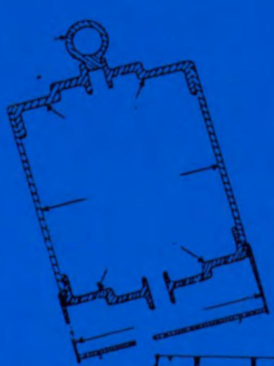
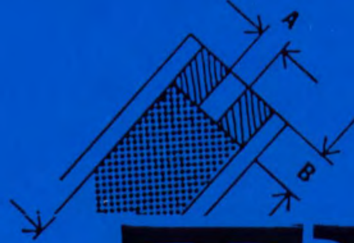
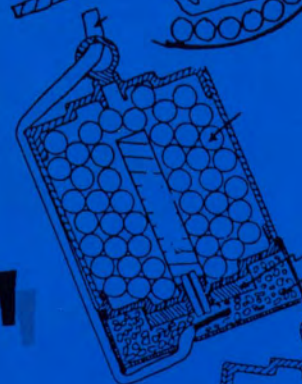
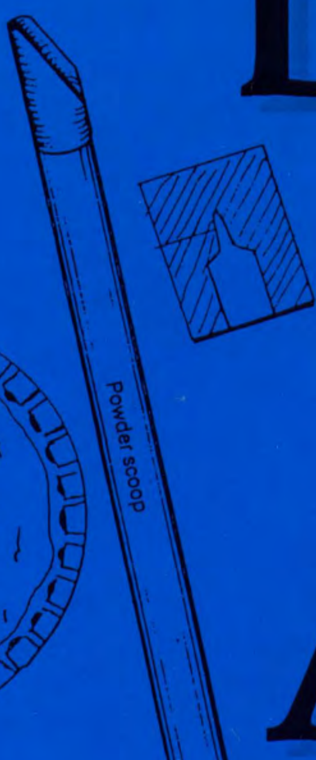
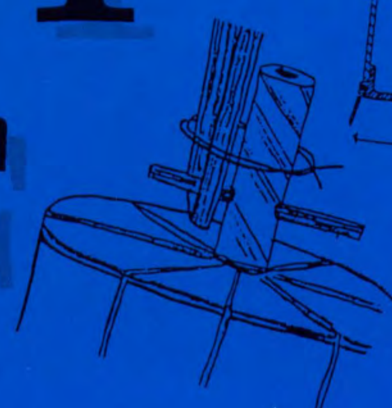
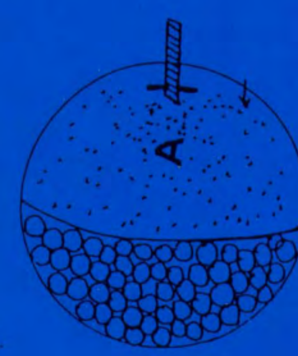
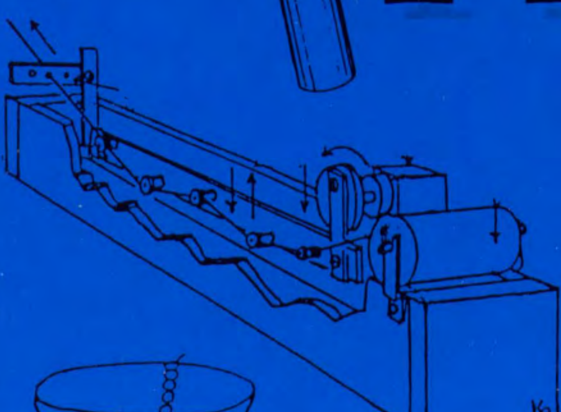



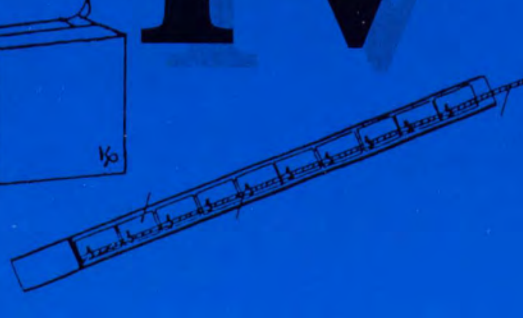
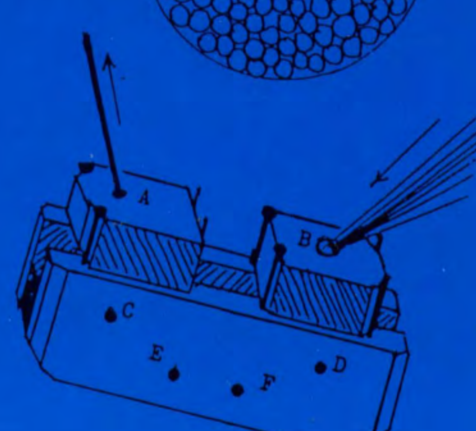
THE BEST OF AFN IV





THE BEST OF AFN IV

Edited by Jack & Dorothy Drewes

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PREFACE TO THE 4TH VOLUME

It's hard to believe that five years have passed since we introduced *The Best of AFN III*. It seems like such a brief period, yet the fireworks experimenters and writers who bless American Fireworks News with their articles each month have managed to give us enough work to make this the biggest of the three *Bests*. And we have enough great articles left over to get started on *Best V*. Indeed, we do owe it all to those fine people who want to share their fireworks information with the world.

Eighty-three (83) pyro writers are represented in these pages. What a cross-section of incredible fireworks knowledge is found in that group! None of this would be possible without their courage in discovering this fireworks information and then deciding to pass it along to other fireworks enthusiasts.

The fireworks scene has changed a great deal since our first tentative steps with the skinny *Best of AFN* (later absorbed into *Best II*). That was a little over ten years ago but developments have been so fast that it could have been one hundred. We've seen effects such as glitter and strobe emerge from the obscure or secretive to main line effects that everyone can achieve. We've seen rapid development in enthusiasts becoming hobbyists and then becoming professionals. We've seen technological developments such as displays that used to be fired with guys running around in the dark with red fusees to wireless shooting systems and computer-operated displays.

The *Best* series is keeping pace with those developments. *Best IV* contains some truly advanced pyrotechnic information, such as mortar separations, and fusing problems, and other display situations. But we managed to keep some basic material available too, and a whole bunch of how-to articles. We are very pleased with some of these how-to articles, because they show how easily obtained Consumer Fireworks items can be used to make display-quality devices. And new developments like StickyMatch® just make it so much easier!

It's time to get started with your new book. If you are rather new to all this, I urge you to begin with the very first two articles, STARTING OUT and ORDERING. They were written by the fellow who wrote *Introductory Practical Pyrotechnics,* a book that we highly recommend for anyone who wants to do hobby fireworks in a systematic and, well, practical manner. These two articles are a fitting beginning of *The Best of AFN IV.*

As you work your way through the book, please keep in mind that an accident usually leads to very dire consequences, both physical and legal. It is healthy to keep reminding yourself that things happen fast in high energy reactions, so careful workmanship and good housekeeping are essential.

Fireworks clubs offer great opportunities for every fireworks enthusiast, regardless of his experience. We asked Ken Barton, President of the Texas club to tell us about such clubs:

REASONS FOR JOINING A FIREWORKS CLUB

Pyrotechnic Artists of Texas has been in existence only since 1997 but has already created subtle changes in Texas fireworks, and more dramatic changes in the lives of its members. Many PAT members have learned much about pyrotechnic safety and at least five, possibly ten PAT members have gone on to get their Texas Pyrotechnic Operator's License as FireAnts.

We in PAT have become more exposed to the fireworks industry and its products, and our children have also experienced more thrills with fireworks at our events. (The smiles attest to the happiness.) We have also learned more about Texas and federal fireworks laws, and that knowledge keeps us out of difficulties we'd rather not experience the hard way.


JULY
THE GLORIOUS FOURTH.
THE PITCHER.
AT THE PICNIC.

STARTING OUT

One of the hard things in any endeavor is getting started. There you are at home - you know you want to get involved in amateur pyrotechnics, you may have just recently discovered that you are not alone and that there are thousands of amateur fireworkers all over the world, but you are still at a loss about how to start. It seems so daunting - there is so much to learn, you have to gather together materials, and you want to do it safely. Where to begin?

In my opinion, acquiring knowledge is the first and most important step. Knowledge is the key to success and survival. Let's face it - fireworks are dangerous, and the only way to reduce that danger is through good working habits and knowledge. If you are going to use flash bags to break your shells, then it is important that you know how to mix and handle flash powder. If you want to begin modifying existing formulations then it is important that you know that a mixture of a chlorate, a nitrate and finely divided aluminum is known as a "Death Mix". Why? Because some books have formulations that contain such a mixture, or you may someday be tempted to use chlorate if you happen to run out of perchlorate. In any case, this chlorate/nitrate/ aluminum mixture can occasionally suddenly heat up and catch fire or explode, and the inexperienced worker should avoid such mixtures. Where do you find this knowledge? Well, there is very good news - there are numerous sources of that information now available, due to the efforts of groups like the Pyrotechnics Guild International, authors like Dr. Shimizu, and journals such as AFN. In my opinion, you cannot buy too many books, tapes, and magazines. However, buying them all is expensive, and so you might want to prioritize your purchasing order. I would suggest the following order:

First, I would suggest that you buy my book at around $40 (shameless plug!). I'm not just saying this because I wrote the thing, but because I wrote it to fill a gap in the existing literature. It was designed to be a lab manual for the absolute beginner. *[Introductory Practical Pyrotechnics,* available from Skylighter.]

