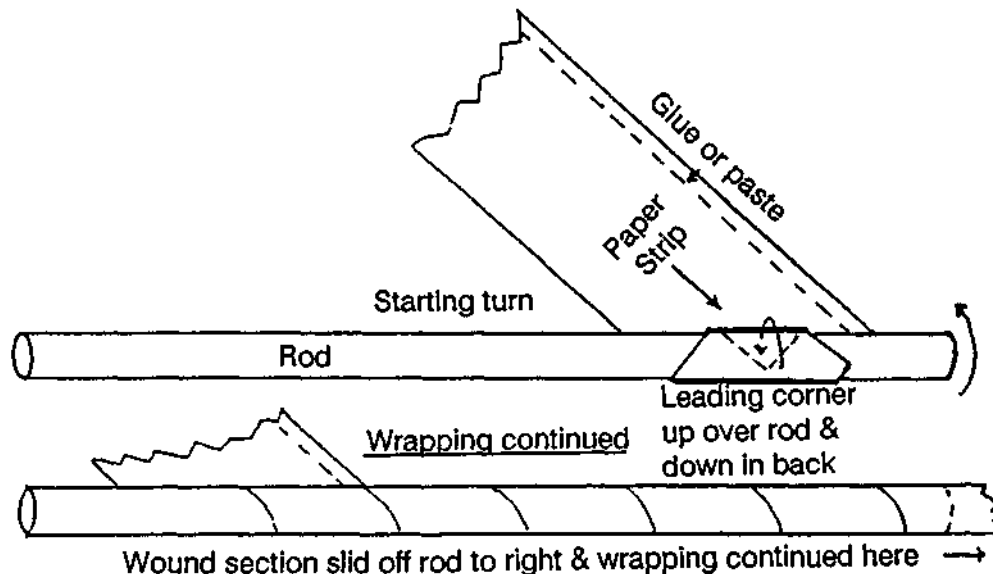
## #2 - FOR SPIRAL-WOUND TUBES

Match-pipes made by this method are not quite as durable as the parallel-wound type, but will serve adequately for many purposes, and they have two advantages: 1) the tubes can be rolled more easily and of any desired length without joining sections together, simply by feeding more paper and pulling the forming rod out the end at intervals during the winding, and 2) the rod does not need to be slotted. A metal rod approximately 5/16" in dia., spirally wrapped with a continuous strip of paper 4" to 5" wide, glued or pasted along

one edge, will make perfect match-pipe. The wider the strip and, consequently, the farther each turn is overlapped, the stronger and more durable will be the finished tube.

The spiral-winding operation should be quite clear from the following two drawings:

I continue equally-spaced turns around the rod until it is full to the left-hand side, then sliding the resulting tube off the right end, I continue back toward the left, and so on, until the desired length of pipe has been made. The left end of the rod could be chucked in a slowly-turning lathe, if available, freeing the left hand to guide the strip and the right hand to apply glue or paste to the edge. KO





## MAKE YOUR OWN BLACK MATCH

Early on in my pyro pursuits, I knew I would have to come up with an ordinary, everyday fuse for endless sample testing, experimental prototypes, and some finished products. Visco was too valuable, making paper fuses fussy and labor intensive, and commercial black match expensive. I needed something using low cost, readily available ingredients, simple to make, and easily produced in large quantity whenever needed. The solution was to be found in Weingart's section on formulas and methods for making black match. I came up with a composite of his formula 2 and 3 for rocket and candle match on Pg. 58. By averaging the ingredient quantities of the two formulas, I saved a little nitrate and produced a very reliable match which burns briskly and is extremely fast when piped.

Potassium Nitrate	54
Charcoal	13
Sulfur	8
Dextrin	2

From Weingart's original idea of extruding the match through a spout on a cup came a tuna can with a short piece of brass tubing. I use about an 8-ply medium weight cotton twine which I get in a 420 ft. ball for \$1.89 at a local drug store. When soaked with compound, it pulls neatly through 3/32" i.d. brass tubing, making a nice, round match. I bought a 12" piece of this tubing, with an o.d. of 1/8", at a model shop for 500. Using this size twine and tube requires about one gram of the above formula to make one foot of match. About 50 grams of dry powder and 40 to 50 feet of twine is typical for one batch and what follows is based on these sizes and quantities.

I drill a 1/8" hole in the side of the can about 1/4" down from the top outside edge. I cut about a 5/8" piece of tubing and slightly chamfer the inside of one end. This keeps the twine from snagging when pulled through. I insert the chamfered end in the hole, tilt the tube toward the top of the can about 30°, and solder in place perpendicular to the side of the can. The end of the tube inside the can should be flush with the side; it

may have to be beveled slightly before soldering. I clean and smooth the inside of the tube by hand, twisting a 3/32" drill through it several times.

All ingredients should be finely powdered and screen blended three or four times. I always prepare and reserve 30% more powder than needed for the length of match being made. This additional quantity is for thickening the slurry or making more compound if needed. I put the required amount of powder in a container which will withstand boiling water. I bring about 3 oz. of water just to a boil (I use an 8 oz. Pyrex measuring cup 2 minutes in the microwave). I add water a little at a time to the powder and stir constantly until there is a rather thin slurry. Then, I continue stirring and add denatured alcohol a drop at a time until the mixture just thickens slightly. I found the right consistency to be about that of thinnish tomato juice. As a general rule, I found slurry on the thin side makes a better finished match.

I unwind the twine off the ball and coil the length, say about 40 feet, slowly inside the can as I go. It may be easier to use two lengths of about 25 feet each and make two batches. I try to make each coil lie flat and close to the sides of the can. I cut the twine and feed the free, dry end from the top coil in the can through the brass tube and leave about 4" hanging outside. The twine will now feed out of the can from top to bottom. I make sure this 4" length hangs outside from the tube all through the process; I've had a hell of a time trying to rethread it through the tube when it's soaked with compound. When the mixture is at the right consistency, I pour about 2/3 of it into the can. With a piece of 5/8" dowel or other "stamper", I work the compound into the twine until it is well soaked and thoroughly coated. I try to keep the twine free of tangles and snarls. If the compound is completely absorbed, I add the 1/3 remaining in the container to saturate any dry spots. Any extra I can use to make additional short pieces of match.

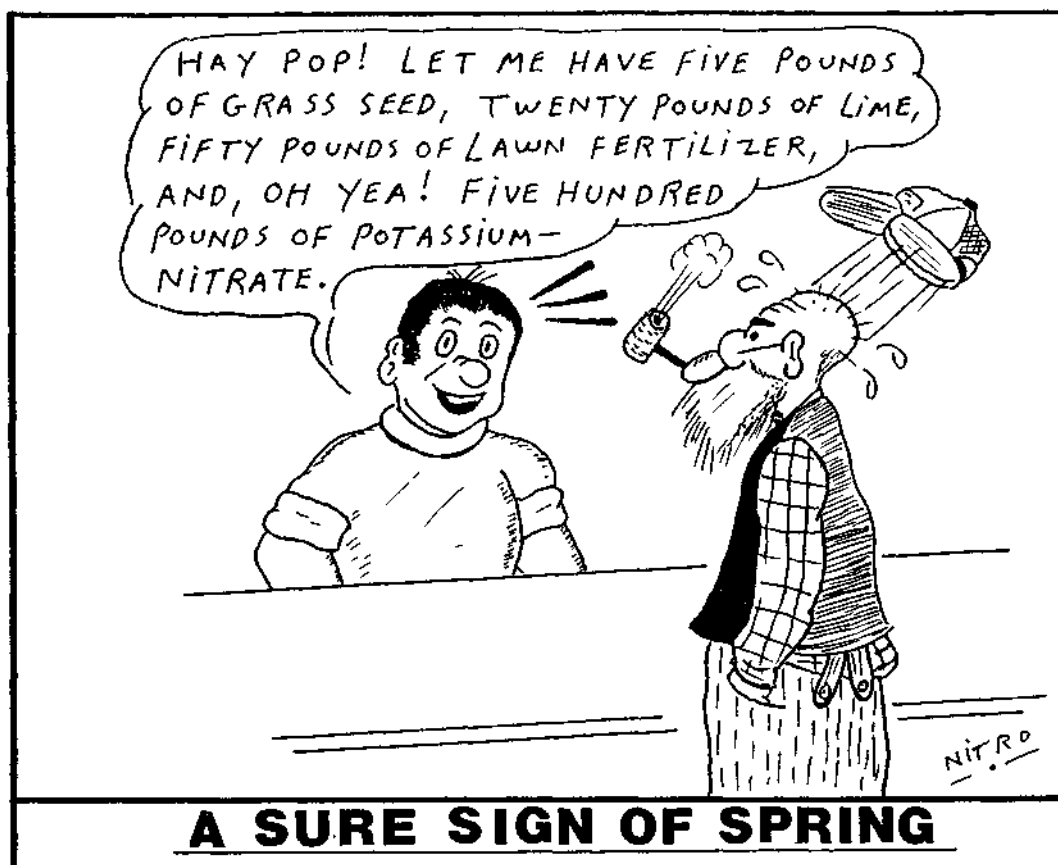
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For drying, Weingart uses a rack but I prefer to drape the finished match between several fixed points. One method I use is to drive a few galvanized nails at 4" intervals a short way into each of two boards. I clamp or nail the boards to a couple of old tables, chairs, etc. and space them about seven feet apart. The twine can soak while I do the rest of the project. I tie the end hanging from the tube to an end nail in one of the boards. I walk back and forth between the boards pulling the match slowly through the tube as I go. I drape the match between the boards alternately looping it around the nails in each. I don't pull the match tight as this will reduce the finished diameter. If I end up with a short length that won't reach, I drape it back and forth over the nearest table, etc. or cut it into shorter lengths and let these pieces hang from a few nails. If the twine tangles while feeding it out, I straighten it out in the can with my fingers so it passes freely

through the tube. I keep a little extra compound in the can so if I have to momentarily retract the twine to clear tangles I can resoak any bare spots. Again, with any surplus compound I cut short lengths of twine and make additional match until the mixture is gone.

The wet cotton twine dries slowly so I allow at least five hours to dry or overnight, if possible. Damp match sputters and burns erratically, if at all. It's dry when it is stiff and brittle and burns quickly and evenly. I am in a high humidity area, so I drape and dry the match in a safe, protected, indoor area. I have to remind myself to be patient with the drying time. When thoroughly dry, I unhook or cut the first tied end and gather the finished match in about two folds as I walk from nail to nail. I lay the folds on a clean, dry surface and cut to desired lengths. I find this black match to be of outstanding quality. SM





## VARIATIONS ON STANDARD QUICKMATCH MANUFACTURE

After the Finger Lakes shoot we had recently I received a few comments and questions regarding the match that I made for my "Jumping Jack" shells. The construction is quite simple, so I will attempt to describe the process involved. First though, I would like to thank certain members of the C.P.A. and the Finger Lakes Pyrotechnic Association for their support and encouragement. I was quite pleased to receive compliments from experienced professionals, especially since I'm rather inexperienced in this field. I would also like to thank the Finger Lakes Pyros for their hospitality. They made me feel right at home after my long, torturous drive through the remains of a hurricane.

The design of this particular style of match came about because of lack of time. In fact, I made this match only 24 hours before the shells were fired. So, initially the match was intended to be one that was quick to manufacture; the bonus of it's being extremely fast came as a surprise.

To start, I procured some "paper rope" from an arts & crafts store. It can be purchased in various colors, as well as being already twisted into a rope, or flat and untwisted. I bought the red untwisted type.

Next, I crushed some FFFFg sporting black powder to a near powder. I would say about 50% of it was not a powder, but tiny granules (much smaller than the original grains though). To this I added enough 91% isopropyl alcohol to make a thin slurry. A strip of the paper rope was laid out flat on a newspaper and, using a coarse glue brush, the slurry was painted on one side of the paper rope. Now comes the messy part. Using my

hands, I twisted the paper into its intended rope shape and a knot was tied at both ends.

The wet match was now hung from a suitable fixture and a clamp was fastened to the bottom. The clamp was twisted in the same direction as the twist in the match until the match was tight and straight. (A suitable means of keeping the clamp from turning, and thereby unraveling the rope, needs to be employed). More slurry was now painted on the outside of the match, and then I let it dry overnight.

When the match was dry (about 12 hours, depending on humidity), I took it down from the hanging fixture and cut the knots off. Then I threaded it into a standard piping (2 turns of 30 lb. kraft, 1/4" i.d.). String was fastened around the outside of each end to keep the inner core from dislodging itself from the piping. The match is ready.

Reports from shooters who have used this match indicate that ignition is nearly instantaneous from end to end and that it crackles and pops during the short time that it burns.

Please be aware that the inner rope core cannot be exposed and used as a leader as is done with standard match. It burns nearly as fast without the piping as it does with it. I attach an appropriate length of visco or other slow burning fuse to one end to perform this function.

Lastly, some sort of alcohol soluble binder might be in order for this mixture, as after the match dries the powder composition will come off the outside if it is not handled carefully. SAR



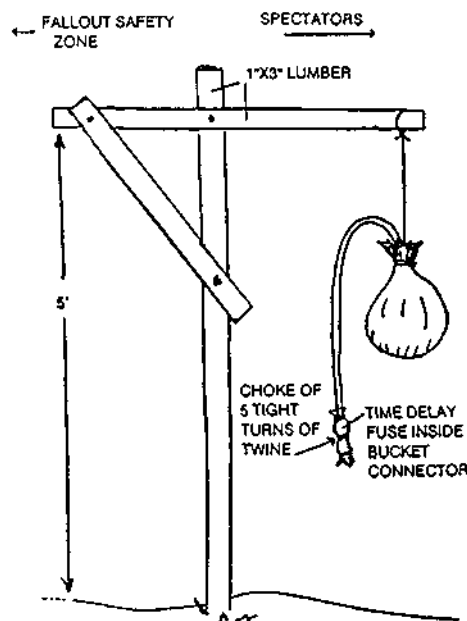
## THE GABE MORT

In Italian, Gabe Mort is pronounced *gah-bay mort*. Translated it means "Dead Head". The Gabe Mort effect is a shock to the spectators of a public fireworks display, and occurs at the end of the Grand Finale. There is no doubt that a few spectators may have soiled their underwear after witnessing the Gabe Mort. It is a thrill that is rarely seen anymore. It was taught to me by the late Anthony Palumbo, grandson of the late great fireworks master, Joseph Chiarello of Beacon, New York.

The "dead head" is easily constructed and set-up. It consists simply of two medium sized brown paper bags, placed one inside the other, then filled with five pounds (yes, 5 pounds!) of a good wholesome flash powder. The sack of powder is then hung with twine from a wooden yardarm at the end of the Grand Finale. An electric squib, or a delay fuse, is connected into the quickmatch to time the detonation so that the spectators believe the display is over. At that very second, Kaboom! If a time delay fuse is used to delay the Gabe Mort, a choke as shown in Figure 1 must be used to prevent quickmatch flame blow-by from bypassing the delay fuse. An alternate method is to tie an individual bucket at each end of the delay fuse.

The sack charge is suspended about 5 or 6 feet off the ground at about the height of a man (dead head). The effect of suspending the charge at this height is to create a concussion shock wave that follows the ground, intensifies at a few hundred feet distance, and smacks the spectators in the chest. I have felt the wind from the Gabe Mort at 200 feet away and it is awesome! The largest Gabe Mort I have assembled on a Grand Finale was 10 pounds of flash. It was also the last time I used that much. The display was fired in a park within a city, and many people complained of things falling off their walls in their homes. Several automobile burglar alarms were also set off, and a few babies cried. However, the crowd did roar with laughter and applause! Cutting back to 5 pounds is effective and quite enough.

There are a few words of caution that need to be considered. Two or more paper bags are used to



strengthen the sack, and to catch any powder leaks the inside bag might have. A double paper sack can also block penetration of sparks that may land during the display. Plastic bags need to be avoided because of their static electricity potential for an accident, and the fact that plastic bags melt easy should a spark land during the display. The end of the quickmatch that is inserted into the bag of powder needs to be choked off with twine. Two turns of twine, and a clove hitch knot, make a good choke. The choke is to prevent powder leakage into the quickmatch piping.

The yardarm is constructed of 1" x 3" furring lumber (see Fig. 1). The end of the yardarm, upon which the powder sack is hung, points to the spectators. The powder sack hangs between the yardarm upright pole and the spectators. When the sack explodes, the yardarm is splintered and blown away from the direction of the spectators toward the fallout safety zone. The display operator who supervises the Grand Finale should be back at least 50 feet, and should lay flat on the ground when the quickmatch nears the Gabe Mort end of the Finale. There must be no operators or assistants on the side of the Grand Finale away from the spectators. This is the direc-

tion the yardarm splinters will be blown.

The firing sequence at the end of the Grand Finale should finish with three delayed salutes, the last being the Gabe Mort. As the last color shell is fired, a 3 second delay fuse in line with the quickmatch is started, then the first 4" aerial salute is fired. As this first 4" salute is fired, a second 3 second delay is started, then the second 4" salute is fired. As the second 4" salute is fired, the final delay is also started, then the awesome Gabe Mort concussion! An alternate to this sequence is to use three Gabe Morts at the end of the Grand Finale. The first two are 1- pound charges and the last is a 5-pound charge. Electric firing of the Gabe Morts can be substituted in lieu of the fuse delays.

Making the delay fuse elements to connect in line with the quickmatch is very easy. I always used 1/4" o.d. Japanese time delay shell fuse. I would cut the fuse 1 1/2" long and cross match each end 1/4" in, with thermolite igniter cord. An alternate to using thermolite cross matching is to split the ends of the fuse 1/4" in, and prime the inside of the splits with a black powder/water slurry, or nitrocellulose lacquer. If nitrocellulose lacquer is used, I would roll the ends of the lacquered fuse in fine grain black powder while still tacky. I would then tie a dime size coin wrapper on each end of the delay fuse, making sure the clove hitch knot was tight and right behind the cross match. The ends of the coin wrappers would meet in the middle, and one could not see the time fuse underneath. Using two coin wrappers, and tying each end assures there will be no flame blow-by when the quickmatch flame snaps to the starting end of the delay. I found this delay technique useful in many other applications such as set-piece work.

This effect is exciting, shocking and gets rave reviews from most spectators. However, once I was accused by a display customer of having a bad bombshell. He thought a shell exploded in the mortar or on the ground. I learned quickly to tell the customer about the Gabe Mort before the display to prevent a misunderstanding. It's a great effect to shock and scare the spectators, but shocking and scaring the customer can backfire.

WO

## NEAPOLITAN GROUND BOMBS

I enjoyed the story about Cobo-Morto. It brought back memories of when my father would make Cobo-Morto. The following was his Neapolitan way of making them.

Pop made three sizes of ground bombs: full 4", 5" and 6" outside diameter, and on special occasions, he would make 8" and 10". Whenever he would sign a contract for a fireworks display, especially for Italian festivals, the committee would always request a cobo-morto for the finale. I am 74 now, but my recollections go back to when I was 9 or 10 years old. When I came home from school, Pop would put me to work helping. He would have two or three boxes of newspapers and my job was to lay out 40 sheets of newspapers to a set. When they were ready, Pop would feather the ends of ten sheets and paste them. He would use a 4" o.d. chipboard roller, about 30" long to roll the newspaper the long way, then pull the roller out and flatten them from center to ends. He would then get a 2 1/2" diameter wooden roller and wrap three turns of 30# kraft paper around the roller, folding the back end about 2 1/2". He would place three or more strips of rolled newspaper into the kraft paper and continue to roll it until it was tight. He would place the last sheet of 50# kraft paper three turns, fold the back and extend the top about 2 1/2". Then he would remove the wooden roller, leaving 2 1/2" of paper on the top for the final fold.

The next step was to get spool tubes and wrap three turns of 30# kraft paper around the tube, with 3/4" of paper extended out of each end. He would place three pieces of quickmatch into the tube, with 1" sticking out of each end. He would fold the ends of the tube and tie the paper to the quickmatch. Then he would place the spool into the chipboard (with hole) disc, and set them aside until he needed them.

He would then mix the composition for the ground bombs:

*Continued on next page*

# THE BEST OF AFN III

Potassium chlorate	8 lbs.
Sulfur	2 lbs.
Aluminum black	1 lb.
Antimony	1 lb.

Pop would tell us never to use this composition for aerial salutes, or reports for shells, due to the sensitivity of the composition. The 2FA black powder propellant charge could make the shell burst in the gun!

After the composition was well mixed, he would load the ground bombs. He would place three pieces of quickmatch into the composition from top to bottom. Then he would place the disc with the spool and quickmatch on top of the composition, fold the 50# kraft around the disc, glue, and place another disc on top of the glue. The next step was to string it with 45 strands down the side and around. Then he would dip the shell in hot fish glue up to the spool. Next he would empty a bag of sawdust on a sheet of 30# kraft paper, then roll the glued shell in the sawdust. Then he would place them on a screen and let them dry.

The next day he would wrap 3 turns of 30# kraft paper around the shell, leaving about 4" on the end to tie. He would tie a 36" quickmatch lead into the top end of the shell, then tie a 3" wrapper on the top end of the quickmatch lead, and place a piece of time fuse 3" long, crossmatched at each end with fine quickmatch. He would then place another 36" lead and tie to the time fuse, folding 12" zig-zag to retard the burning time.

There would be five ground bombs to a set, two 4", two 5", and one 6". We would use four or more sets to a display. They were always placed on the ground in a clear area.

The cobo-morto was always part of the finale. Our finale would start with 3" colored shells, color and whistles, serpent no stars, repeating

shots (2) layers, lampetti dark, spider web and salutes 3", 4", 5" 6" o.d. Pop would run a 60-foot bundle of quickmatch at the start of the spider web shells to the cobo-morto - all going off at the same time, ground bombs and spider web shells. I must say my father's spider web shells were the best I have ever seen. All spider web shells were made with flash bags.

After my father passed away, my brothers Jim, Ralph, Tony and I continued to operate his business. We changed the format of making cobo-morto ground bombs. Instead of rolling newspaper, we would buy 6" chipboard cases with a cap sealed on one end. We would use white glue on the cap and place a 6" disc over the cap and seal with masking tape. For the top of the case we would use a 6" disc with a center hole for the Japanese time fuse. The fuse would be cut 3", 4", 5", 6" long, all crossmatched with igniter cord. We would place the time fuse in a disc and set aside until needed.

I would mix the composition for the ground bombs using:

Potassium perchlorate	4 lbs
Sulfur	1 lb.
Aluminum, atomized	1 lb.
Titanium	1/2 lb.
Bran	1 lb.

We would fill the cases with composition to the top and place the disc with time fuse over the composition.

We would use masking tape to hold the disc and place white glue around the fuse. We would cut 50# kraft to size, paste the shells, and let them dry. When well dry, we would place them in cartons until needed for our displays. We still tied them in with the spider web shells in the finale, firing them either electrically or manually. LJS

## WATER FIREWORKS

A number of years ago, I watched a display fired from a barge. The beginning of the display was announced with the firing of a 200 foot waterfall hanging from the side of the barge. While the waterfall was burning, a flight of Ruggieri's water bombs was fired. With the low flight path arching over the side of the barge, the shells lifted gently (lobbed) from deeply angled mortars, and plunked into the water. After a couple of seconds the shells bobbed up to the surface and burst like mine shots out of the water. It was an impressive display and somewhat novel with the waterfall in the background. The reflection off the water was awesome!

Water shells can be made easily from plastic shell casings. The secret to a successful performance is to get the shell to float with plenty of buoyancy, and to provide it with plenty of time to travel, splash down, and recover from the dunk. It is also important to allow time for the shell to orient itself in the water (it may hit the water spinning) so that it projects its stars skyward during the burst. This means the heavy side of the shell is down with an air pocket at the top. Trying to do this successfully with a single shell casing, that has an air pocket assembled in, is near impossible because the bulk of the shell tends to be submerged with only a little of the top surface exposed out of the water. In that case, the shell bursts into the water extinguishing itself quickly. Also, if the water is the slightest bit choppy, it will keep the shell dunking and bobbing, assuring failure.

This problem is solved with the double shell casing technique that can be seen in Figure 1. A 4" plastic shell is assembled inside a 6" empty shell casing. The technique for making 4" plastic ball shells is too lengthy to detail in AFN, but can be obtained by purchasing my "Technique in Fire, Volume 2, Quick Assembly of 3", 4", and 5" Plastic Ball Shells". In that report, I give in-depth details of how I make plastic ball shells, including special plastic "welding" glue, and a special burst formula.

The time delay fuse for the 4" shell should be about 4.5" long to give a burn time of 10 sec-

onds. After the 4" shell is made and the special glue is allowed to dry for 3 days, the shell can then be assembled into the 6" casing as depicted in Figure 1.

It is important to assemble and glue broken pieces of plastic from a 3" shell casing to support the 4" shell inside the 6" casing. This takes the stress off of the time delay fuse during lift set-back, and keeps the 4" shell from rocking back and forth during handling. After gluing in the support pieces, the glue is allowed to dry for three days before closing the 6" shell.

The seam between the two halves of the 6" shell is now glued with a weaker glue than the glue revealed in Volume 2 of "Technique in Fire". PVC pipe cement, available at hardware or plumbing supply stores, will do well to seal the 6" ball shell casing, keeping out water. My plastic "welding" glue should not be used on the 6" casing (except around the time fuse hole), as it will cause the casing to shatter when the 4" ball bursts. The weaker PVC pipe cement allows the 6" ball to break open at the seam. This in turn allows the bottom half of the 6" casing, with the hydraulic cushion of the water, to deflect the stars upward.

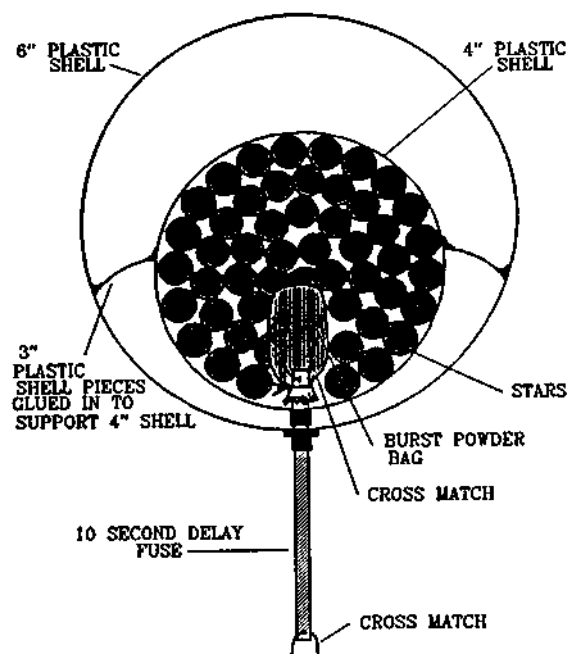


FIGURE 1

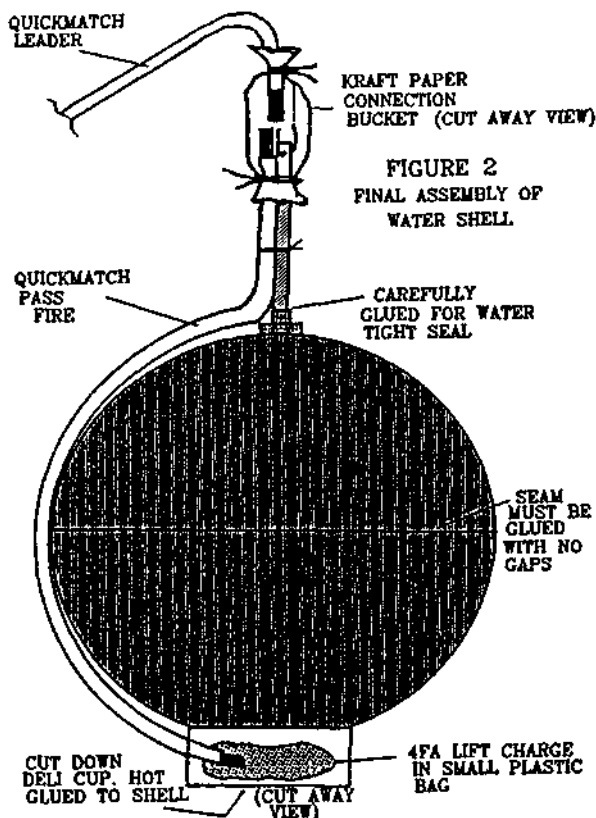
# THE BEST OF AFN III

The beauty of the 6" casing technique is the shell will float in the water with the heavy side down. When the shell bursts, the bottom half of the 6" casing acts as a parabolic reflector, directing the bulk of the burning stars upward and out of the water. The 6" casing also allows for plenty of air space to give the shell lots of buoyancy with half the shell out of the water.

Figure 2 shows the final assembly of the shell with the lift charge and the leader fuse attached. The lift charge must be kept small so that the shell does not travel far before entering the water. The shell's flight path altitude should stay low and the shell should drop into the water about 150 feet out. The angle of the launch mortar must be low to work together with the low lift powder charge. Three-quarters of an ounce of 4FA is plenty of lift with a mortar angle of about  $10^\circ$  above horizontal. It is very important that trial firings be made of this shell so that the operator understands how to safely set up the display. Distance of travel over the water; width of the lake, pond, or river; and placement of the spectators are all factors to be considered. This shell must never

be fired over water in the direction of spectators. The only exception to this rule may be if the shell launch is from a barge about a thousand feet off shore.

When the distance over water is a safety concern, and is too small to allow firing from a mortar, the shell can be assembled with an electric match instead of the delay fuse. The wires of the match are passed through the fuse holes of the two shell casings with each fuse hole thoroughly sealed with hot melt glue around the wires. The shells can then be placed in the water with pieces of cinder block as anchors and a mooring line to attach the shell to the anchor. A hair net can be placed around the shell to attach the anchor line. A small red plastic flag with a wooden stick may also be attached to the shell. If the body of water is tidal, plenty of slack in the anchor line should be given to allow for high tide or the shell may end up submerged at display time. Pleasure boats must also be kept out of the area once the shells are placed. Firing wires can be run to shore, or to an anchored row boat at a safe distance. WO







## WINTER PROJECTS - A TIDY LITTLE ELECTRICAL FIRING BOX

Having put on backyard 4th of July displays for friends and neighbors over the years, I've found that the audience, particularly those who have seen them before, are always interested in what new trick I might have up my sleeve. Many in the group, having rarely seen Class C displayed with a plan in mind, are easily impressed; a few, however, are always looking to see what's new.

One year, having paid attention at the PGI convention, it was lance work. Another year, having been fortunate to find an antique 150-cap T-handle blasting machine during the spring, I cleaned it up and brought it out with great fanfare. With much ceremony it was used to open the "show" with a pair of Silvery Swallows. Another year I pounded a bunch of nails into a board and made a crude firing board.

Because I'm not an ice fisherman there is ample opportunity in this part of the country to work on projects during the winter. The *pi-ce de resistance* this time turned out to be a tidy little electric firing "panel", based on a design that appeared in AFN #89, Feb. '89. The circuit diagram, shown below, is exactly as described. It includes the diodes he mentioned as a means of eliminating parasitic currents, as well as status-indicating LED's. Calling my device a panel is taking liberties however, as there are only eight firing switches. Let me explain.

I like to start projects building around something already on hand; in this case I had found a large spool (about 300-400 feet long) of 12-conductor wire (24 gauge, solid) at a flea market for \$5. Because of some size and connector considerations I wound up using only 9 wires, 8 for the individual circuits and the 9th for a common ground. The other 3 wires are extras.

Everything is housed in a small plastic "hobbyist's" box: 4 3/4" x 2 1/2" x 1-11/16" (Radio Shack #270-222; \$2.49). On the cover of the box are mounted the switches and LED's; on a small piece of circuit board (2 1/4" x 1 1/2") are mounted (squeezed) the remaining components.

A maze of

color-coded wires connects the circuit board to the switches/LEDs. These wires should be 22 ga. or smaller if you hope to get the cover on the box.

Output is through a 9-pin connector (D-sub type, RS #276-1538; \$1.39) mounted on the side of the case. The unit is powered by a 12-volt battery (I tried 9V but it wasn't enough in the finished configuration) and is fuse protected (RS #270-362; \$1.49) by a 3A fuse (RS #270-1246; \$0.50). The fuse is like a safety switch; removing it prevents accidental firing. The fuse holder, which is a panel mount design, fits in the last available spot of the top of the box. Eight circuits is all this size box could handle.

Total cost for the "box" so far is \$35.77 (the majority of the cost is tied up in the switches) plus a whole bunch of trips to Radio Shack to pick up the parts. At this point I decided I had spent enough and started to cut corners. I connected 75 feet of my 12-conductor cable to the 9-pin male plug (RS #276-1537; \$0.99) and the other end was connected to my distribution "system": 9 nails pounded into a board; one for each circuit and the ninth for the common ground. Wires were soldered to the nails. Connections to the squibs are made with some of that great 2-conductor yellow wire (advertised in AFN) and alligator clips.

In use everything is hooked up and the 3A fuse inserted. If all the circuits are properly connected, all the LED's will light. If any are not lit, it indicates that those circuits are faulty (open) and connections should be checked. Any squib can be used but the homemade ones described in the March '92 issue of AFN (#126) are just fine. Estes Rocket ignitors (6 for about \$2.00) may be used if the squibs are connected to something easily ignited, like black match. When the spring-loaded switch is moved to the firing position the LED's go out and full power is transferred to the squib. When the switch springs back into its open position, it re-energizes the LED-containing circuits.

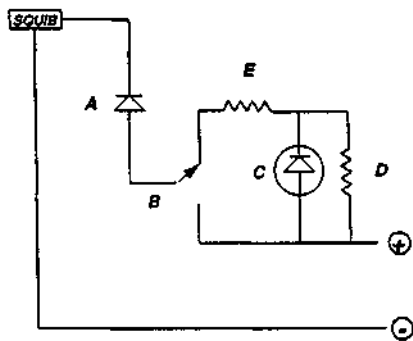
With the homemade squibs, I've found that the nichrome wire usually burns through so that the LED will go out once the circuit has been fired. For other squibs, including the Estes, the wire does not break so that the LED will remain on even though that circuit's squib has already been fired.

Unlike professional models which can switch between common grounds and use the same switches to fire another series of squibs, mine does not. In my case I decided mobility was the key. Thus, I have several 75-foot cables that I simply plug the box into as required.

As I mentioned before, this was a fun, winter activity.

## **FIRING CIRCUIT (one of eight)**

*Cost per circuit (less squib) = \$3.60*



- A Silicon diode Type 1N4001 (RS #276-1101)
- B. SPDT Spring Loaded Switch (RS #275-619)
- C. 12V Light emitting diode (LED)  
(RS #276-068)
- D. 560 Ohm 1/2 watt resistor (RS #270-020)
- E. 1000 ohm 1/4 watt resistor (RS #271-1321)

Fig.1. The basic circuit diagram, repeated for each circuit. <sup>1</sup>A or 1/2 watt resistors may be used. Numbers are Radio Shack parts. BEB

## **COMMENTS ON ELECTRICAL FIRING BOX**

The original AFN article [Issue #89] contained an error in that the resistor values were reversed. The value of the shunting resistor should be 560 ohms, while the resistor connected to the switch should be 1,000 ohms. Both may be 1/4 watt values. [The error has been corrected in the diagram shown in this book.]

The use of diodes is not required, unless multiple, switched grounds are used to increase the firing capability of the panel without adding more switches. From the article, it appears that the author used 8 switches to fire only 8 circuits, with only one common ground. Unless he plans to add an additional cable and a means to select one of the grounds, diodes are not required.

He made a comment to the effect that a 9-volt battery didn't work, and that a 12-volt one did. Well, if you tried to use a 9-volt transistor radio battery, I'm not surprised, as it can't put out the current required. In addition to the voltage, one must consider the available current that the battery can deliver, in order to fire a matchhead.

The reason for the use of the 560 ohm shunting resistor is to prevent the LED from continuing to glow after the matchhead fires. This occasionally occurs when there remains residue (across the otherwise open matchhead) from the blackmatch, which allows a leakage current to flow. The shunt resistor acts as part of a voltage divider to reduce the voltage appearing across the LED, to a value below that required to light it (1.8 - 2.0 volts). This scheme is almost completely effective, except, of course, when the matchhead leads actually melt and short together. SMB

## COMMENTS ON ELECTRICAL FIRING CIRCUITS

Circuits required to make multiple ground firing systems reliable and powerful are simple enough to make. In my opinion, no shunting resistor need be placed across LED continuity indicators, because in my direct experience of thousands of firings without this shunting resistor in the circuit, less than 10% of the LEDs remain lit after firing, and these only when the wires short. All of this is meaningless anyway, as the show progresses forward, not backward, and after you fire a circuit you are always looking ahead to the next cue.

The fired cues are smoke in the sky, and looking back at these indicators is a strange thing to be doing if you are firing the display. Your system should be vaporizing every squib in its path, the way the Mark II Ultimate did for Alonzo Fireworks at the 1992 Toronto Competition with three 450 cue zones firing simultaneously across a five hundred foot front. Our system's flawless performance is contingent upon simplicity.

Below I have sketched the simple circuits. By using a 4,300 ohm 1 watt resistor for the LED, the system can operate at voltages of 12 - 48 volts. At 12vdc this allows .003 amps, and at 48 vdc it allows .011 amps (or 3 - 11 milliamps). LED's are so sensitive that 1000 ohm resistors put more current into the squib than is necessary for continuity testing.

Not only are switches saved, but main cables as well, with a multiple ground system. There is no need to run separate main cables every time more cues are added to a multiple ground system. Just extend the cables 20 feet further and add another ground wire. It's that simple, and it works every time. Ten ground wires turn 25 positive wires into 250 cues, and with just 25 buttons and 10 toggle switches.

We use high quality isolation diodes at every squib terminal's negative connection to the ground wire. I recommend 6 amp 400 volt diodes. We always put indicator lights on the ground selector panel; that let's us know which ground is on (or if there is a short between grounds).

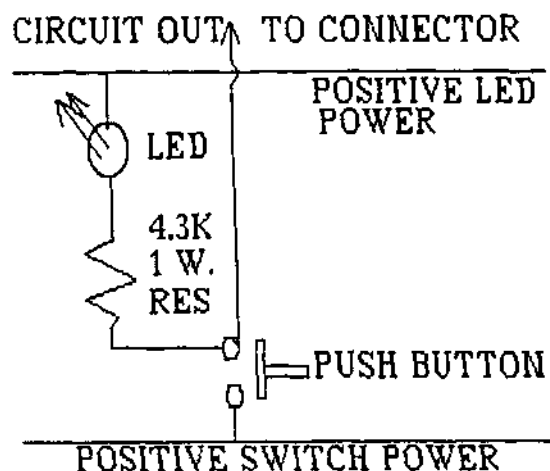
We put a GMOV metal oxide varistor on the 12 to 48 volt input power to clamp any voltage spikes (typical clamp voltage 60 volts, full clamp at 150 volts). This helps to make the diodes last forever, especially if there is a lot of "long distance shooting". Two key switches are a great idea also: One to energize the ground selector box "ARM/CONTINUITY" (the LED's always have positive power), and the other to give positive firing power to the switches (FIRE).

The momentary switches are inductive load rated to 5 amps at 28vdc and 10 amps resistive 28vdc, normally open, of course. These switches are directly handling near-direct-shorts and potentially inductive loads.

I found the RS-232 / DB-25 cable and connector format to be ideal because the pins are machined from solid copper and not stamped.

Finally, I've found that speaker terminals make great squib terminals and are readily available as well.

"Keep it simple and it will keep working." FM





## DELAY CIRCUIT

There are many professionally designed delay circuits in the public domain. Here is a suitable circuit that will operate from a 7.2v nicad power pack.

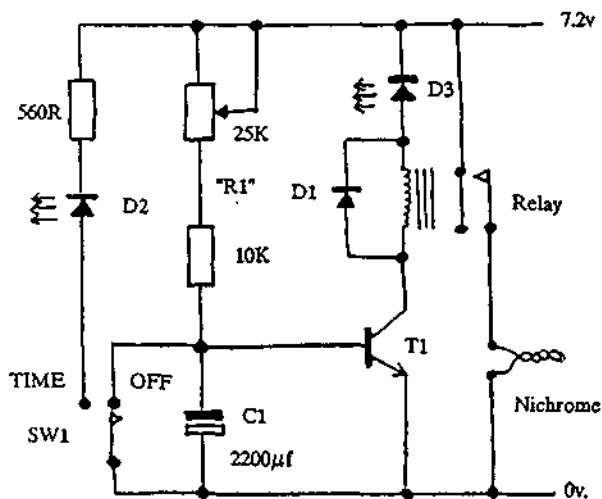
In my opinion, a variable delay invites accidents, so I have chosen RC to give around 5 seconds.

A more modern circuit would replace the relay and the transistor by an SCR device.

### Circuit Notes:

- R1 and C1 set the delay. R1 must be less than 50k.
- T1 switches the relay ON when its base voltage reaches about 0.7v.
- D1 stops back emf.
- D2 lit indicates "retire immediately".
- D3 lit indicates "run like hell".
- RY is a 5 volt relay with a 125 ohm coil.

SS



## MORE ON TIMER CIRCUITS

S.S.'s circuit is simple and uses only one battery. However, some comments are in order.

LED D3 indicates that the relay has already been powered and, in practice, you will not have enough time to "run like hell". The 125 ohm coil of the 5 v. relay means that the relay will draw a current of about 40ma, which might be a bit much for the average LED. One could possibly put two LEDs in parallel here or preferably use a high current LED. Another option is to use a relay which draws less current.

Five volt relays might be harder to find than 6 volt types. One could use a 6 v. relay here if one excluded the LED which drops the battery voltage by about 2 volts. As I mentioned earlier, this LED's purpose is actually debatable as it does not tell you anything that you probably don't already know, i.e., that the device has actually fired. By the way, the LEDs in both circuits are shown the wrong way around, as is C1.

S.S.'s circuit can be improved by adding a power ON/OFF switch between the battery and the circuit. Special care needs to be taken with C1 to ensure that all the connections between it and the other components are sound. If connections to C1 go open circuit, the relay would be powered immediately when power is applied to the circuit.

- the operator might set the wrong time by accident;
- the time delay pot might be accidentally bumped before retiring, resulting in the wrong time being set.

The first problem is human error, which will always be present and cannot be eliminated by more careful design criteria. The second problem can be overcome by careful design. Here the time delay pot can be positioned where it is difficult to alter its setting by accident. Another option is to have a multi-pole switch to switch in fixed time settings, e.g., 5, 10 and 15 seconds. IvM



## SIMPLE ELECTRIC MATCHES

The following items will be needed:

1. Needlenose pliers.
2. Razor blade.
3. Masking tape.
4. Nitrocellulose lacquer.
5. Insulated copper wire (22 or 24 AWG).
6. Paper safety matches.
7. Nichrome or tungsten wire.
8. Black powder for primer.
9. Ohmmeter

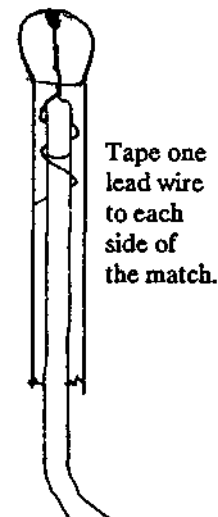
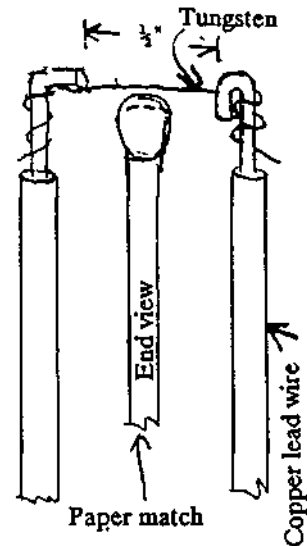
My first step is to cut two lead wires to the desired length. I use about 6-inches. I strip the insulation back about 12/16", then bend the wire into an L shape about 1/4" from the end of the bare wire.