Which book to buy next depends a little on your goals and inclinations. I personally enjoy reading and rereading Dr. T. Shimizu's book "Fireworks: The Art, Science and Technique". It is primarily written with an eye towards aerial shells, and it is written by a scientist and discusses some of that aspect, as well as focusing on the techniques. It's a bit pricey at around $70, but I have read my copy ragged. I don't think anyone will go wrong buying it. Alternatively, one could spend about the same money to buy the Best of AFN numbers II and III (Where is Best of AFN I ? Best of AFN II ate it). These are collections of best how-to articles of AFN, and include technical, craft, scientific and humorous articles. The articles were mostly written by amateurs for amateurs, and deal with their trials, tribulations, successes and learning-experiences. Overall these collections form a mine of information.

There are other books available, including the Rev. Lancaster's book ("Fireworks, Principles & Practice", which is an excellent technical book on many aspects of fireworks), and the affordable but somewhat out-of-date books by Davis and Weingart. These latter books are very interesting sources of constructional details, but many of the formulas are considered outdated and too dangerous for modern use.

Once one progresses past the stage of rank beginner you will want to consider books such as Bill Ofca's *Technique in Fire* series, and the various educational books by B. and K. Kosanke, Bleser, Oglesby, etc.

Another excellent source of information is magazines, newsletters and journals. Apparently you already know about AFN. Another good source is club newsletters. You will probably want to join the PGII, and they send out a bulletin that contains a lot of information about PGII events and technical articles about the construction of fireworks. The advertisements are also an excellent place to search for suppliers. Recently I have been very impressed with the newsletter put out by the Florida Pyrotechnic Arts Guild.

Of course, you will want to search out and join your local pyrotechnic club (if you are lucky enough to live in an area that has one). The advantages are numerous - most importantly, they can give you hands on mentoring. Many clubs will often host informal classes, and they can help you gain experience to get your shooter's certification, and they will know the local laws and regulations.

However, not everyone is lucky enough to live in the area of a pyrotechnics club. There are many parts of the country without. In some cases you might be able to find a local mentor. You can try to find one by advertising in AFN, the PGII Bulletin, or on the Internet (below). You can also get the next best thing through videos. There are numerous videos available through AFN and through private individuals. Advertisements for these videos can be found in the back of AFN, the PGI Bulletin, etc. There are both "convention videos" and "topic videos". The former cover talks and classes given at various conventions, and may have from five to ten different short classes or topics. The latter are "purpose made", and cover topics such as making cut stars, making single and multi-break shells, shooters safety, etc.

Of course, one of the best learning experiences (short of working with an experienced fire-worker) is to attend a convention, such as the annual PGI convention, Western Winter Blast, or some of the more local conventions such as Fall Florida Fireworks Festival, the Summer Fireworks Festival, etc. The larger conventions not only have lots of shooting every evening, but they have full schedules of classes and seminars. In fact, they often have to schedule two or three talks/classes at the same time, and the problem lies in selecting from this cornucopia of possibilities. In addition, the contacts you make can lead to many learning opportunities throughout the entire year - for example, during my first convention I met people who freely said "call me if you have questions".

Then there is the Internet. Beginners should approach the Internet with caution, both pyrotechnically and socially. ANYONE can publish anything on the Internet - there is no censorship for content or quality. There have been many cases where malevolent or ignorant people have published dangerous information — "recipes" which have such high risk factors that I shudder to think about them. On the other hand there is a lot of very good information out there - award winning fireworkers and professionals also publish on the Internet. One good place to start is to browse the world wide web starting at my web page: www.pyrosafety.com People have told me that it's a good page, and it has a good list of pointers to good information.

Another Internet resource is the Usenet newsgroup rec.pyrotechnics. Unfortunately, about two-thirds of the postings on rec.pyro are ... how do I say this... "ca ca". Few are of any value. How can you tell them apart? Well, first of all you should "lurk" (just read without writing a lot of stuff). After a few weeks I think it becomes obvious who are the serious fireworkers... They cite examples, they quote sources such as Shimizu, they explain the experimental basis for their conclusions, and they generally discuss issues in a calm and mature fashion (even the most knowledgeable occasionally get angry when faced with a particularly dense and dangerous individual). Rec.pyro also abounds with "flamers", people who are rude, and who enjoy ad-hominem as an art form... don't let them discourage you.

There are also a few semi-hidden mailing lists. Somebody will invite you to join one or more of these when you start to get noticed as being a serious poster on rec.pyro. Yes, I know this is a little elitist, but the people who manage these mailing lists have established this policy to try to keep the signal/noise ratio high. In fact, these mailing lists were pretty much formed as a refuge from the garbage on rec.pyro

Finally, I would like to give you some anti recommendations - books or pamphlets that are SO bad they deserve special mention. High on this list are The Anarchists Cookbook, Ragnars Guide to the Recreational Use of Explosives, The Big Book of Mischief, The Terrorists Handbook, and Phone Phreaking and Kewl Bombz. In fact, anything with typography of the sort "kewl bOmz" is automatically suspect. There are a lot of kids who delight in copying and re-editing the same garbage, and passing it around. For some reason they have developed the use of alpha-numeric substitution for phonetic spelling, along with random capitalization (They s33m to thlNK it is k3wl!). Also, many of the books from the militia movements are of exceedingly low quality.

Start getting books, and start READING. TIP

ORDERING

Some of the questions I often get over the Internet is "What should I buy?", "How much should I buy?" and "Where do I buy it?". These are all excellent questions. Beginners don't want to buy useless chemicals, paper or plastic products, or buy far too much or far too little of something. They also don't want to pay too much, or receive bad material, or have somebody take their money and not deliver the promised goods. The good news is that it is possible to determine what one needs by oneself. The bad news - nobody has a "kit" that one can buy, and so everyone has to figure it out for themselves.

The key to the first step is planning and visualization. And the first step of planning is to set goals. One can hardly plan on how to get "somewhere" if one doesn't have a "somewhere" as a goal. Oh, I suppose a person could just randomly do things until they discover that they have completed a project, but that's inefficient (and generally very dangerous in pyro!). So, a beginner would be well advised to set one or more goals. There is something to be said for starting with simple projects, and working up to more complex goals. This helps give the person practice in handling fireworks, and helps build confidence as each small project succeeds.

Thus, let us say a person's prime goal was to make a 3" round shell with color changing stars. This is where the beginner must either rely on local tutoring, or where reading, knowledge and visualization are critical. The person must read up on the topic until he can visualize each step. The books I mentioned in a previous article are a good place to start. This reading will help determine what materials and tools are needed. For example, the building of a 3" round shell has several subgoals built into it - the shell consists of hemis, and requires a quickmatch leader which contains black match, lift powder, time fuse, cross match, burst, and stars (how about the gun to fire it?). This is where flowcharts come in handy. One can use these to help plan out projects and to help determine proper sequencing. For example, since home-made meal is used in making coated rice hulls, black match, cross match, and priming stars, this material should be made early so that it is available for every one of these processes.

Once the flow chart is made, there will be entries such as "make meal coated rice hulls" and "make stars". Each of those entries will have sub entries, such as "weigh out chemicals", "screen them", etc. (Of course, these entries can be dropped when one becomes more experienced and is sure that the equipment is on hand). At this point the types and amounts of various pieces of equipment and chemicals start to become more obvious. It can be seen that a balance is needed, as well as cups or dishes to hold the chemicals while weighing, screens, bowls, etc. Once those have been identified, it is generally the case that the expensive specialty items come in singles (balances, ball mills, etc.), while the multiple items are cheap and relatively commonly available (cups, spoons, mixing bowls, etc.). It is a good idea to order the specialty items early, since the project will be delayed until they arrive. The cheap stuff from the supermarket can be obtained at almost any time. That leaves the chemicals. One of the most common questions that I get in e-mail is "What chemicals should I buy, how much of each, and from whom?".

The flow chart and the goals can help determine this. Let us take as an example a person who wants to make round shells. They can use a spread-sheet program to help determine what they will need. First, they need to select a limited number of types of stars and compositions. There will be Black Powder for various purposes, as well as some color stars. The beginner should choose relatively simple stars, avoiding magnesium metal and chlorates. The beginner should also choose a limited number of stars, such as red, white, blue, green, yellow, charcoal tail, blond streamer and perhaps one or two more.

The left most column (called column A) will be a listing of the names of each type of chemical, starting in about row 5 (rows 1 through 4 will be used to label the columns and other things). Then, the percentages for the first composition chosen can be entered into column B. Thus, for Shimizu's Blue #2, the numbers would be 67 for potassium perchlorate, 10 for red gum, 13 for black copper oxide, etc... Next, column C can be used to calculate how much of each chemical will actually be needed. To calculate how much of each chemical will be needed, one has to estimate the total amount that will be made before the next order. This is entered into cell C2 (column C, row 2). This weight can be given in pounds, since the chemicals are generally ordered in pounds. Then the amount needed for each chemical is calculated using a formula (all formulas are given in Excel, but other systems are similar). For each cell, the formula is =(C2*B<row number>/100). Thus, if the potassium perchlorate is in row 5, then this formula would read =(C2*B5/100). In this case, if the user wanted to be able to eventually make 5 pounds of Shimizu Blue #2, then this would calculate that the user needed 3.35 pounds of potassium perchlorate just for these stars. This process is repeated for each of the other compositions - for example, the red stars can be put in columns D and E, and the green stars put in columns F and G, etc. Always keep the percentages for potassium perchlorate in the same row (for example, row 5). Add new rows as needed for new chemicals. In this example, a new row would be needed for strontium nitrate for the red stars, and another one would be needed for barium salts for the green stars. However, do not make new rows for old chemicals. In each case the first of the two columns will contain the percentages, and the second column will contain the amount needed calculated by a formula similar to the one given above.