I take the tungsten or nichrome wire and wind it around the bare copper wire, making 4 or 5 turns up to where the copper wire is bent. Then I crimp the copper wire down on the tungsten. This makes both a mechanical and electrical connection between the two wires. At this point I test the connections by gently pulling on the two lead wires. There should be no slippage of the tungsten. At this time I could solder the copper wires for additional strength but I haven't found it necessary.

Next I cut a groove in the top of the matchhead and center the tungsten wire in the groove. I bring the lead wires down each side of the paper match, then secure them to the match with a short piece of masking tape.

I always test the squib, using an ohmmeter. For nichrome wire, the resistance should be 5 ohms,  $\pm 2$  ohms. For tungsten, it should be 1 ohm or less.

To finish the squib, I dip the head of the match into a nitrocellulose lacquer. This seals the tungsten wire to the match and does not hinder the operation of the squib. After drying, I apply a coating of black powder primer. I build it up to about a 1/4" diameter. The last step is to again dip the head in the nitrocellulose lacquer. JE



## ELECTRIC MATCHES & SQUIBS

The terms electric match and squib are often used interchangeably in the fireworks industry. However, there are at least two good reasons not to do this, one technical and one legal. Technically, these are two different items both in terms of form and function. Legally, although both are Class C explosives (Explosives, 1.4G), squibs are on the BATF Explosive Materials List, which invokes all the regulatory requirements normally reserved for display fireworks, blasting caps and dynamite.

Figure 1 is a sketch of an electric match. The item consists of a short length of high resistance wire (bridge wire) mounted across copper cladding on an electrically insulating substrate. The high resistance element is surrounded by a heat sensitive pyrotechnic composition. Coated on top of this first composition may be a second less sensitive composition which enhances the pyrotechnic output of the device, and to some extent serves to protect the first composition. Finally, there is normally a coating of material (often nitrocellulose lacquer) to further protect and strengthen the electric match compositions. Wires to facilitate making electrical connections (leg wires) are usually pre-attached to the electric match. Photo 1 shows a collection of electric matches.

The function of an electric match is to produce a small burst of flame somewhat like that produced by the composition on a safety match. The output is initiated by the passage of an electrical current through the device. This heats the bridge wire and in turn ignites the pyrotechnic composition. It is the amount and duration of the electric current that determines whether an electric match will ignite. Figure 2 (courtesy of Atlas Powder Company, Dallas, TX)<sup>1</sup> illustrates the firing characteristics for Atlas matches as a function of current and time for which it is applied. Note that "all-fire current" is defined as the minimum current that is required to cause 100 of 100 matches to fire, when applied for a specified amount of time. (It is the authors' belief that when no time is specified, it is assumed to be 5 seconds.) "No-fire current" is defined as the maximum cur-

rent that can be applied that results in 0 of 100 matches igniting, when applied for the same amount of time. Between these two regions in Figure 2 is another narrow region in which it is uncertain whether the electric match will ignite.

It is true that electric squibs contain an electric match as an initiator; however, squibs contain an additional charge of pyrotechnic material, specifically, a base charge. Also, squibs have an external casing, usually made of metal, giving them an appearance similar to that of a miniature detonator (blasting cap). The effect of these two added elements greatly magnifies their effect upon functioning. In fact some squibs are so powerful as to allow them to initiate high explosives<sup>2</sup>, making them essentially equivalent to a small detonator. Figure 3 and Photo 2 illustrate the construction and appearance of squibs.

Regarding the correct identification of electric matches and squibs, there is some clarification that should be made with respect to Photos 1 and 2. Note that the electric match pictured in the center of Photo 1 has an appearance somewhat similar to that of a squib. However this device is essentially solid plastic with only a small recess in the end, in which the bridge wire and match composition are contained. Similarly, the electric match on the right has an inert plastic sleeve over the point where its leg wires attach to the match tip. Also note that there is a small difference in scale between Photos 1 and 2, with the items in Photo 1 appearing slightly larger relative to those in Photo 2.

Thus it should be fairly clear that electric matches and squibs are substantially different classes of items. Presumably that difference is one reason for squibs being on the BATF Explosive Materials List. As most readers already know, the presence of an item on this list invokes stringent storage, record keeping and licensing requirements on the item's possession, sale and use. Thus squibs are definitely BATF regulated items. The regulatory status of

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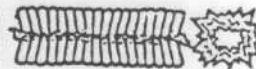
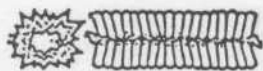
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electric matches is not entirely clear. Some might argue that they are included under the general category of "igniters", which is on the explosives materials list. However, note that model rocket igniters, such as those shown in Photo 3, are definitely a form of electric match. These are available for purchase in literally thousands of hobby shops and are certainly not considered to be regulated. Further, the BATF is certainly aware that millions of electric matches are used annually to ignite fireworks and that most are being sold, stored and used as unregulated items by fireworks companies.

It is a mark of a professional to know and use the vocabulary of his field. Also, because of the difference in regulatory status, and because of the limited experience of some enforcement personnel in identifying and differentiating between electric matches and squibs, it is little short of foolish for anyone in the fireworks trade to carelessly refer to electric matches as squibs. (It might be of some interest to note that care was taken in revising NFPA 1123-1990, Code for the Outdoor Display of Fireworks, to use the correct term, i.e. electric match.)

The authors gratefully acknowledge the assistance of George Jackson, Federal Law Enforcement Training Center, for providing the photograph of the squibs and other technical data; and Paul Cooper, Sandia National Laboratory, for a review of this article.

## References:

- 1) Atlas Powder Company, 1987, *Explosives and Rock Blasting*, Atlas Powder Company.
- 2) J.H. McLain, 1980, *Pyrotechnics: From the Viewpoint of Solid State Chemistry*, The Franklin Institute Press.

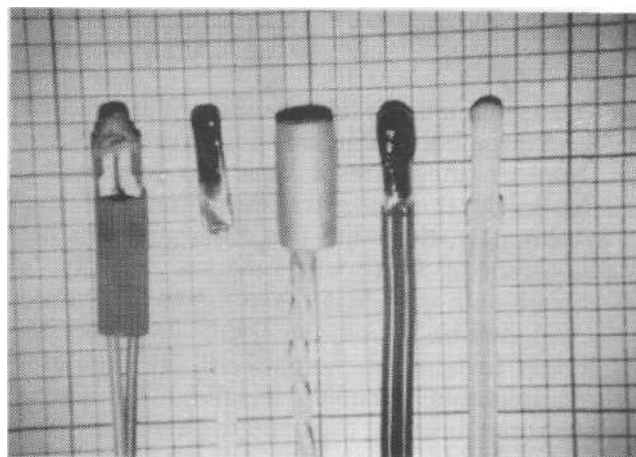


Photo 1. Typical electric matches. Grid is 0.1 inch.

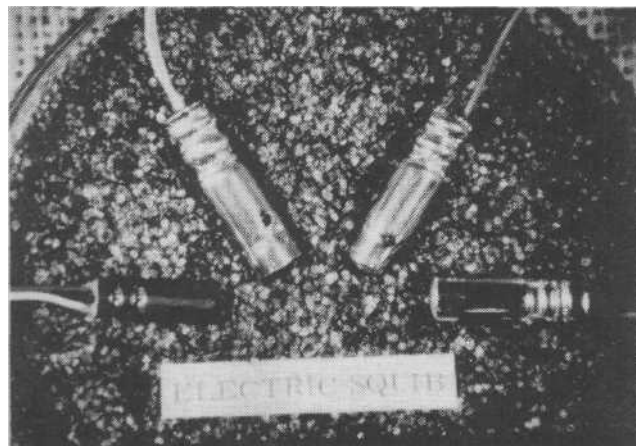


Photo 2. Typical electric squibs. By George Jackson, FLETC.

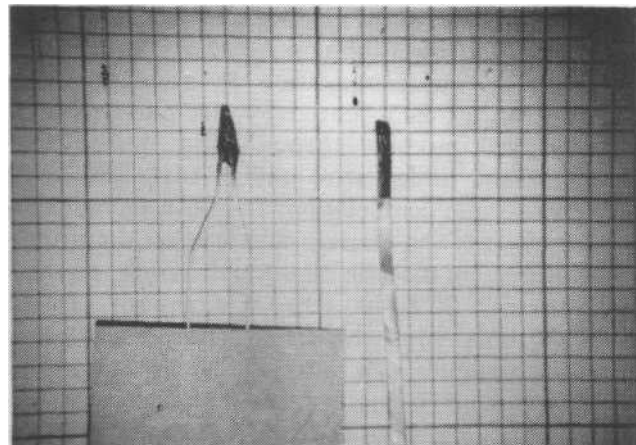


Photo 3. Two types of model rocket igniters. Grid is 0.1 inch.



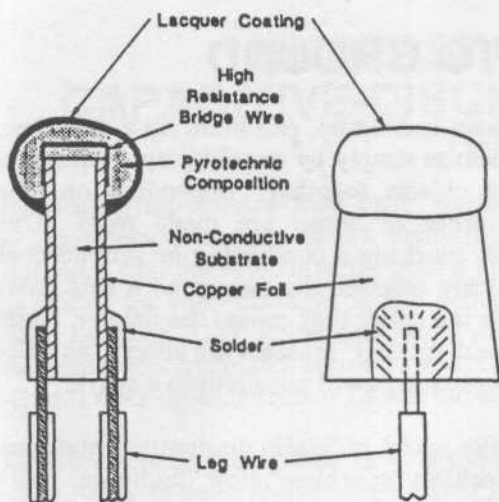


Fig. 1. Construction of typical electric match.

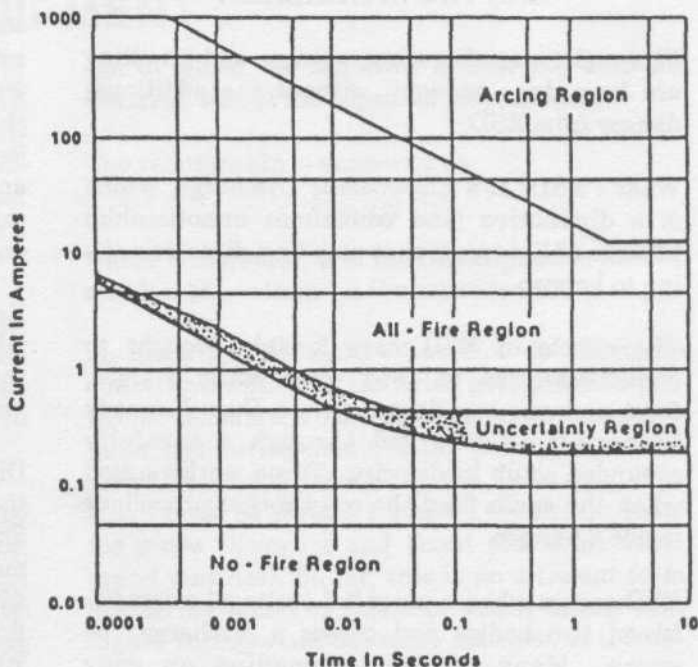


Fig. 2. Electrical response characteristics of Atlas electric matches, courtesy Atlas Powder Co., Dallas, TX

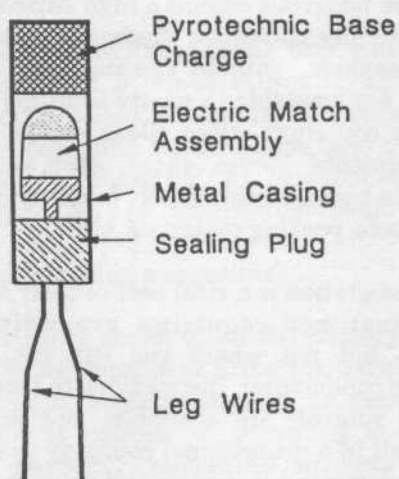
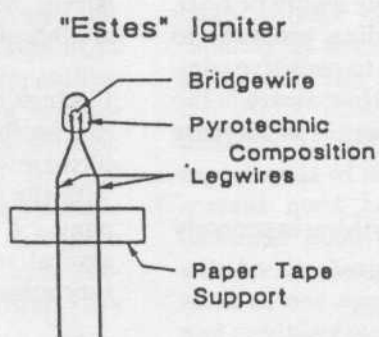


Fig. 3. Construction of typical electric squib.



"Bridge-wireless" Igniter

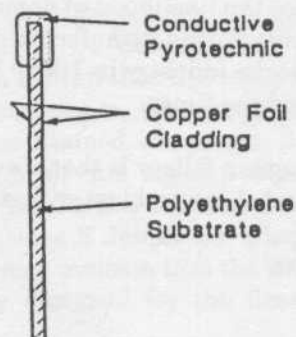


Fig. 4. Construction of 2 types of model rocket igniters.



## TO GROUND OR NOT TO GROUND

### ARE YOU SPARKLESS?

Fireworks manufacturing, storage and handling are hazardous enough, without the additional danger from ESD.

What's ESD? It's *Electrostatic Discharge*, which, is a diminutive (and sometimes unnoticeable) relative of lightning, that may be a disaster waiting to happen.

The effects of ESD were forcibly brought to public attention in 1964 when static charges, from a plastic bag draped over a Cape Kennedy spacecraft, discharged through a carefully grounded squib bridgewire. Three workers died when the squib fired the solid rocket propellant inside a hanger.

ESD occurs when a potential (voltage) exists between two bodies and causes a discharge, or spark. Many of you, depending on your geographic location, are familiar with the effect of walking across a rug on a dry day and then touching a metal object such as a doorknob. Zap!

But what is surprising is the magnitude of the voltages which can build up; 35,000 volts on a very dry day.

The electronics industry is acutely aware of ESD, and a large trade exists providing products to reduce the likelihood of damage to sensitive components during manufacturing. How aware is the fireworks industry in 1992? I'd say it is 20 years behind the times.

A common fallacy is that if everything is properly grounded, no problem will exist.

Wrong!

You, as an individual, can build up a significant static charge simply by standing up, walking, or rubbing objects together, depending on what your clothes or shoes are made from. Once charged, touching a conducting or grounded object quickly releases the energy as a tiny spark, and it is the spark that causes the danger. Notice that I said "quickly" releases the energy, as a slow enough discharge will not produce a spark.

Enter the world of "static dissipative" materials, which exhibit "sparkless" slow discharge, unlike the results from the use of conductive-surfaced or grounded materials.

Dissipative materials exhibit a high surface resistivity, carefully chosen to discharge static in a few milliseconds, without causing ESD. These materials are available in nearly limitless forms: worktable coverings, floor tiles, paints, liquid floor treatments, gloves, shoes, shoe and wrist straps, tote boxes, clothing, poly bags, mixing containers, tools, packing materials, etc.

Proper installation is a vital part of their application (sometimes requiring grounding the material, but not where you can get to the grounding conductors). Instructions to install the materials yourself are available, but you may wish to call in a professional company to make a survey, recommend materials and even do the installations.

Listings of suppliers and installation companies can be found in electronic industry trade directories and magazines, available at your library or with the help of almost any large electronics company. I have been accumulating catalogs for several years, and hope to put together a directory someday.

So, stay "sparkless" and ungrounded, but be dissipative! SMB



## UNDERSTANDING AND USING CAPACITIVE-DISCHARGE ELECTRICAL FIRING EQUIPMENT

Electrical-firing articles that have appeared in the fireworks literature dealt primarily with equipment that operated directly from a low voltage (12 or 24 volt) battery. A few articles discussed building "C-D" firing equipment and that many more electric matches could be fired from a C-D unit than directly from a 12 volt battery.

The intention of this article is to acquaint the reader with capacitive-discharge ("C-D") firing units, their advantages and disadvantages, the circuits used with C-D equipment, and how to understand and compare published ratings.

A capacitive-discharge firing unit stores energy obtained from a power source in an electrical component called a capacitor. Putting energy into the capacitor requires time, and the process is known as "charging". An example of charging is the recycling of a camera's electronic flash.

### Why bother using a capacitor?

A capacitor is useful when the primary source of power is not capable of firing the circuit directly, or when a voltage step-up is desirable. A capacitor is capable of providing a very high firing current, measured in tens or even hundreds of amperes, whereas a battery may not be able to do so directly. Therefore, one benefit of using C-D units is high firing current capability. Capacitors are commonly used with a voltage step-up circuit so that firing is at high voltage. For example, power sources may be 3, 9 or 12 volt batteries, while the output firing voltages may be 30 to 400 volts. The C-D unit charges a capacitor to a high voltage which is then discharged into the circuit to be fired (thus, the term "C-D").

Energy is the ability to do work; in pyrotechnic applications it is the ability to generate heat used to fire the electric matches. The unit of energy is the Joule (rhymes with "pool").

Energy stored in a capacitor is related to the volt-

age to which the capacitor is charged, and the electrical size of the capacitor (capacitance).

The relationship is expressed as:

$$E = 1/2 C V^2$$

where E is Joules, C is the capacitance in farads, and V is the voltage on the capacitor.

So much for the math - but how do we relate Joules and voltage to the firing potential of a particular C-D unit? To do this we first have to determine the series-circuit total resistance, then divide the firing voltage by the resistance. The result must be at least 1 ampere (minimum value for series Daveyfire and Oxral and some other brand matches). So far, this is no different from any series circuit calculation, and it means that higher voltages can fire more matches, or the circuit wires can be longer.

Now, how does a 200 volt C-D unit rated at 2.6 Joules compare with a 200 volt 6 Joule unit? The answer, surprisingly, is that in a simple series circuit both have the same firing capability. The reason lies in the fact that commercial electric matches require only about 2 millijoules of energy to fire, that is, 2 thousandths of a Joule. High voltage units become limited in firing capacity by the circuit and match resistance long before they run out of stored energy, otherwise a 2.6 Joule unit might be able to fire 1300 matches! This doesn't mean that the value of the capacitor is of no importance, because the firing current must be maintained for about 2 milliseconds (.002 seconds); too small a capacitor will be discharged before the matches fire. In most of our applications 2 Joules are adequate, and anything more may indicate that the product was not specifically designed for the fireworks industry.

Looking at literature for commercial blasting C-D units you will find mention of energy ratings, blasting cap firing capability, voltage, and charts showing series-parallel firing circuits.



How come we don't use series-parallel circuits in fireworks? We certainly can, but the branches must be carefully balanced, that is, equal in number of matches and circuit resistance. Additionally, there must be published data for every model of C-D unit for series-parallel circuits. The physical layouts of typical fireworks displays is not convenient for this kind of wiring and data is not normally provided. Lacking data (charts), complex calculations would be required for every display, and this simply is not practical for most operators, so let's stick to straight series circuits.

What are the disadvantages or limitations of using high voltage C-D units?

First, the re-charge time after each firing is not instantaneous, meaning that two or more "fronts" may not be able to be fired rapidly. There are ways to minimize this problem, usually resulting in increased battery drain for self-powered battery units, or additional circuit complexity.

Most ordinary C-D units do not interface with the main panel or computer, and are manually operated. However, there are panels which incorporate a full-time C-D "boost", with a fall-back lower limit of 12 volts (battery supply voltage).

An important consideration in selecting a C-D unit is that larger Joule rated units have much greater battery drains than smaller rated units of the same voltage, or require a longer charge time. This is because much of the energy is not used in firing, but nevertheless must be stored and subsequently dissipated in self-discharge safety circuits. Thus, high rated units may be "battery hogs" or slow to recharge.

Some high voltage C-D units on the market tend to ignore two potential firing switch problems. Most firing switches are rated at 250 volts AC, whereas some units fire at more than 250 volts DC. Using these switches on high current, high voltage DC circuits can weld or "stick" the contacts together, rendering the unit inoperable or unreliable. This problem is worsened if the user fires into parallel or series-parallel wired circuits. Another overlooked consideration is that all switch contacts "bounce", that is, the contacts vibrate for some period of time before a con-

tinuous contact is established. Since bounce times are in the same millisecond range as electric match firing times, an unanticipated reduction in firing capacity may result.

Shock, stray currents and leakage; high voltage circuits present a shock hazard to the operator if fingers come in contact with live wires at the instant of firing....be careful. Bare wires in contact with the ground or metal mortars may pick up earth currents or may induce currents into other grounded circuits. While not unique to C-D circuits, the higher voltages are more likely to cause stray current leakage problems. Careful isolation and insulation of all wiring is necessary.

Series circuits are "all-or-nothing", that is, if one match is an open circuit or if there is a break anywhere in the wiring, none of the devices will fire. I strongly recommend pre-testing all matches before connecting them into the series circuit, and then test the completed circuit. Pre-testing will easily identify a bad match, which would otherwise be difficult in the wired system. Testing must be done only with a safe, current-limited (less than 50 milliamperes) test meter, and the measured circuit resistance must be in agreement with the calculated value. All exposed fuses and pyrotechnic material must be protected from stray sparks, otherwise premature ignition will "open" the circuit and nothing will fire when the switch is pressed. Aluminum foil held in place with rubber bands, or "Caplugs" are frequently used to protect fireworks from sparks.

Advantages: you can fire one heck of a lot of matches at once; 80 or 100 mines or comets going up at the same instant is awesome. Similarly, a high voltage C-D unit can fire events over very long lengths of wire. An example was the firing of a 16" shell by the lucky "Make a Wish" kid at the 1994 PGI Convention - from 1,500 feet away. Cheap, discardable wire is usually adequate for high voltage, series-wired circuits.

Hand-held C-D units are compact, convenient to use and not particularly expensive. They represent a means of firing events not otherwise possible, giving the display operator and the public another pyrotechnic treat. SB



## ELECTRIC IGNITION OF SHOCK TUBE FIRING SYSTEMS

NOMATCH™ is a new system for igniting fireworks that replaces quickmatch with shock tube plus flame-to-shock (or electric-to-shock) and shock-to-flame attachments. The system was introduced by B&C Products, Inc., with a press release included in the July issue of *American Fireworks News*, an article in the July issue of *Fireworks Business*, and a demonstration and seminar at the 1994 Pyrotechnic Guild International (PGI) convention<sup>1</sup>. There was considerable discussion, among the PGI attendees, of the potential usefulness of this new system in various fireworks environments. The safety and performance advantages of the system seem obvious<sup>1</sup>, however, the discussion centered only on manual ignition. Below is a brief discussion of two low cost alternatives for electric ignition of shock tubing. For the most part, these are well known and commonly used methods, however, probably not among those in the fireworks trade. It is hoped that this information is interesting and possibly will aid in introducing this system.

Shock tube is initiated by the simultaneous application of flame and pressure. (Some information on shock tube, its construction and manner of functioning, was presented in an earlier article<sup>2</sup>.) The flame and pressure can be supplied by a number of sources, such as a small explosion as might be provided by a small arms ammunition primer. This is the method commonly used in the blasting industry.

At the PGI convention, ODA Enterprises was selling a one circuit capacitor discharge (CD) "Blasting Box". This unit reportedly charges to about 300 volts and delivers about 8 joules of energy. The unit differs from some others on the market in that it does not have a series resistor to limit the firing current in the event of firing into a short circuit. In the application described below, this is an important difference. ODA Enterprises was also selling electric match heads with a Nichrome bridge wire, but without any pyrotechnic coating. When these uncoated match heads are fired by the CD Blasting Box, the energy is sufficient to produce a flash of fire and

a modestly loud "snap", i.e., flame and pressure. Having used similar but more powerful devices to initiate shock tube in experiments in the laboratory, it seemed worthwhile to consider whether the ODA Blasting Box and match tips would successfully fire shock tube.

Upon return from the PGI Convention, a test of the ODA Blasting Box and match tips' ability to initiate shock tube was undertaken. In this test, Ensign-Bickford "Noiseless Trunkline" (shock tube) was used. The match tips were positioned in front of the shock tube by simply using a short length ( 0.5 in.) of 1/8 in. (internal diameter) Tygon tubing. See Figure 1. Using this arrangement, 10 of 10 successful ignitions of the shock tube resulted.

Another common method for igniting shock tube was demonstrated during a lecture at the 1993 PGI Convention. This is to simply cause an electric spark at the end (or preferably just inside) of shock tube. In a conversation with Scot Anderson, it was suggested that a device could be made, somewhat like the Pyrodigital firing module, except that instead of having plug-ins for electric match wires, there could be plug-ins for shock tube. On the inside end of the connector there would be a small spark gap which would be actuated by a signal from a computer. In this way, shock tube could be initiated directly by the spark discharge, without using a match tip. After firing a series of shock tubes attached for one display, they could be removed, and for a subsequent display, new shock tubes inserted for the next use of the firing module.

Upon return from the PGI Convention, a test of the reusable spark gap was conducted, again using Ensign-Bickford Noiseless Trunkline. Two configurations were tried. In one case, a simple spark gap was made by inserting a tight fitting pair of wires into a short length ( 0.4 in.) of shock tube, which was then cut off to expose the ends of the pair of the wires centered in the shock tube. This spark gap and the shock tube to be initiated, were simply connected using the

same piece of Tygon tubing described above. See Figure 2. Using this arrangement, 10 of 10 pieces of shock tube were fired using the discharge of a 0.05 mfd capacitor charged to about 6 kV. Note that connection of the capacitor to the spark gap was made by causing a spark to jump between the capacitor lead wire and the spark gap. Accordingly, only a small fraction of the 1 joule of energy delivered by the capacitor was dissipated by the spark gap for the shock tube. It was suggested that in a commercially produced system, the spark energy would likely be produced using solid state electronics and a transformer attached directly to the spark gap.

As a test of an inexpensive reusable attachment system, a spark gap was built into a compression fitting for 1/8-inch tubing. See Figure 3. In this case, the shock tube is simply inserted into the fitting and the nut tightened to hold it in place. In this fitting, there is a somewhat elastic compression ferrule, such that it can be used repeatedly providing it is not over tightened. Using this system tool, multiple successful firings of shock tube were also achieved. However, because of haste in assembling the unit, the spark gap was not

properly centered, and higher spark energies were required.

It would seem the NOMATCH™ firing system offers significant potential for improved safety and reliability in firing aerial shells, particularly under adverse conditions. It is hoped the above article contributes by identifying some low cost electric initiation systems for shock tube. KS

#### References:

1. Ensign-Bickford Co. and B&C Products, Press Release, American Fireworks News. 154, 1994; "NO-MATCH™ New Display Breakthru", Fireworks Business. 127, 1994; Bill Ofca, "Ensign-Bickford's NOMATCH™", Pyrotechnic Guild International Seminar, 1994.
2. K.L. and B.J. Kosanke, "Dautriche - Shock Tube Measurement of High Propagation Rates in Pyrotechnic Materials", Pyrotechnic Guild International Bulletin. 80, 1992
3. ODA Enterprises, 97 Mark Bradford Drive, Holden, MA 01529.

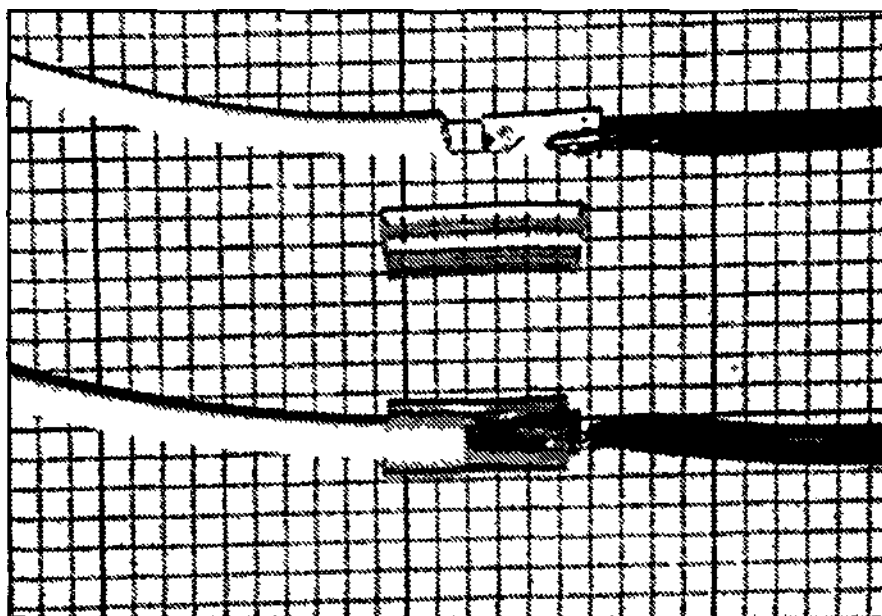


Figure 1 Upper Electric match tip, shock tube, and connecting tubing, as separate components Lower The assembled unit

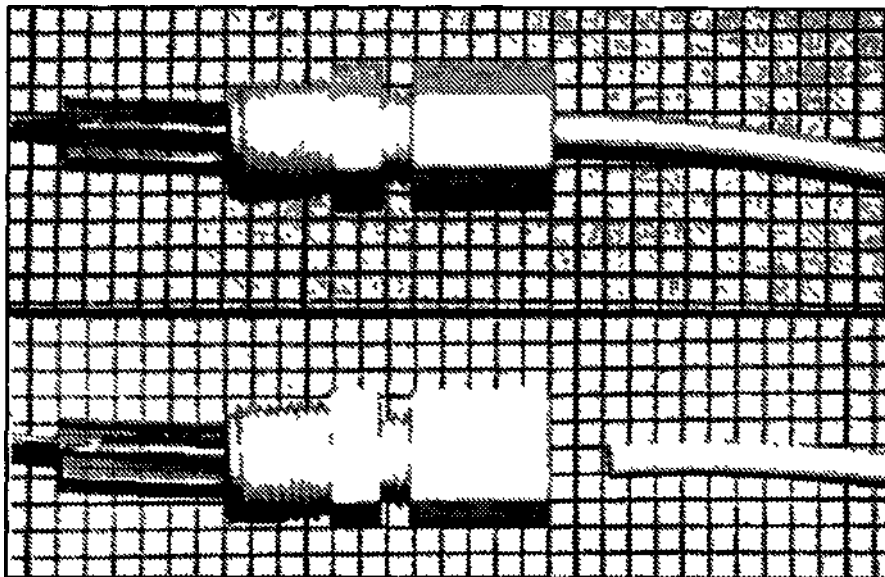


Figure 2 Upper Spark gap, shock tube, and connecting tubing, as separate components Lower The assembled unit

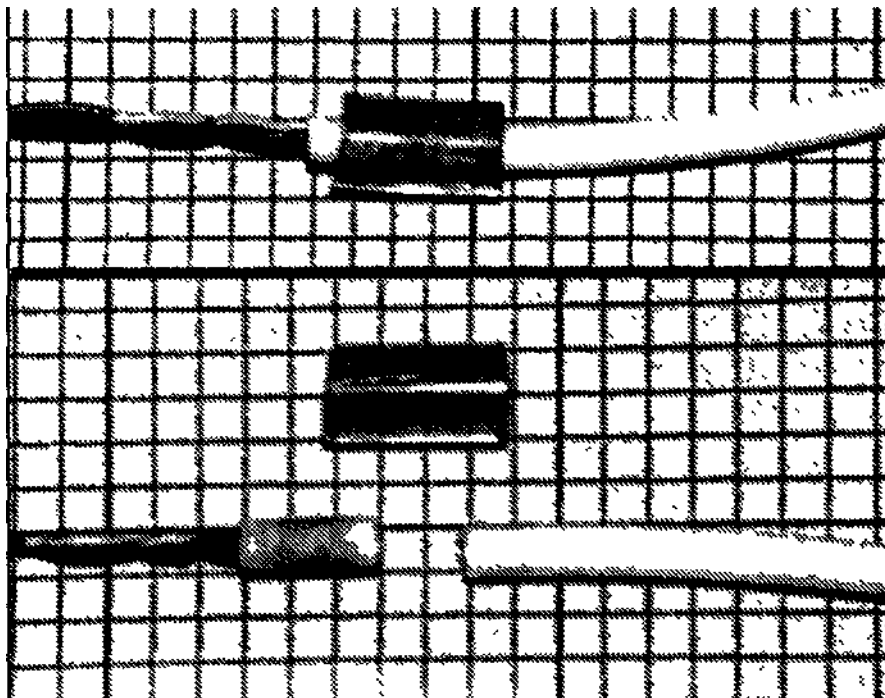


Figure 3 Upper Spark gap built into a plastic compression fitting, and shock tube Lower The assembled unit



## ELECTRICAL PERCUSSIVE ARC SHOOTING OF SHOCK TUBE

The technology for capacitive discharge percussive arcs to start shock tube is not new. The blasting industry currently uses this method, as well as the percussion of shotgun shell primers, to initiate or start shock tube. Both methods are not completely reliable with occasional misfires commonly experienced.

There is a hand-held shock tube starter, which has been on the market for several years, called the "Shurefire Shooter". It is used by blasters to initiate the non-electric blasting system that uses shock tube to convey energy to fire blasting caps. Another trade brand is called the "Cobra Shooter". Both operate by capacitive discharge percussive arc to shoot shock tube. Both are expensive, in the \$350 range. The Shurefire allows about 50 shots, and then the tip that inserts into the end of shock tube, must be replaced for a cost of about \$50. After about 25 shots or so, random misfires to initiate shock tube begin to occur, and become more frequent around 50 shots, sometimes with total failure. The Cobra shooter allows more shots, about 300, and then the entire unit is thrown away and a new one must be purchased for around \$350. This technical method of shooting shock tube is prone to random misfires for many reasons, including weak batteries, arc-tip erosion, blow back tip damage from the shock tube shooting energy, insufficient tip contact with powder coating the inside of the shock tube, tip contamination with moisture and dirt, insufficient capacitor charge time at moment of discharge (operator error), and capacitor failure.

To deliver the high energy wallop required to cause a percussive arc, the current limiting resistor commonly designed into blasting machine circuits is eliminated in the electric shock tube starters. This same resistor is required in blast-

ing machines to add discharge time to the capacitor, thus extending its life. Whenever capacitors are rapidly discharged, a phenomenon known as *dielectric absorption* occurs that stresses the capacitor plates and between-plate insulation. The severity of this stress is a function of how fast the capacitor discharges, and the amount of energy in the charge. Percussive arcs, of the strength required to shoot shock tube, cannot occur with series limiting resistors. Because of this, the useful life of the circuit capacitor is shortened and prone to failure. Perhaps this is one of the reasons the Cobra must be discarded after 300 shots. That, and arc gap erosion, may also be the reason the unit is sealed and does not allow battery replacement.

It is important to realize in these methods that a blaster doesn't get too concerned about a misfire, nor the \$1 per shot cost. He simply cuts off a piece of shock tube from the trunk line and tries again. The electric percussion arc method can cause a shock tube misfire unpredictably, and I have seen it happen often in the testing labs. I have observed that the reliability is not high enough for dependable fireworks initiation. I can't imagine waiting for a cue during a display and having this method of shock tube initiation misfire!

The Ensign-Bickford engineers have assured me that their system of shock tube starting devices for display fireworks will have a very high reliability rate, subject to their excellent quality assurance. One such device will be an electric shock tube starter with an affordable cost that will not obsolete existing electrical firing equipment that is currently in use by display operators. WO





## WHISTLE - JETEX QUESTIONS ANSWERED

"What happened to Jetex" and "Can whistle comp, be wet" were the two technical questions AFN readers asked recently. We got lucky with both.

Last month's issue contained a question from Whistleman who said he used a sodium salicylate/potassium perchlorate comp, in his whistles and found that if he wet the mix first the whistles were easier to make and worked better. But he wanted to know if wetting the stuff made it more sensitive or something.

We got a call from the holder of the U.S. patent for a "Buzzing Pyrotechnic Device & Method". He explained that the comp, used in his tourbillions was indeed the same stuff our Whistleman was using. He said they routinely wet the stuff with 1:1 water: methanol with good results, and sometimes stepped up to 1:3 when quick drying was needed. He emphasized that methanol is the alcohol of choice and not the easy-to-find isopropanol. Of course, whistle comp is never rammed; pressing is the consolidation method of choice.

It might be well at this time to take another look at the sensitivity of whistle comps. John Conkling, in his *Chemistry of Pyrotechnics*, warns "A whistling reaction is on the verge of an explosion, so these mixtures should be cautiously prepared and carefully loaded into tubes." Further, Dr. Conkling points out that the formula using sodium salicylate is "hygroscopic and does not store well", and appends the following warning to his table of whistle compositions: "These mixtures are very sensitive to ignition and can be quite dangerous to prepare. They should only be mixed by trained personnel using adequate protection." Likewise, although titanium whistling devices are very beautiful and effective, based on the number and severity of accidents in the past few years, there is little doubt that adding titanium to whistle comp, adds an unacceptable element of danger, except under very carefully controlled manufacturing management.

### WHERE'S THE JETEX?

A couple of months ago a reader asked why he can't find JETEX fuse any longer. A number of readers responded to the question; here's the best reply:

For those unfamiliar with Jetex, it is a pyrotechnic material deposited on an .008" resistance wire to make a total diameter of about 1/32-inch. The wire can be soldered to copper wires to make electric igniters (a half inch is plenty). Be prepared for accidental ignition while soldering, but I've made hundreds and the product has never ignited.

Jetex makes possible very small firecrackers, and small sugar fuel rockets of unbelievable performance. This rocket can be constructed in two to three minutes. Required tooling is a wooden dowel to roll and ram. I intend to write up a 3- or 4-page manual describing fuels and construction details.

While the 1-meter lengths once came in round tin cans, they were more recently packaged in foil packages. Jetwick (the actual name of the product) was manufactured by the Jetex Company in England as an accessory to the Jetex rocket motor, which was discontinued. The company went out of business.

After a long search I was able to locate the U.S. importer for Jetex. He said the Jetwick had been returned by hobby shops around the country when the rocket motors became no longer available. About three years ago I purchased his remaining stock of several hundred packets. PG

This definitely puts an end to the mystery of why we can't get JETEX any longer. Perhaps one of our readers in England will look into this matter and determine what happened to the machinery to produce JETEX. It might be a suitable supplementary product for one of our fuse manufacturers. JD

## WHY PROTECT MAGNESIUM?

I would like to tell of my experience with magnesium. When my father was living I told him I had some good formulas for Mg comets. He used an Italian expression that meant, "forget it". "No. Mg in my plant, it's too dangerous."

During World War II I was a technician at Picatinny Arsenal, Pyrotechnic Division. At the arsenal they used tons of Mg. All flares, signals, photo-flash bombs, stars, and tracers were made with Mg along with other chemicals. There was a department in pyrotech where the technician and his helper did nothing more than open large drums of various mesh Mg to be treated. I became very friendly with this person and this is what he would do. He would weigh out "x" number of pounds of Mg and empty in a fiber container. Then he would measure a beaker of linseed oil, take them down to the mixing room, empty Mg into the mixer, make a pocket, empty linseed oil and add litmus balls to Mg. He would place a cover on the mixer, lock the door, and at the switch panel turn on the power for the mixer. When power was turned on a red light would appear above the mixing door. This would now become a restricted area. He would return to his work station and set his timer for 45 minutes. After the 45 minutes of mixing, he would turn off the power and remove the coated Mg from the mixer. He would repeat this operation all day.

His helper would scoop the coated Mg into drying trays and place the trays in a drying room at 80° temperature. It would be dry in 8 hours and ready to use.

One day I asked Mr. Robertson, who was a Pyrotechnic Engineer, and the person I worked for, why is Mg coated? He said it was to prevent spontaneous combustion. He told me that when used untreated, Mg would oxidize with other chemicals, heat up and burn.

One day when my helper and I arrived at our work station, there was a call on the P.A. speaker for the following technicians to report to the assembly building. My name was among the 15 others called. We were greeted by the Chief Safety officer plus two Army officers. The chief

told us that between the hours of 6 p.m. and 7 p.m. the night before, there was a fire at the scrap powder pit. The scrap powder pit is where we would dump the scrap powder every night. There were two holes in the ground with a fiber container in each hole. It was located about 60 feet from the back of the building. Every night the containers would be emptied.

The officers asked each one of us what our detail was the day before. They wanted to see if they could find out the cause of the fire. When I was called on I told them that I was given a formula by Mr. Robertson, to mix composition for the 60mm trip flares. One officer asked me what the composition consisted of. My answer was: barium nitrate; aluminum "B"; sodium oxalate; Mg 80 mesh; LoCo.

One officer did not know what LoCo was, so I told him it is linseed oil mixed with castor oil, and is used as a binder. I told them that after I mixed a 2 pound batch I pressed 2 flares, then my helper and I went down to the Island to make our test. When I returned to the main building, Mr. Robertson was there. I told him that the burning time was not in tolerance with the drawing. Mr. Robertson and I made some changes in the chemical weight and I made a new 2 pound batch of composition. I dumped the first batch in the scrap container outside the building. An officer asked me if any scrap powder was in the container before I emptied my scrap? I told him there was not.

The last technician to be questioned was the person who coated the Mg. He told them that when he was weighing the raw Mg some fell on the work bench and on the floor. He said when he returned from the mixing room he brushed it clean and emptied the scrap Mg into the container. He was asked, "Was there any other scrap in the container?" His reply was, "Yes". The officer's conclusion was that when the raw Mg was dumped on top of the scrap composition it heated up and started the fire.

My advice to all people using mg. is to coat it first, let it dry, then use. LJS

## PROTECTING MAGNESIUM II

It was quite interesting to read the article about magnesium. I feel that the U.S. Government used much the same methods of working as the UK governments, and I have no doubt that they worked together quite a bit. He is quite right to say that the reactivity of magnesium can be quite a problem.

The first point is that the magnesium must be coated with *boiled* or polymerized linseed oil. Raw linseed oil, being an unsaturated fatty acid, can create heat in the hardening process. I missed mentioning this in *Fireworks Principles & Practice* on page 56 of the second edition!

On the other hand, I did mention the fact that the coated magnesium should be allowed to cure in a warm place on shallow trays. We reckon that there should be a maximum depth of 1".

In practice, there should be little problem under dry conditions with modern formulations and pretty neutral chemicals. To get a better pressing result, we sometimes mix the oil and the magnesium and then the rest of the materials and allow these to cure together for 48 hours.

These days, with the advents of polyester resins and the use of substances like alloprene, it is possible to use other organic solvents and avoid the use of oil altogether. This is quite useful since the oil is sticky and it tends to agglomerate the grains of metal during the curing.

As sodium oxalate is not the best of chemicals to use with magnesium, we do not use it much over here. Sodium nitrate has always been the favorite for yellow and much use has been made of mixtures of barium and calcium oxalates to produce yellows. RL

## HATES POTASSIUM PERMANGANATE

*It seems to us that about every 10 years or so the pyro hobbyists rediscover potassium permanganate. The resulting binge of research and testing always produces some interesting devices. Alas, the disadvantages of the chemical, not the least of which is staining everything purple, eventually outweigh the advantages, and the hobbyists move on to more rewarding work. The following letter was received some time ago; we held it for the next round of permanganate interest, which seems to be occurring now.*

An article [*Shell Burst Rockets*] by SS described his use of potassium permanganate in some formulations. He is an entertaining writer so I would like to see him live to an old age. Perhaps he would be better off "taking a daily dip in the crocodile pond" than working with potassium permanganate.

I used it in my foolish youth and quickly found that it is an extraordinary nose and throat irritant, to say nothing of what it is probably doing to the lungs. And it has a nasty habit of spontaneous combustion - everyone must have heard of potassium permanganate and glycerin.

There is also a problem with friction sensitivity. About 30 years ago I was testing it as a potential rocket fuel. I don't know why, but I was grinding it in a mortar & pestle, along with some red gum. Was I ever surprised when it ignited! And lucky, since the ratio wasn't correct for fast burning. Whew!