When all of these numbers have been entered, then the total amount for each chemical can be calculated in the next empty column by summing up the individual needs for each star type. Thus, if one was only making blue, red and green (as above) then the formula for the total amount of potassium perchlorate (remember that it is in row 5) would be placed in cell H5, and would be =C5+E5+G5. Of course, if columns H and I were used for yellow stars, then the total would be in J5, and so forth. This will give the minimum necessary amount for each chemical. Don't forget to round up when ordering. Also note that most distributors give price breaks at 5 pounds and 10 pounds, so it might be cheaper to order one 10 pound package rather than a 5 pound and three 1 pound packages.

If a person is especially ambitious they can then utilize the spreadsheet to determine who would give the lowest price on the entire order. This entails entering the prices from each distributor's catalog, and using some simple functions to figure out whose price is less. However, there may be a reason to split the order - for example, one dealer may be more expensive on some items, and less expensive on others. An alternative is to use this to try to dicker - sometimes the dealers might discount one or two items by a small amount just to get all of your business and to make you into a loyal and exclusive customer. Other times, they may just tell you to go get stuffed. I think it depends on a lot of factors, including their current bank balance, phase of the moon, and mood of the spouse. The distributors can be found in the classified ads in AFN.

One final hint - don't overlook the benefits that can arise from ordering in really large bulk. First of all, it can be the case that a 50 pound drum or bag of some chemical might only cost about twice as much as a 10 pound package. That is because the suppliers don't have to pay somebody to repackage it, and labor costs aren't cheap. In addition, some companies charge a lot of shipping fees, such as UPS, Hazmat, etc. However, when the order gets big enough it may suddenly become cost effective to ship by surface common carrier. While that may cost over a hundred dollars, this can be offset because there are no special box or hazmat fees to consider. And that shipping cost is for hundreds of pounds, not tens of pounds. I have seen two or three people pool their resources and buy a quarter ton of chemicals, and the overall shipping costs were far below the normal costs. TIP

CUT STARS

My procedure for making 3/8" cut stars follows: (All measurements are by weight.)

After star comp is mixed, I put one cup of the mixture in a plastic bowl and wet down using a spray bottle of water. I don't wet it too much - a half dozen sprays are all that is needed. I then mix by hand until a doughy ball is made. I know I have used the right amount of water when the small amounts of comp that are stuck to the sides of the bowl stick in a doughy ball when pressed.

I built a star press frame by taking a 8x8x1" square piece of wood and then built a frame around it using 1 x 1/2" strips of wood. I lay the frame down and put a piece of plastic saran wrap over it, then put my wet ball of comp in the middle of the frame on top of the plastic wrap. I then spread out the comp with my fingers as evenly as possible, then put another piece of plastic wrap on top of the comp. I take my 8x8x1" piece of wood and put it on top of the comp in the frame and press down hard, then remove the block of wood and the frame; what I'm left with is a solid slab of comp.

I remove the comp-slab from the plastic wrap and dust the comp with meal powder on both sides. I let it sit for 10 minutes, then cut it into cubes using a thin, but solid piece of plastic. Then I separate the cubes, mist them with water and roll them around in more meal powder. I let them dry for 7 to 10 days.

USING THE STARS IN SMALL SHELLS

My shells are 2-inch plastic canisters using a homemade visco time fuse. With black match being difficult to obtain, I just pour my lift charge down the mortar and install the shell so the reinforced fuse touches the lift charge. A hole was drilled in the side of the mortar near the bottom to accept the igniting fuse. I christened the skies this year on the 4th of July. My breaks were fair, but my colors were great! Upon inspection of what was left of the shells, I found that just the tops were blowing off. My bursting charge was a mixture of meal powder and 4F. Back to the drawing board.

All joking aside, I have found this undertaking to be one of the most infectious, stimulating and fascinating adventures I have ever been on. I feel I have learned a lot, but at the same time I know I have just scratched the surface. You will be hearing from me again. If the pyro is ever needed, just look up to the skies, that's where I will be. GD

	RED	GREEN	BLUE	YELLOW	WHITE	GOLD STREAMER
Potassium perchlorate	6	6	12	8		
Potassium nitrate					28	8
Barium nitrate		6		3		
Strontium nitrate	6					
Shellac	1	1		2		
Dextrin	1/2	1/2	1	1	1	1/2
Dechlorane		3	5			
Black copper oxide			3			
Charcoal - air float	2	2	2	2		1/2
Sodium oxalate				1		4
Antimony sulfide					5	
Sulfur, flour					8	2

METHOD OF PRODUCTION OF MICRO STARS

Micro stars are used in such items as gerbs, comets with crackling stars, and small bombettes. For a long time I have been searching for an appropriate production method for amateurs, without success.

I started my first attempt by drilling 3mm holes in Teflon plastic sheets of 3mm thickness. Then I placed the drilled sheets on a plain, smooth surface and started to paste a slightly wetted star composition into the holes, using a plastic spatula. I left it to dry for a few days. I thought that when the star composition had dried the cylindrical micro stars would be easy to remove. It did not work at all. Nearly all the micro stars were damaged when I pushed them out.

Another method I tried was to form a 3 mm layer of wetted star composition and to cut it into 3mm cubes, like cut stars. In general, it is difficult to get uniform cubes and, in most cases, they stick together, especially if you use nitrocellulose lacquer. Not a method to be recommended.

For my next attempt I searched for a plastic matrix, like a grid. Again I pasted my damped star composition into the matrix, thinking that after drying it would be easy to remove my cubes by bending the plastic, but that was just wishful thinking.

After some time, having already buried my idea of easy-to-make micro stars, I saw a plastic cutlery box in our kitchen. It was the shape of the grid-like spaces of the box that caught my eye. They had the form of little quadratic, truncated pyramids with a 4.5mm edge length and 2.5mm height.

Again, using a plastic spatula, I pasted my damped star composition into the matrix, which was then placed on a smooth plastic surface. After having left it to dry for a several days, I bent the plastic matrix a little bit and - what a surprise - the little truncated pyramids, my micro stars, jumped out. Enthusiastic about my success, I tried an NC lacquer bound ("wetted") star composition. Even this star composition showed no tendency to remain in the matrix after drying, and after a short drying time I got my pyramid micro stars.

I hope I am not wrong if I say that the plastic is polyethylene.

This method is not suitable for large scale production, but works very well for amateur micro star production.

The photocopy above may give you an idea of my cutlery box matrix.

If you do take your wife's cutlery box, please remember to buy her a new one! HWW

BARGAINS IN ODD PLACES

Let me encourage every pyro to watch their local newspapers for school district surplus equipment auctions. This is because old lab equipment seldom attracts a lot of interested bidders. This weekend I went to such an auction and got some real goodies for cheap! I paid $15 each for 5 lab benches, each 6' long with a thick chemical-resistant top. Each bench has 16 drawers for each individual student and a central cabinet for joint equipment. I paid $20 for a 6' by 3' rolling chemical demonstration table with a small hand-pump sink and plastic waste receptacle. I also got a box full of ring stands, tripods, clamps, and assorted lab hardware for $2. The kitchenware sections provided some real opportunities as well - stainless steel counters with sinks, Hobart mixers, etc. In the past I have purchased a fume hood for $25(!) and various old balances at bargain-basement prices. TIP

AN INTERESTING CUT STAR METHOD

I'm not very good at getting all my cut stars the same size. I don't know -- maybe these old eyes just can't see a straight line, anymore. But I found a way to make nicely uniform stars without any skill.

I roll out my cake between gauge strips, like usual. Then, instead of a "long knife", I use a multi-wheel vegetable cutters to make the lines. These cutters are like a pizza cutter, but with four or five wheels, instead of just one.

They make perfectly spaced cuts in the dough. I overlap the next cut by putting the first wheel in the last groove which automatically controls the width. Even if the stars aren't actually cut, it's an easy way to mark out the cuts for evenly spaced lines.

The only things I don't like about my present cutters are:

1)The method only works with a pretty dry dough. Otherwise, since I'm not pulling each row away from the mass as it's cut, the dough tends to 'heal'. Dusting the cake lightly with meal powder helps prevent the stars from sticking back together.

2)I could find cutters only in two spacings (for two different star sizes). I'd like more control over the size.

Actually, with two sizes of cutter, I can make three sizes of star: 1) wide-by-wide; 2) wide-by-narrow; 3) narrow-by-narrow. With various thicknesses of gauge strips, I could increase that even more. My narrow cutter has five wheels on 3/8" spacing, and the wide one has four at 1/2" spacing. Local kitchen accessory stores carry them.

Maybe I'll make a custom cutter with adjustable wheel spacing. LES

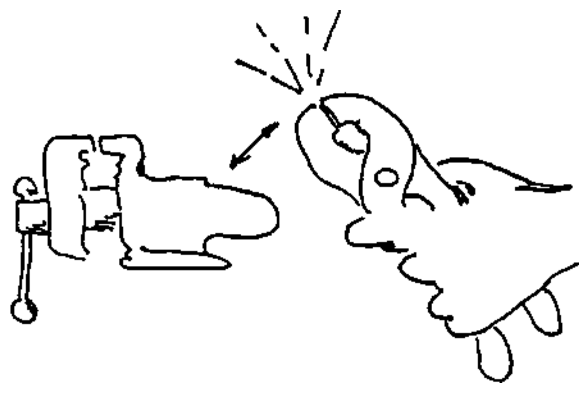
CAP CRAP

I've been a pyrotechnics hobbyist since the early age of around eleven years. My friends had fireworks and I didn't, which were hard to come by and expensive. I was determined to make by own. It helped that my father was a chemistry teacher and that we lived in a rather isolated rural area.