One nice thing about flash made with potassium permanganate is that it is not only powerful, but when you set it off in the snow, you get a beautiful purple color after the KA-POW - neat! RMBS

## SAFETY CONSIDERATIONS

The retelling by "Fireworks Freddie" (AFN #108, Sept. '90) of his experience with a perchlorate/-aluminum/sulfur concretion (the remains of a salute that had been exposed to the elements), which "detonated" when ignited by a propane torch, served to illustrate several important principles both practical and safety related.

**SOLUBILITY OF POTASSIUM PERCHLORATE.** Listed as 0.75 grams per 100ml of cold water, potassium perchlorate is *not* very soluble. A quick run through the calculator reveals that Dr. Pangloss would need nineteen gallons of water to dissolve one pound of potassium perchlorate. (Most of us would require more water.) That is, one pound of table salt will dissolve in three-tenths of a gallon of water! (Potassium chlorate is ten times more soluble than perchlorate.) The low solubility of potassium perchlorate results in three problems.

1) The salute that blew blind and you could not find will *not* be rendered inert from exposure to the elements, over a short period of time. Stars bound with dextrin, after drying, are even more resistant to weathering. Those bound with nitrocellulose will most likely outlast you.

2) In compounding stars and such, you *cannot* depend on potassium perchlorate dissolving and diffusing throughout the composition; good mixing and small grain size (fine mesh) are a must. Remember - safety first in any composition. The oxidizer is always added last.

3) For anyone planning on flushing your ten pounds of perchlorate down the sink/bowl while the sheriff is knocking on your door, it ain't going to work! Trying to explain why you have large quantities of chemicals on hand is not going to be easy. Great is the temptation to order large quantities of chemicals, given that five pound lots are cheaper per pound, and ten pound are even cheaper. The problem is that you will soon find yourself up to your tea cups in good stuff. Just gather up all your materials and envi-

sion how it would look on the front page of the local newspaper! Keeping the quantities down is not only good personal safety, but good political safety.

**REACTIVITY OF ALUMINUM.** Although aluminum is the most abundant metal in the earth's crust, it is never found free in nature due to its high reactivity. Bright aluminum metal quickly develops its familiar dark gray oxide coating, which protects it from further attack. Pyro aluminum retains its brightness as it is protected from attack by a thin coating of stearin (stearic acid) which is added as a lubricant during milling [German dark is the exception]. The coating is not absolute protection and can be breached. On long exposure to water, aluminum will react to form aluminum hydroxide in the form of a gel. The hydroxide also removes the protective oxide layer which results in a more sensitive composition. The constant wetting and drying cycle Fireworks Freddy's salute composition experienced cemented the components with hydroxide gel into a rocklike mass. During normal star manufacture, where drying is rapid, neither of these processes is evident. Had the oxidizer been a nitrate ("death mix"), no problem would have been encountered as the device would have taken French leave long before.

**THE EFFECTS OF CONFINEMENT.** While the statement "the stronger the confinement, the greater the effect (blast)" certainly is true, there are compositions that will function even when unconfined, sometimes to your regret!

Two indicators of this ability are the composition's *Critical Height* and *Critical Diameter*, the minimum amount of material that is required for an explosion to take place with an unconfined composition. Values range from: Any - potassium chlorate/red phosphorus (finger/hand removing mixture), potassium chlorate/realgar (red suicide mixture), potassium chlorate/sulfur (railroad torpedo/blow-up-in-your-face composition).  
*Continued on next page*



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sition), to tablespoon quantities - flash & report/- photoflash mixtures, then to multi-kilogram range.

The cementing action of aluminum hydroxide supplied more than enough confinement for ignition to progress from burning -> deflagration -> "detonation". I have seen cementation that was achieved through safer and more sophisticated means used to good effect. However, for reasons of political safety (mine) and personal safety (yours), I'll not discuss it here.

**STRONG IGNITION.** A quick kick in the pants may produce unexpected results! The heating of the composition with a propane torch effectively raised the composition *en masse* to ignition. This, combined with a hot mixture and strong confinement, resulted in one of life's less pleasant moments: being in close proximity to an unexpected blast! Ranks right up there with being seasick or kicked in the groin!

Fellow pyros have related to me the following stories, which are good examples of strong ignition:

Having had good luck using Lancaster's waterfall mixture (50% potassium perchlorate, 25% bright, 12.5% 30/80m, 12.5% 5/30m flitter aluminum), one 4th of July our pyro thought to use this seemingly innocuous mixture (it burned slowly in an open tube, didn't it?) in a mine. To this end he acquired from a supermarket dumpster (he says he comes from a long line of Irish horse thieves and garbage pickers) a cardboard tube wrapped with 3/4" of plastic film, apparently having been discarded by the meat department. "Strong like cannon barrel", he said. Around dark, he inserted the quickmatch, threw in several handfuls of 2FA, dumped in a pound or more of the waterfall mix, attached a goodly length of visco (God and visco have saved many a fool!), put fire to the fuse and walked back to the duly assembled. "Watch this!!"

The assembled watched in rapt anticipation as visco smoked and sputtered, a small jet of flame issued from the match pipe, fire and fury traveled rapidly to the waiting black powder. In an instant, several dozen dilated eyeballs were treated to a flash of light rivaled only by that from an atomic bomb, followed by a belt buckle thumping blast. After spots cleared from the eyes of a totally chagrined pyro and his acolytes, a search was made for the seemingly indestructible tube. Alas, only the oak bottom plug was found; the tube and its plastic had been reduced to confetti.

**ANOTHER TALE, SAD-BUT-TRUE.** Yet another pyro, in consideration of problems political, and desiring to keep the faith with the 4th through color and light, (rather than sound and fury), ignored the first three rules of pyro safety: NO METAL, NO METAL, NO METAL, by constructing, among other devices, a green magnesium flare in a piece of copper water tubing. Previous experience had shown that the not inconsiderable heat from the magnesium mixture would melt the copper tubing, adding color to the flame.

All went well at first, ignoring the poor color. But then the copper, being an efficient conductor of heat, conducted. Soon, composition so lovingly rammed not more than an hour ago ignited with a violence undenied. Blast! Smoke! Flame! followed by the sickening feeling of something gone seriously wrong! A large piece of this infernal device found its maker, and 'twas not a happy meeting nor a pretty sight! The involved pyro relates that the only good to come out of this was that they most likely saved the life of whomever was standing behind them!

The lessons here conveyed are obvious: you can never be too rich, nor too safe.

Remember - What can go wrong? What will happen if something goes wrong?

DJH



## SIMPLE TECHNIQUES FOR TESTING UNFAMILIAR COMPOSITIONS

I read with interest the account of the unsettling behavior of the Gold Flitter Star [spontaneous combustion of wet pyrotechnic mixes] in the Feb. '88 issue of AFN, as well as LSO's opinion as to the causes. I am familiar with this mix myself, and here is some additional information that may be helpful.

**INITIAL TESTS.** First of all, it's a rule not to walk away and leave a dampened, consolidated composition in a wet state, unless it's been made many times and its behavior is well known. In my opinion, the best procedure for all new mixes is to prepare a mere ten grams in a plastic bowl with a paint brush, and immediately go out and burn a gram of it, using a fuse or blowtorch for ignition - not a lighter or match. Then I would pour another gram onto a hard surface - I use concrete, and tap it soundly with a small steel hammer. I use a tack hammer, swinging it in a bouncing rhythm from my wrist like I would ram serpents or whistles. If it does nothing, I might try another gram with a steel carpenter's hammer on a steel plate. Then I take another gram, put it in a small porcelain mortar and, with gloves and safety glasses in place, grind it vigorously. I do it outside, because de-oxygenated sulfur and/or chlorine reactions stink to high heaven, even in small quantities.

**PUMPING SAMPLES.** That leaves six grams. Even if one never pumps stars, it is a good idea to have a 1/4" star pump, because it is possible to make a surprising quantity of tiny stars with that six grams - sometimes fifteen or twenty. It's best to leave them unprimed until the ignition characteristics become known. The pumped stars will behave differently than the powder, and scoria or trailing effects only rarely manifest from ignition of powder. I usually damp them with 10% (by weight) of 30% alcohol with water. In the case of six grams, I would weigh out 0.5 grams of the liquid. If they come out too wet, as occasionally happens, it's no great loss. The moisture is then incorporated by the "folding in" technique used in baking, and then pressing out the mix with a spatula, in a different plastic bowl. If desired, they also may be pressed flat and cut.

**FURTHER TESTS.** Once the stars are dry, I subject three of them to the same ignition, striking and grinding tests. If it is a chlorate star, I strike one on a matchbook - not to prove that it contains chlorate, but to see how well phlegmatized it is. Not all chlorate stars ignite when struck against red phosphorous - there's a wide latitude, and this test gives some insight into possible behavior of the same star when crunched up against another star containing antimony or sulfur in a shell. The whole process, including drying, usually takes no more than an hour. To test for heat stability, I often dry them on a glass dish on top of the water heater at about 160°F., but with *only* one batch of 6 - 10 grams; none ever auto-ignited.

**DETERMINING PRIME.** At this point the characteristics become pretty well known. If the star is a "roaster", i.e. will not ignite from Chinese fuse, or survives anything more than a momentary brush with a torch flame, it will probably need priming. If it takes an entire second or more in the blowtorch flame, or blackmatch is not doing the job, it will probably need a hot prime. I'm always careful when priming with commercial meal powder as it can flash over the star in an instant and cause a painful burn, since I like to "light and throw". Hand mixed powder with 5% silicon, FeTi, or titanium fines if required, dampened with 10% of N/C lacquer, and smeared on one end, is usually sufficient for me.

**WHAT ABOUT BURNS?** Such tiny stars are usually not a problem, but those containing metal powder can produce a 2000° scorch in a careless moment; blisters beneath the fingernails are not only painful and inconvenient, but will interfere for weeks until they heal. It's best to keep a container of cold, clean water (or snow!) nearby in case of a burn, and get the injured part in it as quickly and with as little thought as possible - one can worry about how it looks later. Recent neurological research on severe burns has found that the neurons in the brain receiving the pain message are actually injured themselves when they receive the message. If the injured part is dunked before the message



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is received, injury is greatly reduced, and healing is much quicker. Learning to move without thinking takes control, but it's possible to dunk in a few tenths of a second. I have learned to be quick - very quick.

**AIR TESTING.** Once initial curiosity is satisfied, I find it best to take a small, reliable Chinese Class C rocket, dump out the original contents, and replace them with the small test stars. A rocket will take the stars higher, and allow them to fall through a greater distance. As an alternative, a plastic film can, with about an inch of visco pushed through a small hole in the bottom, can be filled with stars and burst, and then the lid snapped on. This then can be fired from a No. 3 base mortar with about 1/4 teaspoon of 4Fg powder, and is nearly silent in operation. No prime or glue is needed, as long as the lift is 1/4 tsp, as seen at the Chlorate/Sulfur Star Demo, at the 1989 Jamestown PGI convention.

**KENTISH TRICK.** For larger pumped stars, in small bore rockets, the technique outlined in Kentish [available from AFN] is excellent. The stars are placed end to end on a sheet of light paper the total length of the stars, and wide enough to make three turns. A piece of blackmatch is rolled up with the stars, and the paper is lightly glued at the seam. Once dry, a sharp knife is used to cut between the stars, leaving the "spine" with the blackmatch intact. They will all ignite, with an attractive "blossoming" effect in the bargain. To form a useful opinion no matter how mediocre or attractive, a star must be seen as it free-falls.

**TIPS.** When proceeding to larger batches, I keep in mind that things may still perform differently when coated with priming, and laying in masses in a drying tray. For example, properly damped zinc granite stars, if primed with a mixture containing lampblack, can get very hot in short order. I always proceed with caution and reserve until characteristics have been observed. Here are some more:

- I never undervalue the benefit of cleaning up.
- I don't store finished material near the work

area. Also I don't work near the drying area. I'd place a barrier between them if necessary. This includes overhead areas where sparks can travel.

- I do line all drying trays with some type of paper, to keep crumbs from falling through, even if it's only newspaper, or a paper towel. It can be used indefinitely until it becomes torn or hopelessly contaminated - then the paper should be burned.

- I do dump out any residue (crumbs) between batches, and get rid of it.

- I burn the residue if I can, and see how fast it goes.

- I hit a small portion of the crumbs with a hammer, or grind my heel on them - are they more sensitive than the unprimed star?

- I don't overload one drying tray with too many stars - they won't dry.

- I don't put wet mixes containing a large amount of charcoal or flake aluminum out in direct sunlight - the moisture will be driven in.

**STORAGE.** For storage, I like the various sizes of plastic freezer containers, and for larger amounts, plastic coated milk cartons. They can be obtained by the boxful, free for the asking, from most of the dairy stands that sell the whipped ice cream that comes from a machine. The owners are usually used to people asking for them for seedling trays and fireplace tinder. They must be rinsed out before the milk curdles, of course. These handy containers can literally set in water for weeks, without leaking, they seal tightly by simply pushing the top down flush with the top, protect against 100% humidity at 100°, and will not break if dropped. Some orange juice half gallon containers have a special foil lining that makes them even better, if you're buying the product anyway.

These techniques, while not rigorously scientific nor complete, have prevented the occurrence of any disasters in my 25 years of pyro experimentation. "It works for me." JHB

## RED PHOSPHORUS -- BRIDE OF FRANKENSTEIN

### THE BIRTH OF POTASSIUM CHLORATE

History does not record the discoverer of potassium chlorate so credit is given to the French chemist Claude Louis Berthollet [1748-1822], who in 1786 prepared it as a pure compound and described its properties. Following the custom of the time it was called "*Sal de Berthollet*" [Salt of Berthollet]. Its "extraordinary activity as an oxidizing agent" soon attracted many. The French chemist Fourcroy described it as a compound seeming to *contain the elements of the thunderbolt in its molecules, one in which nature seems to have concentrated all her power of detonation, fulmination, and inflammation.*

Following its 1786 discovery, a series of failed marriages to this terrible compound; sugar - sulphur - ferrocyanides, were to cause an unending series of deaths and dismemberments, e.g., an attempt to manufacture potassium chlorate black powder (Berthollet Powder) in a stamp mill, Essconne France, 27 October 1788, witnessed by M. & Mme. Lavoisier among others, resulted in the destruction of the mill and the death of two persons. To date no useful potassium chlorate-based propellant has been found.

Due to problems with production and safety, little more is heard of this compound until some years later when Rev. Forsyth of Belhelaive in Aberdeenshire, Scotland, 1804, used potassium chlorate combined with sulphur as a percussion primer for firearms, followed ten years later by "Pauly's priming powder" (potassium chlorate, charcoal, sulphur).

An early practical use for potassium chlorate was in matches. The first potassium chlorate-containing matches (*dip splints*) were made in Vienna ca. 1812. They consisted of wooden splints dipped in sulphur at one end, and then coated with a head composition of chlorate and sugar mixed with glue and colored with a little vermilion. They were ignited by bringing the head into contact with strong sulphuric acid kept absorbed on an asbestos pad, in a small glass bottle or leaden vial.

Sulphur-tipped splints with heads made from a mixture of potassium chlorate with about twice its weight of antimony sulphide along with gum or glue called *Consgreves*, were made in 1832. Ignited by pressing the head strongly between two pieces of sandpaper, ignition was often accompanied by a sharp report or small explosion, the heads flying off still burning without setting fire to the splint. Indeed, the combination of potassium chlorate and antimony sulphide is used in the traditional Italian DIE YOUNG salute mixture, and pull-string booby traps.

Use of potassium chlorate in fireworks had to wait the invention of compounds containing strontium or barium. The first published firework formula using potassium chlorate was in Dr. Moritz Meyer's, 1833 *Die Feuererkerei in ihrer Anwendung auf Kunst, Wissenschaft und Gewerbe*. (The making of fireworks as applied to art, science and industry.) Curiously, Andrew Ures' Dictionary of Chemistry, of 1821 contains a compound using potassium chlorate with strontium nitrate for use in a red theatrical illumination.

Because production of chlorates by the "indirect" or "chemical process" was both expensive and difficult, it was not until commercial production by the use of electrolysis began in 1866 in France, that the use of chlorates on a large scale in fireworks and explosives became practical.

### THEN CAME PHOSPHORUS

Although it is the eleventh most abundant element in crustal rocks and is found in all living things, elemental phosphorus was first reported by the physician/philosopher *Paracelsus* (Philippus Aurelius Theophrastus Bombast von Hohenheim, 1490-1541). It then languished more than a century until 1669, when the alchemist Hennig Brandt of Hamburg, attempting to produce the fabled "philosophers' stone" by reductively distilling a paste of boiled putrefied urine, condensing the vapor under water, and producing a waxy substance that glowed when exposed to air. Surprised by the appearance of this new body, he sent a specimen (now known to be



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elemental white phosphorous) to the German chemist Johann Kunckel (1630-1703) discoverer of mercury fulminate. Kunckel, finding that Kraft would not reveal the secret, resolved to discover it. After many trials he succeeded in 1674.

Robert Boyle improved the process (1680) and called the element *aerial noctiluca* (night shining air), however the name *phosphorous* (Greek, light bringing) soon became generally accepted.

The process of preparation remained a secret until 1737, when an unidentified man made elemental phosphorus before the Academy of Sciences in Paris. That same year, Gahn discovered it in bones, and with Scheele, published a process which allowed production in quantity. It remained a laboratory curiosity until 1844, when Albright began commercial production from animal bones, for use in matches in England; 0.75 tonne was produced in 1844, 26.5 tonnes in 1851.

Phosphorus is now known to exist in seven different forms: five crystalline polymorphs and two "amorphous" or vitreous forms. Of these, two have found use in fireworks, in combination with potassium chlorate. White (yellow) phosphorus was used in devices referred to genetically as "Spit Devils". However, due to the toxicity of white phosphorus and problems during manufacture, its use in Class "C" fireworks was voluntary stopped in this country in 1926. It may yet still be possible to obtain similar devices overseas; the New England Journal of Medicine, 1971, reported on 93 suicide attempts in Bogota, Colombia using an indigenous firework, *totes* containing white phosphorus. White phosphorus was used in *Liquid fire* rockets & shells, as recently as the first New York Worlds Fair. (1940's)

In 1848, denser, higher melting point, less reactive, non-toxic, red (amorphous) phosphorous, was produced by Schrotter by heating white phosphorus out of contact with air for several days.

## A MARRIAGE CONCEIVED IN HELL

Soon after, a marriage conceived in hell was envisioned, that of red phosphorous and potassium chlorate. The sire of this union is often called

"Armstrong's Mixture" after Sir William Armstrong, who used the mixture in artillery shells. Date of the nuptials is unknown, although it would not seem unreasonable to assume it was not long after discovery of red phosphorous, to the regret of many who have attempted the ceremony.

Although several patents exist which show the use of potassium chlorate and sulphur as a fulminant or explosive, I have been unable to locate any patents claiming the discovery/use of a binary mixture of chlorate/phosphorus as an explosive/fulminant.

The earliest patent using chlorate and phosphorus with other ingredients is Canouil's 1860 patent using a small portion of phosphorus along with several other chemicals.

William Johnson's English patent No.2377, of 1856, for a "Fulminating Powder" uses red phosphorus and lead nitrate. (The combination of barium nitrate and red phosphorus was used by the U.S. Army in rifle primers for a short period of time during 1949.)

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The earliest firework patent using this infernal combination is Charles Newton's 1867, "Improved toy torpedo and explosive compound". (Japanese Torpedoes using chlorate and phosphorus are described by Tenney Davis.)

The British (1905), recognizing the dangerous properties of this combination, restricted the amount that could be used, to ensure that "articles manufactured shall not be capable of exploding in bulk".

Armstrong's Mixture was used early in this century in *Knallkorken* (Detonating corks). However, following a series of explosions (1908) during shipping: Philadelphia, Pa., fourteen cases exploded, eight killed, fourteen injured;

# THE BEST OF AFN III

elemental white phosphorous) to the German chemist Johann Kunckel (1630-1703) discoverer of mercury fulminate. Kunckel, finding that Kraft would not reveal the secret, resolved to discover it. After many trials he succeeded in 1674.

Robert Boyle improved the process (1680) and called the element *aerial noctiluca* (night shining air), however the name *phosphorous* (Greek, light bringing) soon became generally accepted.

The process of preparation remained a secret until 1737, when an unidentified man made elemental phosphorus before the Academy of Sciences in Paris. That same year, Gahn discovered it in bones, and with Scheele, published a process which allowed production in quantity. It remained a laboratory curiosity until 1844, when Albright began commercial production from animal bones, for use in matches in England; 0.75 tonne was produced in 1844, 26.5 tonnes in 1851.

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Mystic Wharf, Charleston Mass., two cases exploded, three killed, three injured, one horse killed, importation of these devices into the United States was forbidden. These mishaps were in turn followed (1911) by an explosion in the Berlin Post Office, that caused only properly damage. During WWII the Germans loaded *Hinterhaltsminen* [ambush mines] with Armstrong's mixture.

Current pyrotechnic use is confined to toy caps, a use not unknown in the past: Marcellin Barthelet makes mention of an explosion that occurred in Paris on the 14th of May, 1878, involving eight million *amorces* [appx. 64 kgms. of compound] ~ fourteen dead, sixteen injured.

I have it in mind to make up a series of T-shirts proclaiming; "I survived Armstrong's Mixture!", with a box that could be checked proclaiming With all my fingers intact!! There can be NO DOUBT that this combination is one of the most dangerous pyrotechnic compositions known. More than a few have come to regret tempting the wrath-of-the-Gods by compounding it!!! Per-

haps the most famous victim (excluding your fingers-still-intact author) of this infernal combination is the author of *Poor Man's James Bond*. In his book he describes how he was once stirring about 1/2 oz. of potassium chlorate with "a bit of red phosphorus". He vividly describes the damage to the spatula and mixing bottle, and how the fingers holding the bottle were blown off and considerable damage done to the remaining part of his hand.

All this from an half-ounce of material, incompletely mixed! What is obvious is THIS MIXTURE IS NEVER-EVER-TO-BE-MIXED-DRY; it must be compounded wet - perhaps alcohol or water will do - most of the time (as there is still a lot to be said for bad luck). However, now comes the problem: what-do-you-do-with-it-after-it-has-dried? You now have an explosive sensitive to friction, shock, spark, and flame. A pyrotechnic tiger by the tail! I cannot strongly enough emphasize the danger of this mixture. Remember, most of us are into Fireworks-Pyrotechnics-SFX for fun. THIS IS NOT A FUN MKTURE. DJH

## PHOSPHORUS FIREWORKS

While the details of invention and early history of fireworks containing white (yellow) phosphorus is unknown, its introduction into the U.S. can be dated to 1904 when American patents were issued to Marius Magnard of France, and Karl Hufnagel of Germany (both patents being assigned to Edward H. Wagner of New York City). Production is believed to have started in Belleville, N.J. and St. Louis, Mo. in 1904. Later production was moved to Erie, Pa., and Memphis, Tenn. Due to limited market or hazards of manufacture, production was never widely practiced. Of the 57 fireworks plants in the 1920 census, only three used white phosphorus.

The devices basically had the same appearance - "small discs about 1/8" to 1/4" thick and 1-inch in diameter, with a covering of red or black paper, although in some instances sand or a composition of pitch and naphthalene were used for a coating. Sometimes a larger size ~ 1 1/4" or 2" in diameter was manufactured. When the fireworks

were placed on the sidewalk and struck by the heel or some heavy object, they discharged, giving forth considerable noise in a series of explosions in rapid succession, at the same time jumping about and giving bright flashes of light." And were sold at various times as "crazy crackers" (1904), "automatic torpedoes" (1917), "spit devils", "son of a gun", "automatic torpedo", "devil on the walk", "jumping jacks", "tanks", "dancing devil", "Dixie cricket", "holy terror stick", "bingoes", "cargoes", and "flappers".

"In one factory, the toy took the form of a 'tank' and consisted of a small gray pasteboard container resembling a tank and holding a combustible carrier sheet of tissue paper on which were mounted thirty small pastilles [pills] of the phosphorus compound, arranged at regular intervals. A fuse extending through a hole in the top, attached by an adhesive to the carrier sheet, ignited the toy, which exploded in much the same way as the other phosphorus fireworks. The



'jumping jack' from the same firm, labeled a 'Box of Concentrated Noise', consisted of a small red pasteboard box about 1 1/2" square, with a large circular opening in the top through which the carrier's shell was ignited. It had similar pastilles but a smaller number - 24 instead of 30."

The manufacture of phosphorus fire-works consisted, in general, of five processes: 1) Preparation or mixing of the paste; 2) molding; 3) drying; 4) wrapping; 5) packing. Mixing the paste is the most interesting of the processes.

The mixture had to be prepared with extreme caution as incorrect ratios of phosphorus and chlorate, and failure to distribute the phosphorus in microscopic particles, each one contained in a protective sac of gum arabic, would result in a composition very sensitive to friction. The mixing is described thus:

"The preparation of paste, or 'soup' as it is sometimes called, varies little in the three factories. The composition is mixed in a double-jacket kettle with automatic paddle. Gum arabic and water are dissolved to a syrup-like consistency, and white (yellow) phosphorus [mp 44 °C] is added when the solution is heated enough to melt it. Carbonate of magnesium is then stirred into the mixture, later red ochre is added, and finally chlorate of potash is thoroughly stirred into the preparation."

Sadly, these devices came with built-in hazards, both to the user and manufacturer, unique to phosphorus fireworks:

1) Ingestion of even a small amount of white phosphorus may produce circulatory collapse, coma, convulsions, death. The approximate fatal dose is 50 to 100 mg. Analysis of a phosphorus firework found 213 mg of phosphorus! This combination of a food-like firework with a virulent poison led to not a little grief. The American Museum of Safety reported nine deaths of children (ages 4, 2 1/2, 3, 6, 2, 7, 3 1/2, 2, and 4 years) from poisoning due to eating phosphorus fireworks about the Fourth of July, 1925. Latter patents following the lead of the match industry, replaced deadly white phosphorus with phosphorus sesquisulphide (Tetraphosphorus trisul-

fide  $P_4S_3$ ). Whether or not this proved practicable is unknown to me.

2) The breathing of fumes of phosphorus for several years can result in phosphorus necrosis "phossy jaw". The loss of part/all of the upper and/or lower jaw!

3) Sensitivity. In 15 years, there were 18 fires or explosions due to phosphorus fireworks. That number may include those resulting from fireworks containing non-poisonous red phosphorus. One of the more interesting:

On May 14, 1924, in a stationary store in Rochester, N.Y. "Several clerks were handling a shipment of a carload of fireworks that had arrived from Maryland the day before. One box was not placed properly and fell to the cement floor. The box contained sidewalk torpedoes, the kind that jump and sputter when placed under the heel of a shoe. There was a sputter, sparks flew in the none to well lighted basement and explosion after explosion followed in rapid succession.

"Owing to the explosions which scattered fire to all parts of the basement, the fire made terrific headway and spread to all part of the building. One heavy explosion blew the front doors off the hinges, smashed the plate glass windows, and set fire to four auto-mobiles parked in front of the building, one on the opposite side of the street. Eight employees were injured.

"A serious feature of this fire was the poisoning of the firemen by the phosphorus fumes. Within a few minutes after the firemen went into the building they began to fall unconscious from the gas which filled the floors of the building. Five firemen dropped inside the building hidden by the thick smoke. Twenty-five more firemen staggered out of the building and collapsed, unconscious, as soon as they struck the fresh air. When they regained consciousness they raved and fought like crazy men." (Frankly, this part seems a little strange since burning phosphorus produces phosphorus pentoxide, which immediately reacts with moisture, forming a fog of corrosive but non-toxic phosphoric acid, commonly found in soda and candy!)

*Continued on next page*



In 1906 the international treaty of Berne, prohibiting the manufacture of, importation, and sale of matches containing white phosphorus, was signed. In 1914 the importation into the U.S. of white phosphorus-containing matches was prohibited. Finally, at the semiannual meeting of the U.S. Fireworks Manufacturers' Association in New York on January 30, 1926, the following resolution was passed:

*It is the sense of the meeting that the U.S. Fireworks Manufacturers' Association support the efforts of the Department of Labor to eliminate white phosphorus from the fireworks industry.* In a meeting between the Bureau of Labor and all the manufacturers, it was agreed that production would cease on or before August 15, 1926. Devices of this nature may yet be available in Mexico, South America, and Spain.

Described by Weingart as among the most beautiful pyrotechnic effects known to the art, white phosphorus has on occasion been used in "liquid fire" rockets and shells, with the phosphorus being added immediately before launch. Metallic sodium has also been used for a similar effect, notably within sight of Schloss Zauber, and 50 years ago at the New York World's Fair.

First Aid for Phosphorus Burns: "Since white phosphorus will ignite spontaneously and continue to burn when exposed to air, it is necessary to exclude oxygen until the agent is removed from the burn or wound. This may be done by keeping the burn or wound submerged in water or covered with a wet dressing. Alternatively, the phosphorus particles may be treated with copper sulphate, which produces an air-proof black coating of copper phosphide over them. A 5-percent solution of copper sulphate may be used on burns or wounds, and a 2-percent solution may be used in the eye. Particular care should be taken to keep copper sulphate application to a minimum and to prevent prolonged contact with any copper sulphate preparation with the tissues. There is a definite danger of severe copper poisoning in using this therapy.

"The phosphorus particles should then be removed surgically. The copper coated particles can be seen by their dark color. The burn should

be debrided promptly, in order to remove bits of phosphorus which might be later absorbed and possibly produce systemic poisoning." (Although not water soluble, phosphorus is oil soluble).

## References:

Emma France Ward: 1926 - Phosphorus necrosis in the manufacture of fireworks and in the preparation of phosphorus. U.S. Dept. of Labor, Bulletin No. 405, 44 pages.

-1928, Phosphorus necrosis in the manufacture of fireworks. Journal of Industrial Hygiene. 10(9)314-330.

CM. Sails, 1924 - The menace of phosphorus fireworks. New York State Dept. of Labor, Industrial Hygiene Bulletin. Vol. 1, No. 6

TM 8-285. *Treatment of Chemical Warfare Casualties*, 1956.

TM 8-285. *Treatment of Chemical Warfare Casualties and Conventional Military Chemical Injuries*. 1974.

TM 3-215. *Military Chemistry and Chemical Agents*. 1963.

TM 3-8. Chemical Reference Handbook. 1967.

TM 3-9. *Military Chemistry and Chemical Compounds*. 1975.

## Some patents:

759,387 MAGNARD, MARIUS Pyrotechnical compound 1904.

902,650 GRABER, C.F. Pyrot. device 1908.

969,252 DEVER, B.J. & B.J. DELZEIT Pyrotechnic compound 1910.

1,441,551 ADLER, M.M. Pyrot. device 1923

1,441,552 ADLER, M.M. Pyrot. device 1923

1,503,740 ADLER, M.M. Pyrot. device 1924

1,526,196 ADLER, M.M. Pyrot. device 1925

1,538,785 FABER, H.B. Pyrot. article 1925

1,538,879 ADLER, M.M. Pyrot. device 1925

1,549,485 GEHRIG, W.F. Pyrot. device 1925

1,712,555 GEHRIG, W.F. Detonating firework composition 1929

1,771,116 GEHRIG, W.F. Detonating firework composition 1930

1,805,945 GEHRIG, W.F. Detonating firework composition 1931

1,823,376 REIHLEN HANS Pyrot. device 1931

1,975,679 BLANC ANDRE Percussion detonating composition 1934 DJH

## LESSONS LEARNED IN FLASH PRODUCTION

At the PGI convention in Weedsport I related an experience during my discussion on flash powder as I prepared about 1 pound of simple 7/3 flash for the "shed buster" demo. The lesson of the story is important enough that I would like to pass it on to AFN readers.

Several years ago I had occasion to mix some flash powder for a few bottom shots at my outdoor mixing shed. Although the day was ideal, humid and cool, there was an annoying breeze. The amount of composition in process was 1500 grams, and I was using an aluminum similar to 809, so it was a very light stearin coated flake that floated quite easily into the air. After screening the perchlorate I gently mixed the aluminum and perchlorate on a piece of kraft as the first step of incorporation. During the mixing the wind blew small amounts off the table in the air to my left to harmlessly dissipate, or so I thought. After concluding the mixing I loaded the salute casings as the wind continued to blow small amounts of comp off the table. After capping and taping the salutes I placed them in the magazine and left for home.

Two weeks later I returned to my work area and prepared to mix some star comp at the shed. Before I did that though, I wanted to test a few stars that had been made previously and were dry. So I hauled a cinder block sitting next to the shed a few feet to the left, set 2 stars on the block, laid a piece of bare match next to them, and applied flame from my trusty BIC. The first star bloomed into a beautiful purple, the second star lit and rolled off the block. I was still in a half crouch. Suddenly I was enveloped in a brilliant sheet of white with an accompanying WHOOOOOSSHH. Needless to say I was stunned and my first thought was that I had developed one heck of a monster star! Then I noticed the hair on my hands was singed, the material of my left pants leg was melted and charred, and my glasses were coated with whitish particles. Was it possible that the small amount of flash that had blown off the table some 2 weeks before had caused this? The answer was

ABSOLUTELY! The star that rolled off the block had ignited the flash dust on the ground.

I sat there for some time contemplating this. How could it happen? It had rained at least twice since I had mixed that flash, and the amount that had fallen was insignificant, or so I thought. Examination revealed a light film of aluminum oxide now coating the ground around the block and where I was kneeling. Very fortunate was I to have escaped with only singed hair and melted pants!

Several lessons are to be learned here. First it is NOT a good idea to be testing anything around the mixing area because there is no way to contain or remove composition that may be dispersed even by a small breeze. I was 15 feet away and still had the problem. Secondly, the trousers being worn were a rayon blend and melted like butter when hit by the flash. I displayed them at the convention and use them as a reminder. Fortunately it melted outward and I received only minor burns on my leg. Cotton is the answer. I doubt that cotton jeans or pants would have ignited. Thirdly, my glasses are made of safety material and probably saved my eyes from injury. Wearing goggles or other protection ALWAYS when mixing or assembling material may save the operator's sight. I try and practice safety religiously but even so you never know when such a subtle and lurking demon can strike.

Ironically another pyrotechnist related a similar story to me some years ago and I dismissed it as too far fetched to merit belief. Now I know better and you can bet I'm going to listen with a good deal more interest and attention when I hear similar stories. Experiences like mine should serve to reinforce the idea that we should constantly be on our guard, THINKING all the time about how and what we are doing. The "Blast from the Past" was enLIGHTening to say the least, but I've gotten the message. I am not at all embarrassed to share this experience. I learned from it and I hope you will too. CH



## MEASUREMENT OF AERIAL SHELL VELOCITY

### Introduction

In addition to satisfying general curiosity, there are technical questions requiring knowledge of aerial shell velocity. For example, a calculation of how far down range aerial shells will have traveled at various times after having been fired from highly angled mortars requires knowledge of the shell's muzzle velocity and its effective drag coefficient. In particular, the authors (along with Marc Williams) plan to determine the maximum horizontal range of aerial shells which burst after the normal time fuse delay. This study could be conducted empirically by firing different size shells from mortars at various angles. However, such an approach could be prohibitively expensive and time consuming, and it probably would not allow the examination of as many cases as desired. As an alternative, the question could be examined using a computer model of aerial shell ballistics [1]. This would be relatively inexpensive and any combination of shell velocity, shape, and mass; time fuse delay; and mortar angle could be considered. However, without verification using results from actual testing, the modeled results would always be at least a little suspect. Accordingly, the best choice is to conduct a number of field tests to verify the correct performance of the computer model, and then to model the cases of interest. This article is the first in a series, which will describe the down range study introduced above.

To verify the correct performance of the ballistics computer model, it is necessary to know the velocity of aerial shells. In this article two techniques for measuring aerial shell velocities are described. One technique makes the velocity determination within a few feet of the muzzle of the mortar (muzzle velocity). This method is a slight refinement of that used by E. Contestabile [2]. The other method measures velocity by determining the shell's location at points throughout its trajectory. This method is a slight modernization of a method described by T. Shimizu [3].

### Muzzle Velocity Measurements

Velocity measurements can be made by measuring the time taken for a body to travel between two points separated by a known distance. As such, the measurements are the average velocity between the points. However, if the points are close enough together, such that the velocity does not change significantly during the short time interval for the object to move between the two points, the measurement closely approximates the body's instantaneous velocity. Probably the most common method used for this measurement is to setup one or more pair of "trip wires" [a] for the moving object to cross, with a clock started when the first trip wire is broken and then stopped with the breaking of the second trip wire. This is shown schematically in Figure 1. In this case, the average velocity (V) of the object is:

$$\text{Eq. 1} \quad V = D/t$$

where D is the distance between the trip wires, and t is the time interval.

In the case of aerial shell muzzle velocity measurements, these trip wires need to be strong enough to withstand the blast of burning gases, yet weak enough not to impede the aerial shell. The authors used 0.019 inch diameter insulated copper wire. The wire is held between electric terminals, which hold the wire strong enough not to come loose as a result of the blast of lift gases preceding the shell, but weak enough for the wire to pull loose without being stretched by the passing shell.

The method used by Contestabile [2] employed grids of wires as trips; however, he reported occasional difficulty with debris propelled ahead of the shell severing the wire grid before the shell arrived. To reduce the likelihood of such problems, care should be taken to limit the presence of material such as the paper lift bag and quick match shell leader, which could constitute such debris. Also the grid can be limited to just a pair of wires, thus offering a minimum target for debris to strike. Contestabile used



two grids, placed 1 meter (3.28 feet) apart, with the first grid located 1.7 m above the muzzle of the mortar. In the apparatus used by the authors, the first trip wire was only 1 foot above the mortar and there were three additional wires each at two foot intervals. This allows a total of three velocity measurements. One of the test mortars, with colored tape at the positions normally occupied by the trip wires, is shown in Figure 2. The electronics package which fires the electric match and then times the breaking of the trip wires, was designed and fabricated by Gary Fadorsen of Pyrotech International, is shown in Figure 3.

As an example of some muzzle velocity measurements, consider the data in Tables 1 and 2. These are the results from a series of measurements of six identical 3-inch cylindrical shells fired from finale mortars (17.5 inch long).

It seems that the individual 2-foot timing method only produces results with a 1 sigma precision of about  $\pm 1$  mSec. Thus, even though the Pyrotech instrument records times to 0.1 mSec, the values reported in Table 1 are given to the nearest mSec. It had been hoped that greater precision could be achieved with this method. The timing uncertainty is presumed to be the result of variations in the orientation of the shell upon striking the wire and differences in the amount of yield of the wires before the timing circuits open. The net result is that only the average velocity over the total 6-foot interval is precise enough to be useful. Perhaps with



Figure 2 Photograph of a 10-inch test mortar. Colored tape has been used to indicate the location of tripwires.

further refinement of the method, the precision can be increased so that 2-foot average velocities can be generated, thus allowing an examination of the slowing of shells in the first few feet after leaving the mortar.

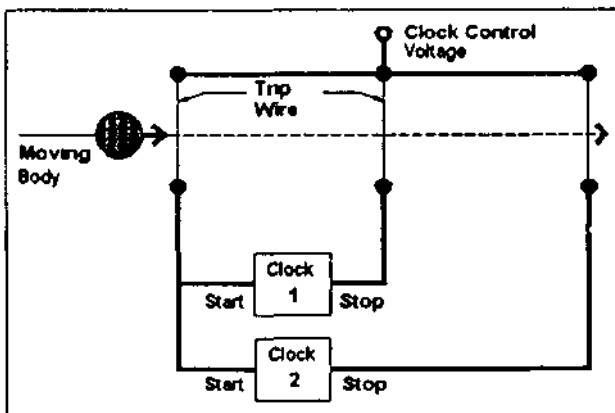


Figure 1 Block drawing of a simple "trip-wire" system for measuring the velocity of a moving body

All electric matches were fired with a current of about 3 amperes, which is expected to produce a firing time of less than 1 mSec [4]. Accordingly, the wide range of times to the breaking of the first trip wire, by shells with similar velocities, is somewhat surprising. This seems to say some interesting things about the dynamics of the combustion of apparently identical lift charges. However, discussion of this subject is better left for another article.

## Aerial Shell Trajectory Measurements

If an aerial shell could be tracked throughout its flight, such that its position can be established at a series of known times, using Equa-



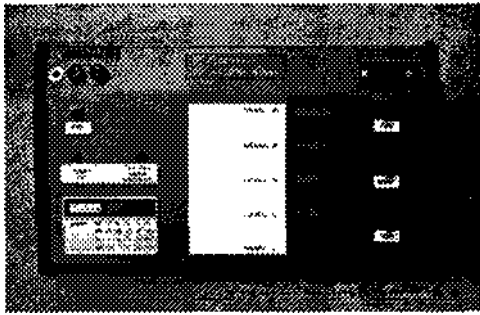


Figure 3. Photograph of the multi-clock electronics package.

tion 1, it is again possible to determine its average velocity during each time interval. Note that in the previous method it was the time required to travel a known distance that was measured, and in this method it is the distance traveled during a known time interval that is measured. To see how this might be accomplished, consider the method described by Shimizu [3]. If a time exposed photograph is taken of an aerial shell with an attached star, there will be created a record of the shell's path. If the trajectory of the shell is nearly perpendicular to the location of the camera, the shell's position as seen in the photograph will be an accurate 2-dimensional representation of its path. If the camera's field of view has been calibrated, such as by taking another picture with a series of landmarks, each of which are visible and separated by known distances, the trajectory of the shell can be quantified. The remaining piece of information needed to establish the shell's velocity along its path is the time elapsing as the shell travels along the path. In the method described by Shimizu this was accomplished by taking the time-exposed photograph through a rotating disk with a hole

in it. Shimizu's disk was rotated at a rate of 25 revolutions per second. In this way the photograph appears as a series of points, each point indicating where the shell was located at each 1/25 of a second throughout its flight.

In the method used by the authors, the still camera and rotating disk were replaced with a video camera. Video cameras record 60 distinct images (fields) per second and VCR's (at least the more expensive newer ones) play back the individual still images one at a time [b]. Thus it is possible to record and play-back 60 images of the shell's position for each second during its flight. If a transparent plastic film is temporarily taped to the face of the video monitor, the location of a shell at each 1/60 of a second during its flight can be plotted using a fine tipped marking pen [c,d]. Depending on how the camera has been set up and the velocity of the shell at that time, the shell may move only a very little during each 1/60 second. In that case it may be preferred to plot the position of the shell once every 6 or 12 images (i.e. every 0.1 or 0.2 seconds). In this study two cameras were used, one zoomed in to measure the shell's velocity as close as possible to its exit from the mortar, and the other taking a wide angle view encompassing the entire flight path of the shell. The results recorded by the two cameras are illustrated in Figures 4 and 5. In these figures the effect of parallax [d] and round-off errors can be seen as slight inconsistencies in the plotted locations of the shell. Such errors tend to cancel out over extended or averaged measurements.

There was one additional modification to the Shimizu method. The externally attached light

Table 1. Raw Data from Measurements of Muzzle Velocity of 3-inch Cylindrical Shells

Shell No.	1	2	3	4
1	59	69	82	89
2	109	121	133	145
3	94	104	(a)	124
4	63	74	84	95
5	94	105	114	124
6	81	82	103	115

(a) This data value was not recorded.

Table 2. Average Velocity Results for 3-inch Cylindrical Shells.

Shell No.	1 & 2	2 & 3	3 & 4	1 & 4
1	200	150	290	200
2	170	170	170	167
3	200	-	200(a)	200
4	180	200	180	188
5	180	180	200	200
6	180	180	170	176
Average = 188				

(a) Measured between trip wires 2 and 4.

producing star was replaced with an internal flare, which was mounted to be flush with the exterior of the shell. In this way, the aerodynamics of the shells are not significantly affected by the light source.