With my father's help I learned a lot, and maybe he did too, as we learned first hand the properties of pyrotechnic chemistry. No pyrotechnic literature seemed available even to a chemist! We didn't know where to look, but we found that most publishers find that type of literature censurable.

My earliest "invention" was affectionately called "cap crap". It was a mixture of 4 grams of potassium chlorate and 1 gram of sulfur. I would grind each of these chemicals very finely in a freshly cleaned mortar and pestle. I would make only very small quantities of this mixture at a time.

Previous to this "invention" a suitable report resulted from taking a roll of caps and striking in on a hard surface with a hammer. Cap crap behaves similarly. When a small quantity was squeezed between the jaws of a pliers and struck against a hard surface it produced a satisfying report.



Years later, another use for cap crap surfaced. I used a loose packet of about 12 grains and attached it to silhouette style steel rifle and pistol targets. A "bulls eye" hit produced a satisfying report and smoke cloud. Even the energy from a .22 caliber long rifle reliably triggered the cap crap. CD

PILL BOX STARS

Making pill-box stars is really not that hard. Here is a simple way:

Rolling tubes: I use a 3/4" steel rod to roll on. Any type of material could be used, as long as the rod is smooth. I feel that the weight of the steel rod makes it easier to roll the tubes.

Paper: 65 or 70 lb. virgin Kraft, three turns. For a 3/4" rod, about 7 1/2" of paper will be needed for three turns.

Manipulation: The paper is cut 20" wide and 7 1/2" long, with the grain running the 7 1/2" direction. Paste is applied to two-thirds of the paper, which is then rolled around the rod, continuing into the pasted area. When completely rolled, the tube is slipped off the rod. Some people paste the entire paper, including the area that touches the rod. That's acceptable, but the rod can get tacky and would need to be cleaned.

Drying tubes: The tubes should be allowed to dry slowly, not in the sun or oven as that could cause them to wrinkle or curve. When dry they may be cut to the desired length.

Composition: There are specific compositions for pill-box stars. Many formulas will burn too long in the tubes.

Pink & Silver Pill-Box Star	
Potassium perchlorate	68%
Strontium carbonate	14
Strontium nitrate	2
Red gum	6
Aluminum bright	4
Aluminum flake, small	3
Aluminum flake, med/lg	3
Dextrin	+2

The composition is moistened with not more than 8-9% 35/65 alcohol/water.

Match: A piece of flat blackmatch is cut to protrude 1/2" from each side of the tube.

Assembly: The piece of blackmatch is placed inside the tube, protruding equally from both ends. The tube is then picked up and scooped into the moistened composition, which is then pressed with the finger and thumb on each end of the tube. This is continued until the tube is pressed full of composition. The star loading may be finished by placing the tube on a ramming tool and tapping lightly. Too much compression will cause the star to burn too long. LP

RED ILLUMINATING STAR

	1	2
Strontium nitrate	55	4
American Dark aluminum #809	-	1
German Pyro aluminum	15	-
Sulfur	15	1
PVC	10	1/2
Red gum or shellac	5	1/3

Notes:
1) Dampen with alcohol. May be cut or pumped not much larger than 1/2" or pillbox.
2) Prime with hot prime like meal/silicon

JB

MAKING COMETS

My first tests were hand-mixed, hand-pressed, and way-too-wet comps. I was mixing the willow and other black powder types until they stuck together like tar. Even with hand-pressing the comps into shape, they were spewing water everywhere. It's a wonder any of them lit.

I bought a rubber rock tumbler and have been milling the black powder comps for 20-24 hours with some 50 cal. lead balls. It has made a difference in burn quality compared to the hand-mixed. I'm also using an arbor press to compact the comets now. It really makes a hard comet. With two wraps of paper on the sides and a thin piece of cardboard on top, these things really throw off some fire dust. It's amazing to me how a 7/8"xl-l/8" comet can spread a 10" diameter lightning strike of fire 150' long.

I've also been working on color comps. I've got a red and a blue that work really well. Firing a color comet with some willow mix on top makes an interesting effect. The color burns going up and at the peak the fire dust kicks in. Once it noses over, it looks like a meteor burning up in the atmosphere.

I've seen the "snowfall" formulation in a couple of books, but haven't tried it yet. It will be on my list of things to do since I've heard it's really impressive when done right! I'm also going to add more color comps. to that list. I'm a little leery of comps with metal additions and don't want to push too fast until I understand more of the basics.

I sure wish somebody would come out with a book or video about comet-making. My guess is there's just not enough interest to do such a thing. Maybe I will in a couple of years. I hope I know enough about it by then that I could. JRT

FURTHER TO MY QUEST FOR GOOD COMETS

I finally got my comets to work! I started using charcoal briquettes for the fuel!

I bust them up and put them in a blender, then screen out the unburned wood and rocks, then ball mill 8 oz. at a time. For some strange reason this stuff helps my comets to stay together.

The fire dust and length of tail look the same as when I was using pyro grade charcoal. It's messy stuff to work with but the results make the effort worthwhile: I'm amazed at how much fire these 3/4" comets produce. I'm in awe at the sight of each and every one.

I haven't had a failed comet since I switched to charcoal briquettes. JRT

CUSHIONING COMETS

I cushion my comets from the shock of the lift charge with thick corrugated cardboard discs. These are cut from dishwasher boxes and the like. The "shock absorbers" keep the comets from breaking up on the way out of the mortar.

GC

LATEX GLOVES REDUCE STATIC HAZARD

In the mixing and use of various pyrotechnic formulas, static electricity is always a hazard to the fireworks maker. Wearing latex surgical gloves greatly reduces this hazard, and may help prevent an accident while mixing or working with various pyrotechnic formulas. The gloves are available through any medical supply house, or ask your local pharmacist to order them for you. The average cost is about $15 per 100 pair. JMcN

BLUE & ORANGE GO GETTERS WITHOUT MAGNESIUM

It all started several years ago when I watched a video of a PGI convention. I observed this new-to-me effect which looked like the stars were "swimming". After cleaning my glasses and viewing it again, sure enough, self-propelled stars. I already had Troy Fish's article entitled "Green and Other Colored Flame Metal Fuel Compositions Using Parlon" published in *Pyrotechnica VII* but had not made the connection. It all became crystal clear after obtaining a copy of Dave Johnson's book "Go Getters". Well, for one reason or another, the idea somehow got shuffled to the dark reaches of my mind. Although it did resurface from time to time, the final catalyst didn't come until the 1994 convention in Pennsylvania. I witnessed some Go Getter shells in the opening display by the CPA and particularly liked the blue ones. Next came the Go Getter seminar by Dave Johnson and Mark Raitzer, which explained how to make the little critters. Unfortunately, the seminar only presented the same three colors that had been listed in Johnson's book, namely red, green and yellow. All utilized magnesium as the metal fuel. Since I really like the color blue, the hunt was on. Inquiries of several fellow pyros resulted in no answer for blue Go Getters. The puzzle finally started to fall into place following a perusal of Joel Baechle's "Pyrocolor Harmony". Right there on page 34 was an ammonium perchlorate formula for violet with an interesting footnote stating "The violet with 10% aluminum and no hexamine is an excellent 'Go Getter' composition".

ORIGINAL VIOLET FORMULA	
Ammonium perchlorate	50%
Cupric oxychloride	15
Aluminum, fine atomized	7
Hexamine	3
Rosin or Vinsol	5
Parlon	20

Having neither rosin nor Vinsol, I substituted saran resin (I figured a little more chlorine donor couldn't hurt). Also, for the atomized aluminum, I used 325 mesh, 30 micron, spherical (KSI, now Skylighter #007) aluminum. While this revised formula worked nicely in initial tests, I soon started observing bubbling and foaming in the tubes about one hour after they had been poured. In most of the tubes the fuses disappeared completely, as they sank out of sight to the bottom of the tubes due to the agitation provided by the bubbling. The foaming was probably caused by the formation of acetone acids which reacted with the aluminum. In any case, the Go Getters were useless since most of the fuses had disappeared and I didn't like the looks of them anyway.

In desperation, I tried something that shouldn't have worked quite as well colorwise as the oxychloride. By substituting copper carbonate for the copper oxychloride, the foaming stopped and, judging by the comments I received at the PGI convention, the effect was quite well received. The final formula is presented below, along with a formula for orange Go Getters. If you want to shift the color more into the "pumpkin" range, eliminate the cryolite and increase the calcium carbonate to 15%.

	Blue	Orange
Ammonium perchlorate	50%	50%
Copper carbonate	15	-
Calcium carbonate	-	14
Aluminum, 325m, 30u	10	10
Saran Resin	5	5
Cryolite	-	1
Parlon	20	20

All chemicals are run through a mixing screen a few times and, with the aid of a funnel, are poured into an acetone-proof plastic (I used an empty mustard squeeze-type bottle made of LDPE (low density polyethylene)). Without access to LDPE containers, one must experiment to find a flexible plastic material that is not affected by acetone. I find that, except for occasionally plugging up, the squeeze-type container works very well and gives more control over the flow of material.

As a side note, these aluminum Go Getters do not explode or burn all the way to the ground like the ones made with magnesium.

Dave Johnson's book covers the construction of Go Getters in great detail so I will cover only the highlights and differences.