To analyze the trajectory data it is necessary to convert it to numerical form. This can be done by removing the plastic film from the video monitor and laying it over graph paper. Alternatively, it is possible to use a plastic film which already has a graph produced on it (such as would be accomplished by making an overhead projection transparency of a piece of graph paper). One way or the other each shell point needs to be converted to an x-y value, and then, using the landmark calibration data, converted to full scale vertical and horizontal distances. At this point, Equation 1 can be used to calculate average velocity between any pair of points along the shell's path. Finally, using the time information (by counting images), the time to apogee and impact can be determined.

When an aerial shell fires, a large amount of fire projects out of the mortar before the shell exits. This fire makes it impossible to see the aerial shell with its internal flare until a short time after it leaves the mortar. For example, in Figure 4, the first shell trajectory point was recorded about 0.1 second (6 video fields) after fire is first seen in the mortar. At that time the shell has already risen about 25 feet. Using the data of Figure 4, average shell velocities were calculated for each tenth second from 0.2 to 0.5 seconds. The results were: 221, 204, 194, and 187 feet per second, respectively.

In Figure 5, each twelfth point along the shell's trajectory was plotted. This corresponds to one point every 0.2 second along its path. In this case, the shell reached its apogee of 340 feet 4.0 seconds after firing. It fell back to the ground at a point 190 feet down range, 9.2 seconds after firing.

Aerial shells tend to tumble after leaving the mortar. When that tumbling is such that the flare is sometimes blocked from view of the camera by the body of the shell, the light from the flare will intermittently dim or disappear.

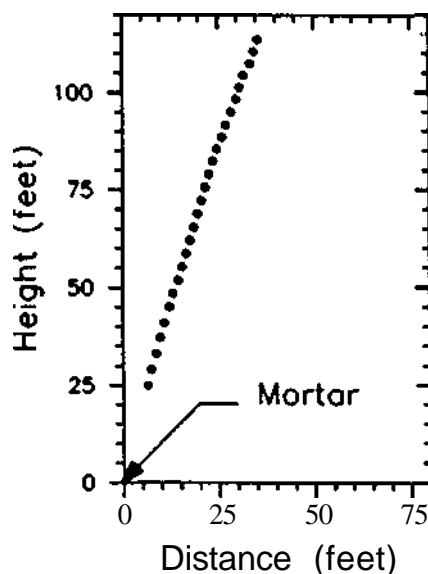


Figure 4. Trajectory of a 4-inch cylindrical aerial shell just after exiting the mortar.

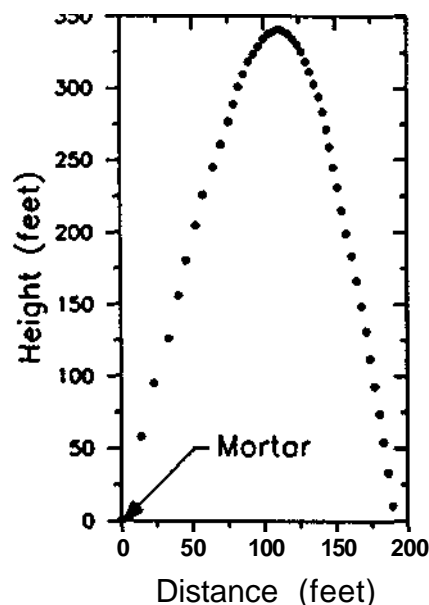


Figure 5. A plot of the entire trajectory of a 4-inch cylindrical aerial shell.

When this happens, it is possible to measure the rate of that tumbling. In a data set similar to that shown in Figure 5, it was determined that the tumble rate of the shell was 5.3 revolutions per second, and was essentially constant throughout the flight of the shell.

## Conclusion

There are other methods, and many variations and refinements that can be used to measure aerial shell velocities. The methods described here are not original and may not be the best for all applications. However, they are the ones most commonly used by the authors and seem to produce adequate results.

## Notes

[a] A trip wire as defined here need not be an actual wire. One possibility considered for aerial shells was to use light beams as the trip wires, such as is often used to measure the muzzle velocity of bullets. However, because of the smoke and fire that exits a mortar well before the aerial shell, this method was discarded as impractical.

[b] The individual images seen on a TV screen are "frames", each of which consists of two 1/60 second "fields" (a & b) through a process called interlacing. In pause mode VCR's produce an interlaced version of just a single field. Upon advancing to the next still image some VCR's advance two fields. These VCR's are sometimes referred to as a-a machines, and there is 1/30 second elapsing between the still images. Other VCR's (generally the more expensive ones) are so-called a-b machines, which advance only one field at a time and have a time interval of 1/60 second between still images. In measuring shell velocities, it is important to know whether 30 or 60 images are reproduced per second; however, all else described herein is the same.

[c] This should be a pen that will write on "anything", such as Sanford's "Sharpie" permanent mark-er, which comes in normal and fine tip configurations.

[d] Because of the thickness of the glass on the picture tube of the video monitor, it is necessary to take steps to avoid errors from parallax when marking the screen. This can be done by looking with one eye and attempting to always position one's eye perpendicular to the point on the screen. Note that small errors from parallax will tend to cancel-out in an extended series of measurements. Another problem with the video monitor is the slight curvature of the screen, which makes it difficult to firmly attach the plastic film. Both problems can be eliminated by using a "frame grabber" and dumping the video display to a computer for analysis.

## References

- [1] K.L. and B.J. Kosanke, "Computer Modeling of Aerial Shell Ballistics", Pyrotechnica XIV. Austin, TX, 1992.
- [2] E. Contestabile, R.A. Augsten, and T.R. Craig, "A Study of the Firing Characteristics of High Altitude Display Fireworks", Proceedings of the 13th International Pyrotechnics Seminar. Grand Junction, CO, 1988.
- [3] T. Shimizu, Fireworks. From a Physical Standpoint. Part 3. Reprinted by Pyrotechnica Publications, Austin, TX, 1985.
- [4] K.L. and B.J. Kosanke, "Electric Matches and Squibs", American Fireworks News. 150, 1994. KL&BJK

## STARS BLOWN BLIND

When an aerial shell bursts, those stars that fail to burn are often said to be "blind stars", or more descriptively as having been "blown blind". This detracts from the beauty of the shell and contributes to debris fallout. The problem can be caused by any of a combination of factors, the most important of which are, the degree of violence of the shell burst and the burn characteristics of the stars.

In simplest of terms, a star will ignite when its surface has been raised to its ignition temperature. The star will continue to burn only so long as the burning surface feeds sufficient energy to the next layer of the star, to raise that unignited composition to its ignition temperature. (See Figure 1.)

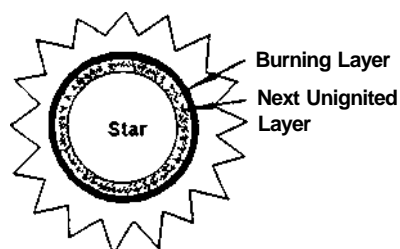
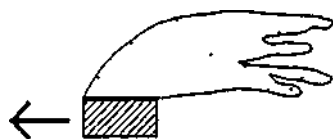


Fig 1 Illustration of a burning star



Stationary Burning Star



Burning Star in Motion

Fig 2 Illustration of the effect of air movement past a burning star

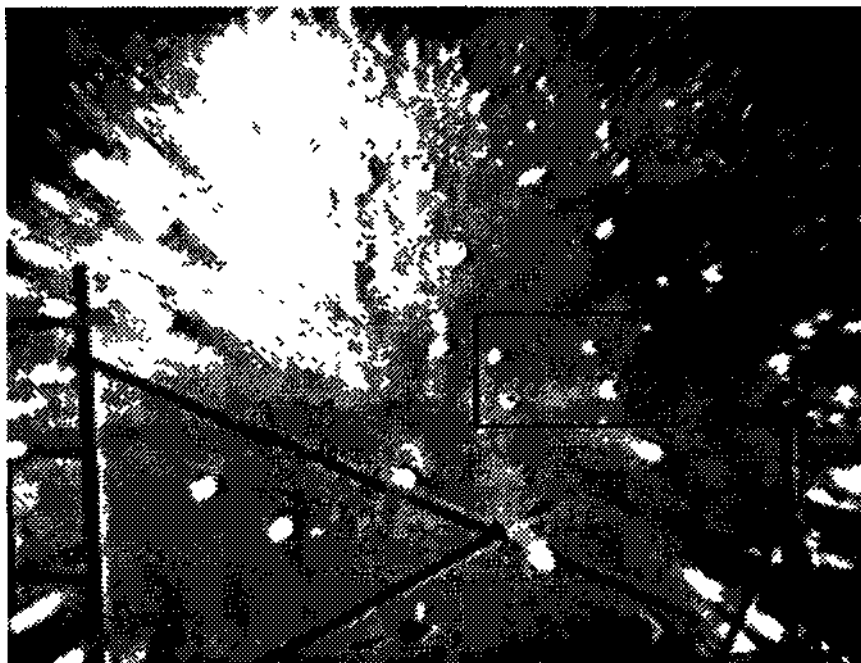


Photo 1 Explosion of an aerial shell in test stand

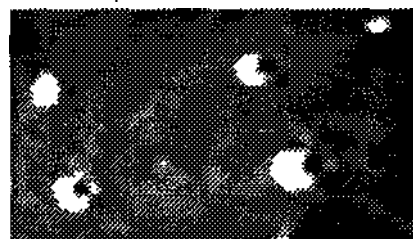


Photo 2 Enlargement of Photo 1 showing the flames trailing the burning stars

One way in which thermal energy is fed to the next (unignited) layer is for radiant energy from the flame to be absorbed by the star and conducted into the star. When a burning star is moving through the air, the flame will be deflected down wind. (See Figure 2.)

Thus, in this case, the flow of energy to unignited composition is impeded. During some recent tests, this effect was captured on film. Photo 1 shows the explosion of an 8-inch aerial shell suspended in a test stand. Photo 2 is an enlargement of a portion of Photo 1, showing stars (dark spots) with their flames (light areas) trailing behind.

If the amount of energy being fed back is no

longer sufficient to raise the next layer of the star to its ignition temperature, the burning star will be extinguished. Among those factors of importance in determining whether this will happen is the speed of the star through the air. The faster the star is moving, the more its flame trails behind, and less radiant energy is fed back. For a given star size and mass, its initial speed is determined by the violence of the shell burst. Thereafter the star quickly slows down, due to aerodynamic drag forces. Thus, if a star manages to stay ignited during the first brief moments after the shell bursts, it will generally burn completely.

Other important factors determining whether a star will be extinguished upon shell burst depend on the chemical nature of the star. For example, one factor is the amount of heat being produced by the burning composition; another is the amount of energy needed to raise a composition to its ignition temperature. (For a more complete discussion of pyrotechnic ignition and propagation, see the authors' "Chemistry of Fireworks" course notes.)

Often star priming is only thought of in terms of aiding star ignition. However, it is also an important aid in the continuation of burning during and just after shell burst. When the authors manufactured spherical stars commercially, it was learned that the optimum amount of rough meal prime to use was, as much as possible without noticeably delaying the visual appearance of the star after the shell burst. Generally this was 10-15% of prime (by weight) for stars larger than 3/8 inch, and 15-25% for stars smaller than 3/8 inch. This was felt to be optimum for two reasons. First, with this amount of prime, perchlorate color stars and even strobe stars would stay ignited even after emerging from hard-breaking shells. Second, rough meal prime (75% potassium nitrate, 15% charcoal, 10% sulfur and +5% dextrin) is the least expensive composition used in making stars. The more of it that could be used without detracting from the star's performance, the less expensive the stars could be made.

Blind stars are often thought of as failing to ignite before the shell bursts. However, as can be seen above, the stars may have ignited, only to

be blown blind by the explosion of the shell. Two easy solutions to the problem are to break the shells more softly or to prime the stars more heavily. KL&BJK

## ASKS ABOUT NICKEL TOXICITY

One of our overseas readers is working with nickel compounds and wonders about the toxic nature of nickel and what occurs during the burning of nickel-containing formulations. He writes:

"I am quite keen on experimenting with the nickel compounds described in Lloyd Scott Oglesby's book on glitter [*Glitter, Chemistry & Techniques*, available from AFN]. My aim is to try and reproduce the crackling effect described. I have some nickel oxide, NLO., and some nickel carbonate may be obtainable. Just one thing worries me: the possible formation of a very toxic substance known as nickel carbonyl,  $\text{Ni}(\text{CO})$ .. This substance is reputed to be toxic at extremely low levels, much lower than many of the other toxic substances formed by burning fireworks.

"I am aware that the exposure would actually be for a very short period of time and that a person effectively breathes in a fraction of the gases actually produced. However, I do hope to experiment with gerbs which will burn at ground level, which means that the gases produced will not disperse the same way they do in the air.

"Nickel carbonyl is reputed to be formed when carbon monoxide comes into contact with an active form of nickel (as in welding stainless steel). What I do wish to know is if this can occur with nickel oxide or carbonate in the average kind of glitter formula. And if it does, what are the hazards?" IvM

## THE MANY PYRO USES OF WAX - Part 1

Several years ago I experimented with different methods and materials of dipping various firework components. The idea driving me was to find a more efficient (labor saving) way of sealing small aerial shells or components of shells. Sealing shells and components (also known as inserts) is perhaps the most important operation in making fireworks that function successfully. If a shell is launching out of a mortar or an insert component is bursting forth in the sky, it is subjected to intense flaming gases at high pressure.

Traditional shell and component construction requires much tedious and laborious effort at gluing, sometimes spiking, and pasting-in to get that just-right effective flame barrier and seal. To understand this better, imagine an aerial shell in flight. The time delay fuse burns to the inside, igniting the cross match. The cross match flares out, igniting the central core of 2FA black bursting powder (or perhaps a flash bag) which in turn generates a tremendous flame and gas pressure to ignite the stars, component fuses, and to burst the shell. The flame surrounds every insert component in the shell and the pressure expands the walls, tearing, splitting and rupturing the shell. The sudden release of pressure hurls the stars and components out away from the center of the burst. The insert components might have been box stars, comets, crossettes, shell of shell, rosettes, lambetties (small reports), sietines (larger small reports) or cannonade (tube) salutes, etc. The components had better have a good flame seal or they will ignite and be consumed at the instant of main shell burst. Sometimes shell inserts will detonate on the burst charge ignition, thereby destroying all the planned effects.

I had tried several different kinds of dipping materials; each proved successful and effective in limited ways. However, all those materials were expensive or health hazards which prohibited mass production. Also, the processes were messy and required suspending the dipped items until they were dry. I had just about exhausted all my ideas and had given up. Then one day, I was having a conversation with my paper tube supplier. I was purchasing a large quantity of

cardboard mortars and asked if they had a way of waterproofing them. They enthusiastically detailed how they dipped the mortars in 300° wax and the paper in the mortars "just sucked it up like a sponge, sealing every fiber in the paper." I thought, "Wow, what an idea, but 300° was out of the question." After much thought, I decided to find out what wax (the canning or candle type) could do for me. What were its limits? At what temperature would it safely and effectively penetrate loaded paper tubes or paper cans I used in making fireworks? How low could I go in temperature and still get good fiber seal? Would the wax-fiber seal be good enough to withstand mortar pressures? Would the wax-fiber seal withstand bursting pressure? Would I need multiple dipping? How many? If successful, what SAFE procedures had to be developed for mass production handling? What equipment was necessary? What were the limits in all these questions and more? When was the use of wax on shells and components NOT desirable? When and under what conditions did it become a hazard to shell performance? What steps were required to make the manufacturing site safe while processing with hot wax?

As I experimented, I got more and more excited with my discoveries. I thought to myself, some of these discoveries have the potential of revolutionizing conventional fireworks making. I have kept these secrets to myself for about 5 years now. The reason was because I was challenging old proven conventional methods which required intense labor. Just about all fireworks companies that have a good product employ the conventional methods and have done so for generations. These new discoveries I had made with the use of wax, while requiring careful supervision of safety during processing, proved to be effective in safely preserving quality and performance, while reducing labor down to an almost embarrassing minimum. This issue could be somewhat controversial if not documented carefully and explained in painful detail. Previously, I did not have much time to write, but now that I have retired from manufacturing fireworks, I am going to enjoy sharing many of my adventures and discoveries with AFN readers. WO

## THE MANY PYRO USES OF WAX - Part 2

The waxing method must be thought of as a system. All of the parts of the system must work together for any of it at all to be successful. The parts of this system are: (1) safe location to do the work; (2) wax melting tools AND temperature control; (3) safe methods; (4) proper paper or cardboard assembly of insert component or shell before waxing; (5) careful 100% inspection after waxing; (5) knowledge of limits.

All waxing should be done outdoors on a sturdy table, weather permitting. Access to an outdoor open rain/sun roof shelter (four or more posts supporting a roof) is better yet. Working indoors is a bad idea simply because movement is restricted and there is nowhere to run should the molten wax container fall or get knocked over. If this happens, it will also be near impossible to clean up the mess once the wax hardens. Also, molten wax spilling on a source of exposed heat energy could flash wax vapors into flame. For this reason, one does not use hot plates or open heat element to heat the wax container. Electric melting pots with cords running across the floor pose a tripping hazard which adds to the risk of spill. If glowing heat elements can be seen through openings or peep holes in the lower enclosed area of the melting pot appliance (such as deep fryer pots), it is NOT a totally enclosed heat source. Anyone who uses such an appliance indoors to wax fireworks is a fool waiting for Murphy's Law to teach him a tragic lesson.

The melting pot (two needed) should be an industrial or lab grade heating vessel with precise temperature control and a totally enclosed heating source. The worker must NEVER use flame, open heating elements or hot plates where he is going to work on, with or near fireworks.

If prices for the industrial or lab grade melting pots are out of reach, the next best heating pot (two required), when used outdoors, is an electric deep fryer or vegetable steamer with a temperature control knob. The electric heating elements on these must be totally enclosed for them to be safe. The temperature control is not precise and a good metal probe dial thermometer (300° F range) or thermocouple with remote temperature indicator is mandatory. A metal probe oven or

candy making thermometer works well. One must avoid glass thermometers because they break easy. Eventually it can be determined where to set the knobs on the deep fryer appliance to maintain the proper wax temperature and the knob dial can be marked. Remember, the temperature markings on these appliances are for hot oil and are not precise. Once the desired temperature is reached, these units will control within 10° F, which is acceptable.

The wax melting process, once started, must not be left unattended. The equipment must be turned off if the operator must leave the area. Personal safety is also important. Safety glasses or goggles should be worn as well as an apron and cotton or rubber gloves.

After each session of wax dipping, the melting pots must be brought indoors after they are cool since water or rain contamination must be avoided at all cost. If the wax gets contaminated with water, it will explode and splatter molten wax 5 feet into the air the next time it is heated for use. Water is heavier than wax and will sink to the bottom of the vessel. The heat source is directly under the vessel bottom and will cause the water to flash into steam the next time the pot is turned on to melt the wax.

The reason two melting pots are needed is because dipping is done in two stages each at a different temperature. The first stage is the paper penetration stage and is done at 200° F. This seals the paper fibers and any pin holes in the assembly of the device being waxed. The item is then cooled to allow the wax to harden (it takes only a few minutes). The second stage of dipping is then done at 180° F, providing a heavier coat of wax which serves to protect the first penetrating layer of wax. The lower temperature is necessary to prevent the second layer of wax from completely melting and stripping the first layer. If the second layer of wax is applied at a temperature lower than about 170° F, it will coat but not stick very well into the first layer. The result is that the second layer breaks and flakes off (in chunks and sheets) from the first layer.

These stated temperatures give excellent performance results and are safe to work with. Many people are using hot melt glue to seal time delay fuses on shells. Hot melt glue has a melting temperature of 350 to 375° F typical. The lower working temperatures of wax stated above involve less risk when you consider the melting point of sulfur (the lowest in the family of fireworks chemicals) at about 300° F.

Some people may think I am crazy but you can't argue with success. I have personally supervised the assembly and successful firing of more than 100,000 2" & 3" waxed aerial salutes **WITHOUT FAILURE** in safety or performance. These shells

were not spiked and they were not pasted-in. There is much, much more to this story.

The reader now knows enough to be dangerous. I have stated temperatures but have not detailed how long to hold items submerged in the molten wax. Also, I have not detailed shell or component preparation before waxing. Remember, as I stated early in this article, the successful use of wax as a labor saving method of production requires understanding of its use as a system. The proper assembly of the shells and components **PRIOR** to waxing is crucial. Those details will be covered next. In the meantime, please continue to leave the wax alone until you get the whole story! WO

## THE MANY PYRO USES OF WAX - Part 3

In Part 2 of this series of articles on wax, I mentioned that the waxing method must be thought of as a *system*. The parts of the system are: (1) safe location to do the work; (2) wax melting tools **AND** temperature control; (3) safe methods; (4) proper preparation and assembly of shell or component before waxing; (5) careful 100% inspection after waxing; and (6) knowledge of limits. As a system, all of these concepts must be practiced for results to be safe and acceptable.

Not all fireworks items can be waxed. There are limits involving size, weight, function, etc. For example, shells bigger than 3" cannot be waxed and expected to perform safely. Wax impregnation and coatings are simply not strong enough to protect the heavier shells from the set-back tearing or rupture that may result in flower pots or detonation in the mortar. Set-back is the shifting of the shell contents, causing their weight to bear against the shell bottom and walls as the shell accelerates on lift ignition in the mortar. For this reason, shell waxing is limited to 3" salutes or smaller (2"). I have successfully fired paper-can-style waxed 3" color shells (spiked or unspiked) with as much as 1.75 ounces of FFA black powder lift. Normal lift for this shell is 1 ounce of FFA powder. I went as high as 1.75 ounces to test the effectiveness of wax in preventing flower pot shells. I did this with star shells because I did not want to risk flower potting a

salute. Everyone should follow this example with their first test shells. As a result, another limit was discovered. Star shells that have been waxed produce burning paper fallout that flames or glows all the way to the ground. This does not happen to salutes because the flash explosion has an extremely fast flame and the high energy disintegrates the shell casing into tiny particles. **DANGER:** Do NOT try to wax and fire salutes larger than 3" and do not wax star shells of any size including shell of shell inserts. Any shell larger than 3" will probably detonate in the mortar and any star shell will produce burning fallout. Anyone interested in the wax process should memorize these stated limits!