THE TUBE

I use a standard 9/16" i.d. x l 1/2" long spiral-wound, machine-made tube with a 1/16" wall thickness, and standard 9/16" plugs. The end plugs do not need to be glued in as the parlon, once it sets up, is quite hard and will not blow the plug until the Go Getter is almost done burning, if at all. The tubes are then bundled into a convenient size package (I use bundles of nineteen) with rubber bands and set on plastic film (Saran Wrap), ready for filling. While Go Getters made with these tubes go quite nicely, the tubes are still relatively heavy. One variation would be to try hand-rolling some tubes from Kraft paper with a thinner wall, to see if they fly better. Go Getters are end burners, so we should not have to worry about blowing out the tube.

THE SOLVENT

A 90:10 mixture of dry acetone:xylene is used as the solvent. Acetone is hygroscopic so it is important to use dry material. Fresh acetone is best, but material of doubtful quality may be dried in the following manner. A small quantity (an ounce or so) of drying agent (calcium chloride or "Damp Rid" in Florida) is placed in an acetone-proof plastic container, the acetone is added, the container is capped and shaken to allow the drying agent to absorb the water. Care must be taken to release the pressure in the container by loosening the cap/lid from time to time. Only a brief time is needed to absorb the water and then the acetone is allowed to settle for a few minutes. Lastly, the acetone is filtered to remove any solids by pouring it through a double layer of coffee filters; then it is stored in an air/moisture proof plastic container and the drying agent is discarded (it's cheap). It is a good idea to dry only as much acetone as is needed for the batch of Go Getters being made. Caution is needed to remember that acetone evaporates very quickly, the vapors are heavier than air and extremely flammable. Good ventilation and no sparks are a *must.*

The acetone/xylene solvent mix is added to the composition in the squeeze bottle at the rate of 33-38% by weight. Some experimentation may be necessary to get the proper viscosity of the mix. The correct consistency is somewhere around a slightly thickened pancake batter (depends on your recipe). After placing the top on the squeeze bottle, about 25% of the air is squeezed out to allow for expansion of the acetone vapor. Then a gloved finger is held over the spout and the bottle is shaken vigorously for two to three minutes or until everything is thoroughly blended. Depending on the size of the batch, the operator may give the bottle a good shaking every once in a while just to keep everything in suspension, and the air must be squeezed out first. Then the tubes are filled to the brim, ready for insertion of the fuse. It is a good idea to keep a toothpick handy to unplug the nozzle, and some paper towels to wipe the nozzle and the operator's hands.

THE FUSE (THE SECRET)

Black match or any other potassium nitrate-containing fuse cannot be used with aluminum Go Getters like it can with the magnesium varieties. This is because of the ammonium perchlorate and potassium nitrate reacting to form the very hygroscopic aluminum nitrate, which will quickly result in a wet interface between the fuse and the composition (believe me, I tried). The trick is to use Thermolite. The Thermolite will not react with the composition, and it provides a nice hot flame to ignite the Go Getters. The Thermolite is cut in pieces about an inch long, then as much of the fabric-wound outer layer is removed as possible. Then it is bent into a narrow U shape and inserted into the Go Getters, U end first, about half way, then laid over against the side of the tube. Once the slurry is poured, the Go Getters set up quickly, so the operator must prepare enough fuses to complete the job. After the fuse is in serted, the tubes are set aside to dry on a piece of plastic wrap until no acetone odor is detected, which should be 3 - 4 days. As the Go Getters dry, they will shrink back into the tube a little because one third of the slurry, by weight, evaporates.

By having two ends of the fuse exposed to the expanding flame front with the shell, ignition of the Go Getters is improved and more initial thrust is generated due to the two points of ignition.

CONSTRUCTION OF A SIX-INCH ROUND GO GETTER SHELL

A round Go Getter shell is constructed much like any other ball shell of comparable size, with a few minor differences. The time fuse is cut to allow a delay of about 4% seconds between cross matching. A fuse extender made from three turns of 30 lb. Kraft is rolled on a suitable former and pasted only on the last 1/4-inch or so of the trailing edge - just enough to keep the tube from unrolling. The tube is then slipped over the cross-matched end of the time fuse and securely taped in place (remember that at this time only the end of the fuse that goes inside the shell is cross-matched). The fuse is glued into the hemisphere and the fuse extender is cut off so that it just reaches the center of the shell. The extender tube is filled with 4f and sealed against leakage with either a small piece of masking tape or pasted paper.

THE BURST

There are two theories behind the burst charge for Go Getters shells. The first is to use a relatively hard burst to scatter the stars and let them swim back toward each other. Since the stars are placed randomly in the shell, and they are not smart enough to know which way to go, the result is a big boom and Go Getters scattered all over the sky, with the distinct possibility that some of them will be driven toward the ground hard enough that they will not burn out before impacting the earth. My preference is to use a soft break, only strong enough to open the shell and light all the stars. Meal powder on rice hulls works well for this purpose. I use a 5:1 ratio of meal to hulls, up to 6-inches, and 4:1 for larger shells. Remember, they are self-propelled stars and don't need to be blown all over the place.

PUTTING IT ALL TOGETHER

Two pieces of tissue paper are cut to a size sufficient to line the hemispheres with enough left over to fold across the top of each shell half to hold the contents in the halves while assembling the shell. A hole is pierced in one piece of tissue and the tissue is inserted over the time fuse and smoothed out against the inner wall of the hemisphere. The second piece of tissue is placed in the other half in a similar manner except for the hole for the time fuse. The Go Getters are then placed against the inner wall of the shell about half way up the wall. Care must be exercised not to obscure any of the fuses.

Now burst is poured in to fill all of the crevices between the Go Getters. At this point, just enough burst is used to fill the crevices and leave a thin layer over the already placed stars. Stars and burst are added in alternating layers until the hemisphere is full. Burst must be forced into the crevices between the Go Getters as this is the only way to ensure shell integrity. The extra tissue that has been hanging over the edge of the shell and getting in the way is now folded toward the center of the shell, secured with a couple of pieces of masking tape. The other shell half is finished in the same manner and the two halves are joined using typical shell glue.

As was discussed earlier, Go Getter shells do not need a hard break. Consequently they do not need to be endlessly pasted with tape or paper strips. My preference is to use two layers of filament (strapping) tape on the 6-inch plastic shells. Paper hemispheres probably need three to five layers of pasted paper. After taping or pasting, the shell is finished in the normal manner with the final cross match, lift and leader. JWD

TESTING STARS

We get a small, but constant flow of questions from people who are having various problems with stars they are making. Perhaps the most common one is the problem of stars being "blown blind". That is, when a shell explodes in the air, some or all of the stars are not igniting. I don't want to go into all of the diagnoses and solutions to this problem. They are discussed in detail in Bill Ofca's book, called "Ignition: Materials, Problems & Solutions".

Over and over I hear from people who are not adequately testing their stars before they are assembled into a fireworks device. Almost everyone will test burn his or her stars in a static situation, that is, while the star is sitting still. But an amazing number of folks never test fire their stars out of a star gun to see how they will perform in the air.

Now a star gun can be just about any makeshift mortar or tube. You can use a simple cardboard tube with just enough clearance for the star to fall down into it freely. Just plug one end of the tube, and drill a fuse hole right above the plug. Stick a piece of Visco into the hole, drop a pinch of black powder into the tube, and then a star. Light the fuse, get back and watch what happens. If your star does light, you will be able to see a pretty good approximation of how it will perform in a shell or a mine.

If your star doesn't light, you may have one or more problems. You may have put too much lift powder under your star, propelling the star so fast that the flame actually blows out. Test another star with less powder and see if it ignites. Remember, if the star is a close fit to the firing tube, then it will only take a very small pinch of powder. If the star still does not light, even with a smaller amount of lift powder, your problem is likely priming. Either the star is not primed or the prime you are using is not hot enough to light the star composition. Again, I refer you to Bill Ofca's book for more details on priming solutions.

Simple, cardboard-tube star guns are cheap, but they have the drawbacks that one-size-does-not-fit-all-stars, and that they eventually burn up and come apart so you have to keep making new ones. At one point in my pyro career I actually had time to make a lot of stars. I had my friend John Smith in Baltimore make me up a star gun out of steel with five, different-sized barrels: inside diameters of about 3/8", 1/2" 9/16", 3/4" and 1-1/16". He welded the guns in a straight line vertically onto a flat steel plate, drilled Visco holes in the base of each gun, and even spray painted the whole thing flat black. Neatest star gun I have ever had. It doesn't wear out. The different inside diameters of the tubes let me shoot any sized star I made using almost no lift powder. In fact, I can shoot them so silently that my next-door neighbors can't even hear a thing when it fires. HG

KITCHEN PYRO - AT VULCAN'S FORGE

I had obtained some -100 mesh iron powder to use in making sparklers. As a test, I dropped a few iron grains into the flame of the kitchen stove.

What occurred was a group of bright orange "slivers" of light - none of the desired branched sparks.

On a hunch, I looked up an entry by Takeo Shimizu in Lancaster's 1972 *Fireworks Principals & Practice* (page 228). He states that pure iron sparks don't branch, but alloys with up to 7% carbon do.

In a creative mood (especially since my wife was out and wouldn't see me tossing noxious materials on the stove) I rubbed a little graphite into some iron powder. When some of the mix was put in the flame, bingo: multiples of branched orange sparks.