So far, I have successfully used wax to produce: box stars, comet stars, comets, crossettes, rosettes, lambetties, sietines, cannonades, 2" aerial salutes, 3" aerial salutes, and 3" nautical (fired into a river) star shells. It is important to note that wax not only flame proofs (during lift or burst) small shells and inserts, it also waterproofs. It also will waterproof visco fuse. Contrary to popular belief, visco fuse is only water resistant, not waterproof.

Three inch aerial salute shells must be prepared in a special way. Casings should be 2 1/2" in diameter, 2 3/4" long, have 1/4" walls, and can be spiral or convolute wound. The paper end caps





must have a snug, tight fit against the shell wall when assembled. Ace Paper Tube Corp. of Cleveland, Ohio is an excellent source for quality casings as described. The end caps must be reinforced on the INSIDE with inside diameter snug fitting 2-ply 1/8" cardboard or chipboard discs. The discs do not have to be glued to the inside of the end caps; a press fit into the cap will suffice. The end caps AND discs are glued to the casings with generous proportions of Elmer's white glue spread around the inside circumference of the cap and circling the disc, covering at least 1/4" in from the edge of the disc. Remember, the casing wall is 1/4" thick and the discs inside the end caps must be sealed against the wall radial end. The caps must be sealed against the outside diameter of the walls where they meet.

After filling the casing with flash powder, the other cap with inside disc and time fuse inserted through the center hole, is glued in the same manner to close the casing. The time fuse is sealed and secured to the end cap on the outside with a generous fillet of a hot melt glue.

The seam of the top and bottom end caps around the shell wall (circumference) MUST be taped with one complete turn of masking tape. The tape must then have all the air bubbles smoothed out by spinning the shell under hand pressure. Air bubbles allow wax to seep under the tape, rendering the tape's adhesive useless. All of these mentioned steps are part of the system for successful performance after waxing.

Two inch aerial salute casings are prepared the same except there is no need for any end cap discs.

Shell dipping in liquid molten wax is actually the easy part. Working outdoors on a sturdy table, I would turn on the two wax melting vessels and bring them up to temperature with a 3/4 full charge of wax. The wax pot cannot be filled up as it would overflow from displacement when a shell is submerged. One wax pot should be set and controlled at 200° F and the second wax pot set and controlled at 180° F. These temperatures must be observed with a good thermometer, preferably a metal probe dial thermometer. It is

necessary to wait for the temperatures to stabilize before proceeding, which could take up to 2 hours.

With the wax in a liquid state and the temperatures stable, wax dipping may commence. I am sure to wear safety goggles, gloves and an apron. All cords and wires should be carefully dressed down so that no one can trip on them. Now I would pick up one of the salute shells by the time delay fuse and submerge the entire shell in the 200° F wax for 15 to 30 seconds. The wax should cover the entire top of the shell and to the top edge of the hot glue fillet around the time delay fuse. I don't worry if any wax gets on the side of the time delay fuse. However I would avoid submerging the open end powder core of the time fuse. I carefully observe the bubbles rising from the salute casing as the wax penetrates every fiber and pin hole opening it will find. The submerge time of 15 to 30 seconds is to allow deep penetration of the liquid wax. Then I remove the shell from the wax and set it down on a smooth hard surface. Marble is best because it is cool. Formica or equivalent is acceptable. If the weather is hot, a small fan blowing air over the waxed shells helps to cool them faster. The appearance of the waxed shell should be dull and dark brown. I dip as many shells as the cooling area surface will hold but I don't allow the shells to touch each other.

Once cooled, the shells are ready for the second dipping in the lower temperature 180° wax. I dip the shells in this wax the same as described for the first dipping except I would do it quickly. I would not submerge the shell in this second dipping any longer than 2 seconds nor any less than 1 full second. After removing the shell from the wax, I would be careful not to tilt or drain the puddle that forms on the top of the shell, but carefully set the shell down on the cooling surface. The bottom of the shell may stick to the cooling surface (formica or marble) and some wax may come off when the shell is picked up. If enough time is allowed for the wax to cool and harden, only a little, if any, wax will break off. I keep the cooling table surface clean by scraping any stuck wax off with a spackling knife. WO



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## THE MANY PYRO USES OF WAX - Part 4

In Part 3 we saw in detail how I prepare and dip in molten wax (2 stages) small 2" and 3" aerial salutes. I described how the casings must be first properly and thoroughly sealed, how the time delay fuse is sealed with hot glue, how the end caps and discs are assembled and glued, and how the outside of the caps are then taped tightly with masking tape. It is important to understand that the described method is successful and reliable as an assembly system. Substitutes in material or methods may not yield acceptable results or may be unsafe.

There is only one purpose in using wax to finish small salute shells or certain shell inserts: to seal and fireproof the item from premature ignition in a sequence of performance. When considering the small shell shot from a mortar or an insert item burst from a shell, the ignition environment surrounding the shell or insert item is intensely hot but for a very short time. Wax requires much more time to melt and therefore is a successful barrier in these circumstances. For wax to be a successful barrier to flame under pressure each and every time a waxed shell is fired, all the ways and means that a flame leak can occur must be checked.

The traditional way to flame-proof a shell is to "paste-in" the shell with multiple layers of kraft paper saturated with wheat paste. When the worker "breaks" paper with paste, he squeezes and mashes several layers of kraft paper sheets together with copious amounts of watery paste sandwiched in between. This effectively seals the pores of the paper fibers but not 100%. If it did seal 100%, only 1 turn of paper during shell pasting-in would be required to protect the shell from lift-flame when blasted out of the mortar. Hence, with small shells there are usually 4 or more turns of kraft paper during pasting. With larger and heavier shells, the kraft paper not only seals the shell but also gives strength to the shell. The heavier and larger the shell, the more paper (and twine spiking) are required to give the shell strength to endure the forces of lift set-back and flame pressure. Fortunately, small 2" and 3" salute shells are light and have casings strong enough to endure these forces provided

they are effectively sealed. Wax provides this effective seal barrier.

When small shells are dipped in 200° F molten wax, the paper instantly sucks the wax like a sponge into every pore and fiber. The shell is seen giving off hundreds of bubbles as the micro-sized pin holes and spiral seams in the cardboard casing fill with wax. For this reason, wax is tremendously more effective at flame sealing than paste. However, the drawback is that wax does not add any strength to a casing as multiple turns of kraft paper will. Hence we are limited to utilizing the wax sealing method to small salute shells and inserts. The second and final dipped coat of wax is cheap insurance for a well sealed shell.

As with all fireworks manufacturing, it is important that each shell be 100% inspected after final dipping. Any holes or gaps will be obvious and the shells can simply be redipped. It has been my experience that shells failing visual inspection after wax dipping are rare.

During the hot summer, these shells should not be left in the direct sunlight while setting up a display. Sometimes the final wax coating will melt, soaking into the final paper wrap. The wax rehardens as soon as the shell is loaded into a mortar or is placed in the shade. While the shell looks messy, I have never experienced a problem when the shell is fired. Remember, with 2 dip-pings, the shell is impregnated with wax for an effective flame seal.

Crossette, box and comet stars can be waxed quickly, saving considerable time by eliminating paper pasting. The cylinder shaped comet or star is held on one end and dipped once, leaving one end open for ignition. The dip is done quickly to only coat the pressed star composition, thus effecting a controlled end burn by flame proofing one end and the sides. The flash core of crossettes can be sealed with hot glue and a small cardboard disc.

Saetines, lambetties, cannonades, etc. can be effectively wax sealed too. Surprisingly, quick dip-

ping with wax does not ruin well made 12 ply black match. It controls the burn and slows it a little when coated (not soaked). Black match should not be soaked in molten wax or it could be rendered useless.

There is much to yet be discovered with wax as a useful production material in the making of fireworks. Wax is a tenacious material that will stubbornly stick to just about every material including glass. It seals like plastic, is pliable and malleable. It has a low melting point, making it easier and safer to work with than hot melt glue and yet is hard at room temperature. When heated to 200° it has a very low viscosity with extremely good penetrating quality.

Some of the old timers will undoubtedly think I am crazy. To the best of my knowledge I have stated the limitations of this process as I have learned them. I freely admit that waxing shells will not replace all the performance attributes of pasted shells, especially large caliber. However, you can't argue with success and I have supervised the manufacture and safe firing of over 100,000 2" and 3" aerial salute shells in the past five years. Productivity increases for making aerial salutes with this process are about 400%. I have personally dipped over 1,000 shells in one day. Do you know anyone who has pasted-in that many shells in one day working ALONE? This, of course, was after the shells were assembled and prepared for dipping by others.

Remember the importance of working with wax within the limits of the system (review part 2) and think safety when working on this or any fireworks materials! WO

## QUOTE OF THE MONTH

Concerning mention in AFN of somebody putting gravel in their Class C items, someone at the PGI convention reported seeing a sign in a fireworks shop in China:

*No sand in our crackers.*

## MORE ON USING COARSE ALUMINUM TURNINGS

*See original article on next page.*

Coarse aluminum turnings are very difficult to work with, with lots of problems to solve.

One problem is that if one uses quite a lot of it in fountain formulas (from 10% in meal powder-based formulas, up to 50% in perchlorate-based white flitter fountain formulas), the turnings act like little springs, preventing the necessary compacting the pile of mix during loading. Every time one wants to compact another scoop of comp, the upper level is raised because of the springy turnings. This introduces unpleasant air pockets and voids, leading to a deafening report when these white fountain candles are lit.

Another problem occurs when the fine ingredients are first mixed, and then the coarse turnings are introduced. Because of that, fine oxidizers and fuels accumulate in the voids of the turnings, leaving, depending on the type of oxidizers and fuels used and the amount of air pockets, little bombs which will later on after lighting, act like one huge bomb.

A solution to both problems would be to chop up the coarse round turnings into non-round chips. Because of the toughness of aluminum and the size of the turnings, very heavy milling probably would be needed. RP

I've a rocket in my pocket,  
I cannot stay and play.  
Away she goes,  
She burned my toes,  
It's Independence Day.

David Herdt  
Contributed by e.e.h.

## USING COARSE ALUMINUM TURNINGS

The aluminum I'm referring to is the cheap and readily available type which you can get (often for free) from anyone who works with a lathe.

I do not recall having read anywhere that you can use this type of aluminum in pyrotechnic applications. Winokur<sup>1</sup> states that they produce "no aluminum effect". When mixing this aluminum with black powder, I could not get white sparks either. But when I mixed magnesium turnings and potassium nitrate (1:1 ratio) I got a fierce white flare. Doing this with aluminum produced a significantly lesser white light. However, I have heard from two Dutch pyro colleagues that in combination with other fine mesh aluminum powders one could use this aluminum, i.e., let it burn and produce white sparks. I have not tried this. In this situation, the temperature is much higher and therefore the big particles could burn instead of just glow. But fine mesh aluminum powders are generally highly priced, so the advantage of using aluminum turnings is (partly) gone.

I tried a composition based on Troy Fish's glitter mix<sup>2</sup> but I enlarged the percentage of sulfur. The main reason for this is that the aluminum particles are so large. I will give the composition which I used in my first try. Because of lack of time, I have not yet attempted to alter percentages to achieve better effects.

In my black powder I use fertilizer grade potassium nitrate and agricultural grade sulfur. From the potter hobbyshop I obtain my magnesium carbonate. The glutinous rice starch ("toko") comes from a Chinese food shop. I use no soft charcoal, but just the ordinary barbecue type.

The resulting effect is not a real glitter, but nevertheless, the effect was nice. It could be described as a combination between a badly

functioning glitter and a "firefly" effect. The aluminum sparks are significant! The white sparks seemed like some kind of stretched flashes. I use the word fountain, but Americans consistently seem to call them "gerbs", for a reason unknown to me. The fountain had a very similar effect, but care must be taken not to consume the effects within the container! Adding some polverone granules to the mix could help to make it burn with more gas production.

I put the cut stars in a 4" cylinder shell, but they burned almost to the ground. This brings me to an interesting secondary effect, which would be wonderful for shooting sites next to water. If the smoldering dross (which would pose a fire hazard in dry locations) hits wet surfaces, it explodes with a loud snap, then spreads white and gold sparks from the point of impact. This is also a very nice effect!

Why the aluminum in this composition does work is probably caused by the sulfur. I think the aluminum in the first step reacts with the excess of sulfur in the surrounding hot inorganic reaction products (dross). In a second reaction step, the product is burned in atmospheric oxygen. This system is probably very complex. The reaction between aluminum metal and potassium poly-sulfides has been proposed as being very influential in the glitter effect<sup>3</sup>.

### References:

1. Winokur, R.M., *The Pyrotechnic Phenomenon of Glitter*, Pyrotechnica #2, 1978, pg. 13.
2. Fish, Troy, *Glitter Stars Without Antimony*, PGI Bulletin #24, 1981.
3. Oglesby, L.S., *Glitter, Chemistry & Technique*, published by AFN, revised edition of 1989. RW

COMPONENT	STARS (Parts)	STARS (%)	FOUNTAIN (parts)	FOUNTAIN (%)
Mealpowder	200	65.9	500	74.9
Sulfur	60	19.8	119	17.8
Aluminum turnings	17.4	5.7	35	5.2
Magnesium carbonate	14	4.6	14	2.1
Glutinous rice starch	12	4.0	-	-

## FLASH & THAT GUT FEELING

An experience I had with aluminum is worth passing on. The device was one of the cones (volcanoes) described in Lancaster on page 165. Not having the exact type of aluminum called for (I wonder how many pyros actually do), I experimented with a mix of coarse and fine atomized and some fine flake. The fine flake was probably my undoing as it was a low density powder. Mixed with the other ingredients it produced a mix which was impossible to press down firmly into the cone-shaped case. My gut feeling at the time was that I could possibly have an explosive mixture on my hands and saw a lot of sense in the suggestion in the text that this particular mix was usually damped with a solution of shellac in alcohol.

I was rather impatient to try the device that evening and decided to risk dispensing with the shellac in alcohol, which would have meant waiting for it to dry out. I made two cones. The first I tried out on my own to see if it works properly. It did, giving a beautiful silver shower of sparks. Later that evening I proudly showed my wife and young son my second silver volcano. Luckily I stuck to my rule of always standing a fair distance from any device once the fuse has been lit. This one produced the loudest bang I had heard for a long time!

The bang was pretty powerful, the full extent of which I only realized the next day. I found that the two bricks I had placed the cone between had been thrown a couple of yards. The one brick was broken in two. The actual case, made of paper, was torn but not blown into fragments. To me this indicated that the device had actually detonated and not merely deflagrated.

Analyzing what went wrong and why the second cone exploded and not the first, I came to the following conclusions:

- The mix should have been damped and the damp mix pressed firmly into the case;

- The second cone had enough time for the mix to slowly settle at the bottom of the cone, leaving a critical air gap at the top.

This incident has certainly taught me a few things. The most important lesson is not to be impatient. The second is if one has a gut feeling telling one that something is dangerous, then follow that gut feeling! The third lesson is that any mix which is in any way similar to a flash mix will behave like one if the conditions are right.

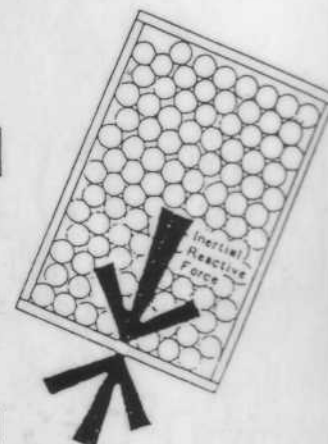
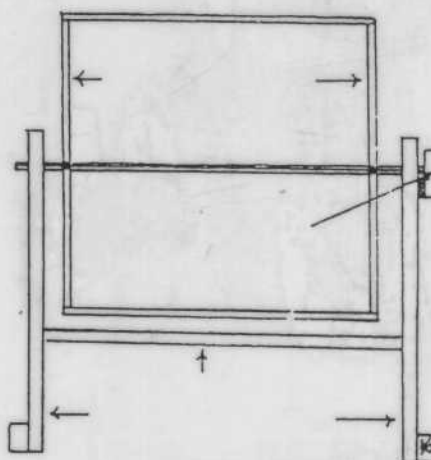
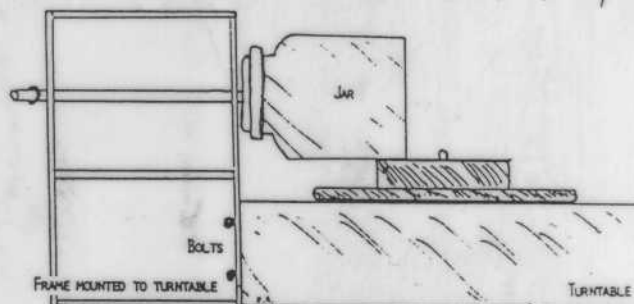
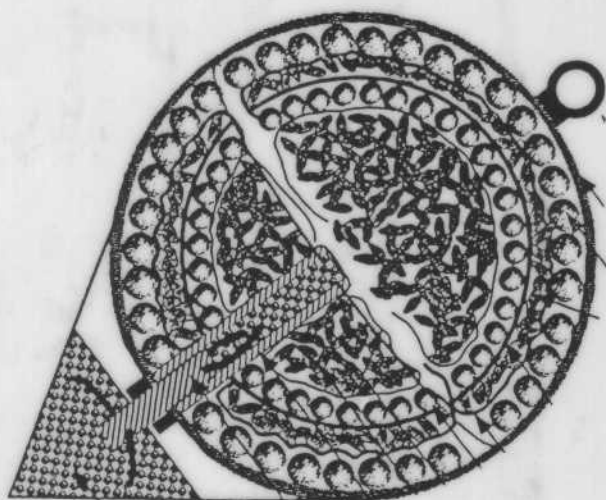
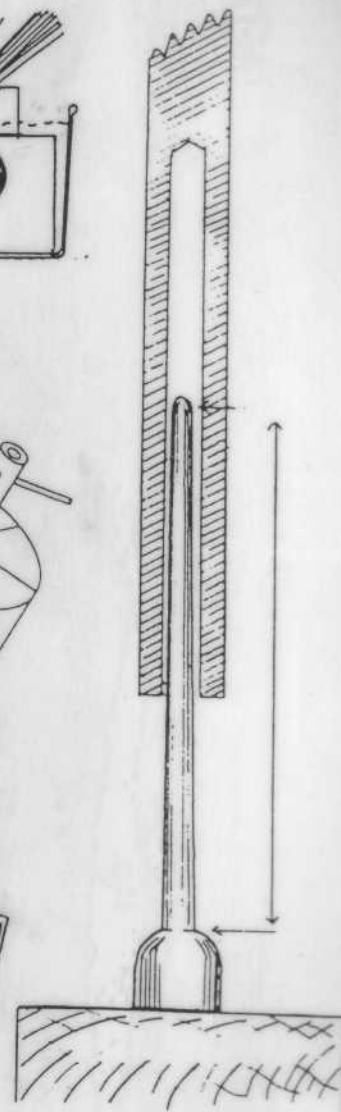
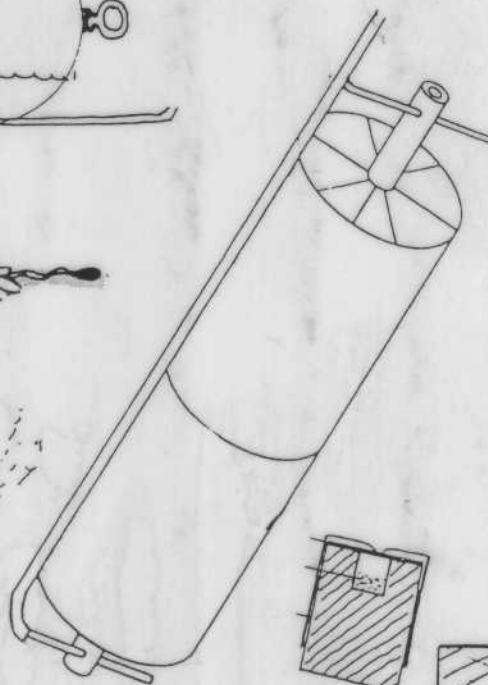
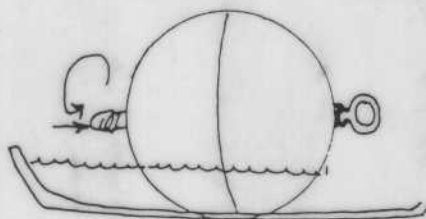
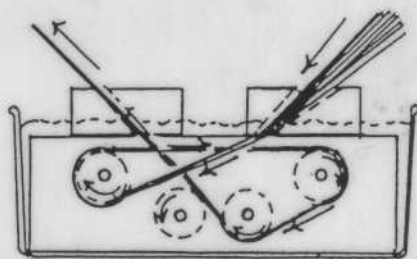
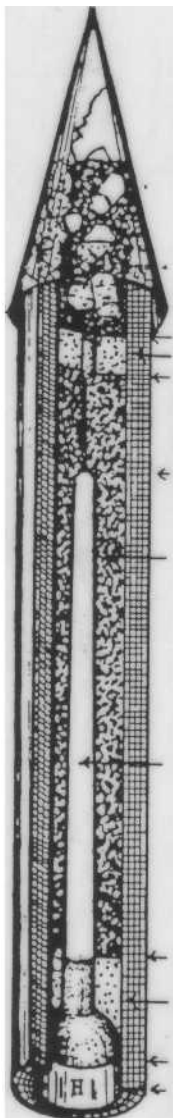
This last lesson is a very important point always (I believe) to bear in mind. One can be very careful to avoid accidents when dealing with "actual" flash mixes and not take similar precautions when using similar mixes for gerbes, stars, etc. From now on I will certainly be more cautious with any oxidizer/fine metal powder mix, whatever its application. IvM



CHARGING HEAVY ROCKETS

there are old pyros,  
and there are bold pyros,  
but there are no  
old, bold pyros.





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