Unfortunately, graphite did not improve the dull sparks of ferro-aluminum. FJ

BRILLIANT ILLUMINATING SILVER ELECTRIC NON-SIZZLING RED COMET SHOWER STARS

Traditional red/silver stars have been made with potassium perchlorate/strontium carbonate/fuel/aluminum, and such formulations are given by Ron Lancaster (Fireworks Principles & Practice, p.92), among others. I find this kind of star very disappointing because the amount of aluminum required for a good show of sparks invariably harms the color, so that only pink is obtained. Ken Kosanke has suggested two alternatives, both of which are markedly superior to the use of aluminum. One uses coarse atomized magnesium (*Sizzling Colored Comets,* AFN No.63) and the other uses coarse titanium (*The Use of Titanium in Pyrotechnics,* PGI Bulletin No.67). These articles also list equivalent formulations for blue and other colors.

The effects of the magnesium and titanium are substantially different from each other, the latter producing longer lasting sparks which are slightly yellowish. The red/titanium formulation has no chlorine donor and is therefore not truly red, but rather deep pink like the parent $KClO_4/SrCO_3$/fuel systems. My own preference is to use a fairly pale pink when I want pink, and red when I want red. This avoids confusion. Whenever I see a deep pink I am always left wondering whether it was supposed to be that way or whether it was intended to be red and didn't quite make it. The red effect can be obtained by following Joel Baechle's suggestion (Pyrocolor Harmony, p.12) of adding 10% titanium to Sam Bases' ammonium perchlorate red star #15.

I like to have a greater profusion of long lasting sparks than is allowed by these kinds of compositions, without spoiling the balance and contrast between the head and the tail. One solution is to use a brilliant (illuminating) type of star which can tolerate a greater amount of titanium, while maintaining good color and contrast. Such a solution is given for green by Ken Kosanke in his titanium article and I offer here my red, which is formulated along similar lines.

Brilliant Red/Titanium Star	
Strontium nitrate	40
Titanium (10-20 mesh flake or 10-40 mesh sponge)	20
Magnesium (granular 40 mesh)	15
Polyvinyl chloride	15
Polyvinyl acetate	5
Potassium perchlorate	5
(Dampen with isoamyl acetate)	

It is not necessary to coat the magnesium with linseed oil as the polyvinyl acetate binder provides adequate protection, and the stars can be kept for years without any sign of decomposition or decrease of performance. The stars are fast burning and can be fired from the ground, as in Roman candles, etc., as well as aerial effects. The same composition is also excellent for hanging cases for waterfall effects. Such thin-walled cases containing the PVA-bound composition have functioned perfectly after hanging overnight in the rain. I prefer to use PVA for binding because I find it easier to handle, but parlon devotees could no doubt adapt the formulation.

Returning briefly to the blues mentioned earlier: The potassium perchlorate formulations given by Ken Kosanke are serviceable but not sufficiently deep for my purposes. I prefer the approach of Dave Bleser (AFN No.66), adding ferrotitanium to an ammonium perchlorate blue star in a similar way for a long, bright tail, and as little as 5% titanium can be highly effective while maintaining excellence of color. Magnesium should not be added to an ammonium perchlorate blue composition because of incompatibilities.

Addendum

A solution of polyvinyl acetate (PVA) in various solvents is sold as glue, particularly in Europe. Pyrotechnists have told me of their success in using solvents other than isoamyl acetate [banana oil] for PVA binding, but I have no experience in this and so refrain from comment. What I had in mind in referring to parlon was to replace the combined PVA and PVC contents with 20% parlon, utilizing its binding properties by means of acetone, butanone (MEK), or other suitable solvents. Again, this is speculation to be realized by the interested reader.

Many pyrotechnists have a legitimate concern over the very high corrosion potential of magnesium. The use of PVA or parlon for binding effectively coats the magnesium particles with plastic, thereby preventing decomposition. An alternative solution, which I have recently adopted, is to replace the magnesium with a high magnesium content magnalium, which allows the use of more conventional binding techniques without causing corrosion problems.

Here is an alternative formulation:

Brilliant Red/Titanium Star	
Strontium nitrate	40
Titanium (e.g., 20-40 mesh)	20
Magnalium (65:35, atomized 150 mesh)	15
Polyvinyl chloride	15
Accroides Resin	5
Potassium perchlorate	5
(Dampen with alcohol)	

Stanbridge (Pyrotechnica XVII, 1997) has suggested that the designation *Accroides Resin* as commonly used by pyrotechnists may be incorrect. I have no expertise in this matter and have no reason to doubt Stanbridge's assertion. The material I favor for binding here is a medium grade sold by Sigma Chemical Co. labeled as "Gum Accroides". It gives the appearance of being essentially identical to material sold by pyrotechnic supply companies labeled as "Accroides Resin" [Red gum]. Finer material does not mix as easily, and coarse material generally contains extraneous matter. CJ-W

SIFT THOSE CHEMICALS

How many of you pyrophiles just assume that a 5 lb. lot of chemical XYZ is ready to use when it arrives from your supplier? I used to, until one day when I noticed a significant amount of debris was failing to pass through my 40 mesh star comp sieve. After isolating the offending culprit, I decided to sift the material all by itself. I was quite amazed at the volume of "stuff that was removed by this process.

Repeating the procedure on various other chemicals yielded similar results. Organic resins seem to be particularly prone to this type of contamination. Following is a list of chemicals I've experienced this problem with, including the identity of some of the material removed:

- ✓ Red gum: leaves, sticks, sand.
- ✓ Sulfur: unground crystals.
- ✓ Charcoal: unground particles, sand.
- ✓ Aluminum: flakes <u>way</u> out of mesh range.
- ✓ Parlon/Strontium carbonate: unground particles out of mesh range.
- ✓ Shellac: sand, unground particles.

I'm sure there are others which could be included. The point of this discussion is to alert the pyrotechnist to a potential source of inefficiency in their efforts to perfect their formulations. The weights alone of these contaminants may alter the constituent ratio in some color formulas and hence adversely affect the color. Even if this does not occur, I certainly don't need sticks, leaves, grit, etc. in my mix when I'm trying to cut or roll stars!

The solution is to sift chemicals individually before storing for future use. This way I <u>know</u> my composition percentages are true and will undoubtedly enjoy the pride of improved formulations. LC

PRIMING COMET SHELLS

To get the best effect from an Italian canister-style comet shell, the diligent pyro strives for a somewhat harder break than the usual cylindrical star shell. With fewer effect "units" in the comet shell and each "unit" being larger and burning longer, wider separation of the stars results in an enhanced effect.

The ferocity of "brisance" [pronounced *bre-z'ance;* Ellern definition: ability of an explosive to shatter its solid confines or surroundings] of the overall shell burst is a pressure phenomenon adjustable on two fronts: 1. degree of containment and 2. strength or brisance of the burst charge. Observing the differences between Oriental ball and Italo-American canister break patterns readily illustrates the interplay of these two factors.

Fulcanelli[1] describes the variation sometimes used for spiking comet shells "...a closer pattern is occasionally used; typically the number of side strings employed is increased to that normally used on the next larger size of shell. For example, a 5" comet shell might be spiked with 32 side strings (the pattern ordinarily used for a 6" shell) instead of 24. Circumferential spiking is also closer, to match the closer vertical spiking, making small squares on the side walls." This tighter pattern is meant to increase containment and hence burst pressure and diameter (factor #1). Some builders seek to increase burst radius by using "hotter" (read faster or more brisant) break charges. Indeed, "slow" flash powders and their various combinations are sometimes employed (factor #2).

Often the successful achievement of a wider burst pattern introduces the frustrating problem of poor star ignition. In actuality, ignition is enhanced since increased containment and/or more brisant burst comps both result in higher intrashell pressure and subsequently higher temperature as per physical gas laws. The real problem involves critical wind velocity. Even though the comets are lighting well initially, they begin to fall upon shell rupture as they are propelled in open air at such speed the flame front is stripped away from the reacting surface. What good is a horizon-to-horizon break if most (or all) of the comets are blown blind? This problem usually occurs within the first few milliseconds after case rupture; if the comet can be engineered to stay lit during this interval, the flame front can "catch up" as the comet decelerates. Cut or rolled stars are easily primed by rolling them in the ignition comp of choice until a sufficient layer is achieved. Priming comets in this fashion, however, is usually impractical since the comet diameter increase due to prime build-up multiplied by the number of comets in a ring usually disrupts the fit around the inner shell periphery.

A simple technique was developed by which priming is effected after the comets have been loaded into the shell casing. After all comet rings have been properly loaded (each ring being staggered in brick-house fashion atop adjacent rings and tightly sawdusted or "rough powdered" in) the shell is up-ended and gently tapped to remove excess sawdust or polverone. Thick nitrocellulose lacquer is painted over the inner cylindrical surface of the comet charge facing the burst core using a narrow paint brush. Immediately following the painting, a generous scoop of priming comp is dumped into the shell and the entire unit is rotated in barrel fashion until the wet N.C. layer has picked up all it can take (alternately, after adding the prime, the open end of the shell can be covered and the whole thing shaken to distribute the prime). All excess prime is dumped back out of the casing and the shell is left to dry completely (preferably outside due to the acetone vapor). Upon drying the burst charge is introduced and the shell is finished in the usual fashion.

It should be obvious to the reader that this method is only feasible for use with raw, uncovered comets. It cannot be used with papered comets (i.e. crossettes or color-changing cavity comets) since burn-through of the paper covering would occur, thus spoiling the effect. Nevertheless, the author has found it to be an excellent method of ensuring ignition and he currently employs it on all unpapered comet shells regardless of composition. Even colored comets can be successfully fired using this technique.

Two points of some importance deserve mention before concluding. First, the N.C. lacquer employed in this technique should be thick, about the same viscosity as cane molasses, so it will stick where it is painted, without runs or sags. As reported by Hyman in Cardwell's review[2], the author compounds his own N.C. lacquer using rifle or shotgun grade smokeless powder and dry acetone. Single-base nitrocellulose powders work best, such as Accurate™ brands 2015 BR, 2495 BR, 3100, 4350, Solo 1000, and Solo 1250. Avoid Winchester™ and Alliant™ (formerly Hercules™) brand powders as they are all double-base, nitroglycerine-containing products. The powder granules are mixed with acetone in a 1:9 (10%) or 1:10 (9%) ratio and allowed to stand in a tightly capped jar for several days with occasional shaking. The resultant product is a thick, black liquid (black color probably due to the graphite coating) with a slight yellowish-green cast, which is excellent for many pyrotechnic applications. A very inexpensive source of smokeless powder for N.C. lacquer was recently discovered in the Class "C" products "Great Balls of Fire" and "Dragon's Breath". The pellets from these two devices make a good quality N.C. lacquer when mixed in a one ounce to one pint ratio with acetone.

Lastly, the priming powder used in this method should be granulated in the 4FA to 2Fg range. These granules are small enough to thoroughly coat the wet N.C. lacquer yet large enough to provide a rough, highly ignitable surface. A good quality ball-milled Black Powder mix that's been granulated through an 18 mesh window screen and dried works well.

References
1) Fulcanelli, A. 1984. Traditional Cylinder Shell Production - Part 1, Issue IX, Pyrotechnica: Occasional Papers in Pyrotechnics, Austin, Texas.

2) Cardwell, Robert G. 1979. Strobe Light Pyrotechnic Compositions: A Review of Their Development and Use. Issue V, Pyrotechnica: Occasional Papers in Pyrotechnics, Austin, Texas. LC

WATER BOTTLE SALUTE

While attending the Science Teachers conference last month I learned how to make a *water bottle salute* that makes plenty of noise but no smoke or physical damage.

To make one, a regular 16.9 fluid ounce water bottle (Deer Park, Zephyrhills, or any local brand) is filled with water, then with the cap on, inverted into a deep tray or shallow basin filled with water (which is what chemists call a "pneumatic trough"). After removing the cap from the inverted bottle, hydrogen gas is bubbled in with a rubber hose, until the bottle is about two-thirds filled with gas (which will displace the water from the bottle).

Hydrogen can, of course, be made very easily by adding small pieces of zinc metal to diluted hydrochloric or "muriatic" acid.

Then the hydrogen hose is removed and replaced with one carrying oxygen gas. (I make oxygen by adding the catalyst manganese dioxide to ordinary 3% hydrogen peroxide solution.) The bottle is filled the rest of the way with oxygen and then the cap is put back on while the bottle is still in an inverted position. The *water bottle salute* is now ready to fire (and will be as long as the cap is left on).

When I do this in front of my class, I fasten the bottle to a ring stand with several heavy-duty rubber bands so it won't jump around from the recoil effect. Then I remove the cap and place my hand over the bottle to hold in the hydrogen (which otherwise would rise upward because it is lighter than air). I then tell the students to prepare themselves, quickly remove my hand from the mouth of the bottle and immediately bring a lighted "Aim 'N' Flame" long-handled butane lighter to the top of the bottle.

It takes a fraction of a second for the explosion to occur (since the rising hydrogen has to reach the flame). There is a quick burst of mostly blue flame, and a very loud, sharp report that really startles the students. There is no smoke because the reaction product is only water vapor.

The only damage that ever occurs is that the bottom of the bottle is sometimes bulged outward a bit. ST

NEW FORMULAS FOR COLORED SPARKLERS

As the school year drew to a close and July 4th approached, the students in my advanced placement chemistry class wanted to know if it would be possible to make fireworks as a special end-of-the-year project. Of course I agreed, but with the provision that our pyrotechnic endeavors be limited to legal fireworks designed to produce sparks and color, rather than audible effects.

I immediately recalled the instructions for "steel sparklers" given in the late Dave Kelsey's Amateur Pyrotechnics booklet. The formula given by Kelsey worked fine, and produced a white flame and long-lasting orange sparks. The logical next step was to make flames of different colors, but this proved to be somewhat more difficult than anticipated.

The only formulas for colored sparklers that I was able to find in print were for "ruby & emerald shower sticks" in Weingart's *Pyrotechnics*. Unfortunately, the formulas seemed a bit too unstable to deal with in a public school science laboratory. (The green formula calls for a combination of barium chlorate and aluminum powder.) So, it appeared that I would have to create my own color mixtures if my students were to produce safe and effective colored sparklers.

The first step was to substitute barium nitrate for the more dangerous chlorate. I also realized that replacing the aluminum powders with magnalium would improve the colors without significantly increasing the sensitivity of the compositions. I then started thinking about possible color intensifiers, and recalled the Parlon/magnalium colored star formulas I'd seen. Some of those formulas include sulfur, so I decided to add some too, to aid in ignition. (Sparklers, needless to say, are notoriously difficult to light with a match or lighter.) Finally, I chose to use the wheat paste called for in Kelsey's formula as a binder, rather than the more hygroscopic dextrin included in the star compositions. Here are the formulas I came up with after a little experimentation.

	RED	GREEN
Potassium perchlorate	2	2
Strontium nitrate	20	
Barium nitrate	20	
Magnalium, -100 mesh, 50/50	8	8
Sulfur	6	6
Wheat paste (wallpaper paste)	6	6
Parlon	4	4

Each ingredient was ground separately in a mortar and pestle, and then mixed together with a spatula on waxed paper. Water was then added, a little at a time, with continuous stirring, until the mixture became a thick paste. It was found to take about 40 ml of water for each 46-gram batch of composition.

The paste was coated on bamboo "shis-ka-bob" skewers which had been purchased at a local supermarket at $2.69 per 100. It took two separate coats to get the layer of composition thick enough to make an effective sparkler. The sparklers were dried in an upright position by inserting their bare ends into foam blocks of the sort used for flower arrangements, and then drying them in our school's drying oven at 120°F. for 72 hours.

We lit the sparklers immediately after removing them from the oven, which probably explains why the red sparklers ignited easily in the humid summer climate despite strontium nitrate's well-known hygroscopicity.

My students and I were both greatly impressed by the performance of our creations. They burned with bright, true colors, while emitting small white sparks. The colors were superior to anything I've seen in sparklers before, an impression that my students seemed to share. In fact, they reported that our sparklers "put the bought ones to shame".

I feel certain that my chemistry students will never forget the flame-test colors for strontium and barium. ST

COLORED SPARKLER UPDATE

In my article, *New Formulas for Colored Sparklers* I gave formulations using -100 mesh magnalium.

When I recently tried to replenish my supply I could not find -100 mesh magnalium at a reasonable price, so I bought -200 mesh powder. Anticipating that this change would radically alter the performance, I experimented with the formulation and found that if the potassium perchlorate is omitted, the -200 magnalium produces a sparkler that has colors that are probably even better than the ones I made before.

Everything else is the same; I just substituted the -200 mesh for the -100, and omitted the potassium perchlorate. ST

SUPER SILVER FOUNTAIN

Lancaster Silver Fountain	
Potassium nitrate	5
Barium nitrate	45
Meal powder	5
Aluminum*	45
Lancaster cautions that the aluminum is critical and suggests a mix of mesh and type. One mix might be:	
Aluminum, dark pyro	15
Aluminum, 80-120 mesh	15
Aluminum, flitter, 10-30 mesh	15

Unchoked Super Silver Fountain	
Ammonium perchlorate	65
Hexamine	10
Stearic Acid	7
Steel Powder or Titanium filing	12
Copper carbonate or Barium carbonate or Strontium carbonate (optionally added for color)	6

I wanted to experiment with the Lancaster Silver Fountain last night, but when I went to make the comp., I had no aluminum flitter, so I substituted aluminum firefly, which is about the same mesh size. I loaded the comp. into a 7 1/2" x 3/4" i.d. rocket motor casing with no throat and a bentonite plug. Then, remembering reported ignition problems, put some blue star mix on top to get it started. I viscoed it and called the family out to watch. The blue comp. fired, but the aluminum comp. didn't. It was cold, and the grumbling from the audience about "duds" and "amateurs" was starting to reach my ears. I told them to wait and then quickly went back to my lab.

By that time the fountain top had cooled, so I put four small bits of thermolite fuse on top of the aluminum comp., then found some fountain base mix which I poured into the top of the cooled casing to a depth of one-half inch. I quickly ran back to the front of the house, which by now was, of course, empty of spectators, they having retired to the warmth of the family room fire.

Undeterred, your intrepid pyro stuck in a piece of visco, lit it, and it worked great! The fountain base comp. caught easily, which lit the thermolite, which burns at a high temperature. That lit the comp. with no trouble - just a momentary die down between the comps. The unchoked fountain attained a height of about 15 feet, and ended with a great light and brilliant white flare - a truly spectacular "bang for the buck" for 100 gms. of comp! My appreciative audience witnessed all through the window, with only vague mutterings of "it's about time" and "why didn't it work the first time?"

Actually, this is a variation of a step-wise prime, although the above has the advantage of being a specific answer, as well as being tried and true. It's just to ram half an inch of fountain base comp. in first, after figuring what color, if any, is wanted to start the fountain (hence the Cu/Ba/Sr carbonate add-in), then the rest is rammed with the Lancaster Silver Fountain comp. I am going to try this with a choked version and see how it works. This is one super fountain for very little effort. WWG

L

LIGHTNING BOLTS

One of the questions people ask is "What are some projects that are quick and easy?". This is important if one is trying to enthuse beginners who don't have the skill or confidence to make complicated devices. A few simpler projects can often launch them down the road to pyro-addiction.

One surprisingly simple yet effective project is the construction of "lightning bolts". These can take many forms. The simplest form uses masking tape, a bit of visco, commercial or good-quality homemade Black Powder and some coarse metal or broken bits of stars.

First, the pyrotechnic composition is made by mixing granulated metal with a good Black Powder. Commercial 3Fg works great, although a good homemade BP will work. The amount of metal isn't critical - I've seen lightning bolts work with as little as 5% or as much as 25% (by weight) of metal. The metal can be any one of the common spark metals, such as iron, titanium, zirconium, aluminum, etc. Don't forget that anyone can get bags full of free iron turnings from local brake shops. These can be treated with a light spray of WD-40 to help them last a little longer in the presence of the potassium nitrate and sulfur. However, this is a light coating and these lightning bolts may not last for more than a few weeks, especially in a humid climate. The Black Powder can also be loaded with bits of broken stars.

Next, about 2' to 6' of masking tape is laid on the bench, sticky side up. The width is not critical, but 1" works pretty well. Tape which is wider than 1" works better than tape which is narrower. A 3" to 4" bit of visco is laid across the tape about 1-inch in from one of the ends, leaving from 2" to 3" exposed on one side. Then, a plastic spoon is used to drizzle a line of pyrotechnic composition down the length of the tape. This line should be about half as wide as the tape, and it should NOT be allowed to reach the edge of the tape. Then, another piece of tape is placed sticky-side down, capturing the visco and the pyrotechnic composition. This completes the lightning bolt. Basically, this is similar to metal-loaded Sticky Match®, except the tape seals from side to side and there are no overhanging sticky edges.

This is then hung from a stick, a bit of wire, or draped over a fence, and the visco is lit. One must be very careful NOT to allow the fire to get near the lightning bolt, as the seal is not perfect, and small fire leaks may exist along the edges. When the visco hits the BP core it acts like weak-walled quickmatch. The fire flashes from end to end, blowing open the tape and sending a shower of sparks up to ten feet in all directions. Not bad for a few teaspoons of BP and a few grams of metal granules!!!!

After the lightning bolt is fired, the masking tape generally proceeds to burn, creating a smudgy black smoke and leaving carbon smudges on the ground. Thus, some people might find the use of thin paper tape to be preferable! In this case some 1" wide (or wider) gummed Kraft tape can be laid on the table with the unwetted glue upwards, the visco placed and the powder train laid down as before. Then, the top layer of tape can be wetted, and pressed sticky-side down over the lower tape. This makes an instant quickmatch. Unlike the masking tape, this has to be allowed to dry for an hour or two before use. But it doesn't tend to burn as often, and the fire is less obnoxious if it does catch on fire. TIP

PAPER PLUGS

When you're all out of particular cardboard plug you need, here's a fix. If just a few are needed, they are easy to make. I just cut circles of thick paper about the thickness of a manila folder, and then, using a dowel or rod, shove them into a hole drilled in a piece of wood. They may not be as pretty as store-bought plugs, but they definitely tide me over while I'm twiddling my thumbs waiting for my pyro supplier to get the ones I need back in stock. HG

SAFETY ISSUES CLOUD KITCHEN UTENSIL USE

I am writing today about a couple of safety issues that would interest many of our readers. This relates to two experiences I had while making Black Powder.

At least one author recommends using a 12 cup glass coffee urn, such as the type that comes with coffee machines (e.g. Mr. Coffee), to make Black Powder using the CIA precipitation method. I had an urn crack and split while gently heating it, nearly dumping the entire contents on a hot electric plate, which would certainly have made a horrible mess at the very least, not to mention the possibility of ignition once enough water had been driven out of the mixture. I then checked every manufacturer of coffee machines as well as replacement urns and they specifically warn against using the urns on a gas stove or electric heating element. The glass is not Pyrex and is *not* heat resistant. Stainless steel or glass cookware or a Teflon coated aluminum pan would be a better choice. No aluminum would be exposed to the nitrate because of the coating, and would be unlikely to react significantly because it is solid and not finely divided as in powdered aluminum. A plastic or wooden spoon should be used to stir the mixture, of course.

Secondly, I discovered that a stainless steel bowl will get hot enough to ignite Black Powder when set in the sun. The semi-parabolic shape of the bowl can focus the sun's rays which, combined with the heat retaining properties of black objects, could be enough to heat the powder to over 350°C. and cause ignition. This happened in early April - imagine if it had been July! Nowhere in my reading have I found recommendations against leaving Black Powder in the sun in contact with metal. You can bet that this reader will not make that mistake again!

MKDB

ADDITIONAL INFORMATION ON ABOVE: I had difficulty believing that a stainless steel bowl full of meal powder could reach an ignition temperature of 350°C.

Tenny L. Davis *[Chemistry of Powder & Explosives]* states that 4F Black Powder takes fire at 190°C, ±5°C. The reason for the much lower temperature, and hence, activation energy is sulfur's great tendency to attract electrons and form free radicals. Sulfur is the reason Black Powder is so sensitive to electrostatic discharge (ESD).

A temperature of 190°C could credibly be reached in a shiny semi-parabolic stainless steel bowl of Black Powder, sitting in the sun.

MKDB

POLITICALLY CORRECT PYRO TOOL - THE CAN-CRUSHER

Pyrotechnists as a group have always been incorrigible recyclers. Long before environmentalism became trendy and politically correct, pyros were making the most of cast-off materials. For example, John Babington related in his 1635 book, *Pyrotechnia,* that for the cases of rockets "you must provide some good strong paper, as old Law books, which are both strong and large". We always suspected there must be some constructive use for those stifling, mammoth volumes of verbiage.

Given our historical ties to the recycling movement, it is only fitting that the recyclers should contribute something for the pyros now and then. The latest innovation from their business that I have appropriated for pyro use is a handy little press commonly known as a can-crusher. The can-crusher is an inexpensive press that is designed to be mounted with screws onto a wall or shelf in the kitchen where normal persons use it exclusively for the purpose of crushing aluminum cans. Said cans can then be stored in a much smaller space than their uncrushed counterparts.

The first time I ever saw a can crusher was when I moved to Missouri, one of the states that has no can return law. Here in Missouri we crush the cans and save them up until we get a few bags full. Then we either take them down to the recycling center and sell them for cash or alternatively, we might mill them down into aluminum powder. [More on this subject will be revealed later.] When I installed my crusher, my first impression was that it resembled my arbor press — the one I had sometimes used to press experimental rocket motors. A hand lever on a simple hinge mechanism moves two horizontally opposed plates together with considerable force — the mechanical advantage of my press is about 3:1. Now, that is not sufficient for many pyro applications.

Moreover, the plates have only about 5% inches of clearance between them -- not enough for most tooling. Yet I discovered that the can-crusher had sufficient clearance to use my 4 oz. screaming rocket tooling, as well as sufficient pressure to consolidate my old favorite "red rocket mix" in small cases. I am certain the device would work for some other applications. The can-crusher has the additional advantage of sitting unobtrusively and patiently in one's kitchen or garage, all the while doubling as a politically correct recycling tool between pyro uses. WK

CONES REVISITED

Having experimented quite a lot with cones over the years, I've had several rethinks about them. *[See page 20, Best of AFN III for the author's previous work with cones.]*

One rethink is the issue: buy versus build. And here I'm not talking about the complete animal but about the cone cases.

In my first cone experiments, I literally rolled my own. After finding or making suitable formers, I made my own cone cases from semi-circles of Kraft paper. The process was somewhat tedious. So I was delighted when I found that my sister, who worked for a textile manufacturer, could buy good textile cones for me cheaply. And cheap they were, only a few cents each.

With a cheap supply of textile cones, I started to forget about rolling my own. But recently I've gone full circle when I discovered how much a local hobby shop is asking for them. At those prices one can almost buy a fireworks cone, complete with its pyrotechnic materials! So maybe it's back to rolling my own (or looking for another cheap supplier of textile cones).

I used to be fanatical about preventing the cone tips from burning, so I filled the ends of my cones with Plaster of Paris, shaped into suitable nozzles. These worked OK with a small amount of pyrotechnic material, but got clogged if the material burned longer than a certain time. An adverse side effect was the cone walls under the nozzle burning through. So I finally went back to the method of dipping the cone tips in sodium silicate (water glass). Note that sodium silicate should not be confused with sodium salicylate which is used in whistle compositions.

I had some bad experiences with the bottom plug being blown out shortly after the cone was lit. To get around this problem, I opted for a complex plug consisting of four pieces of cardboard, two thick and two thin. This was a real overkill. Eventually I found the best solution to be one piece of really stiff cardboard. Here I found that the cardboard from the covers of three-ring binders worked the best. I cut circles from this stiff cardboard with a modeling knife. I then pressed one circle into the bottom of each cone and ran a bead of Elmers glue along its circumference.

This method worked well with normal cone compositions, without any blowouts. But one tends to forget just how much pressure can build up inside a cone. I made the mistake one day of mixing in some left-over powder from some magnesium stars in the cone mix. This was just a bit too violent for the otherwise sturdy plug and it popped out with a load bang, sending the rest of the cone into orbit. IvM

BLACK POWDER BURN RATES - APPLES & PEARS

I remember how elated I was with my Black Powder burn rate test results. My latest batch of homemade Black Powder had just clocked in at a burn rate of 105 cm/second.

It was round about midday and my Black Powder had been drying out in the sun since early that morning. I had decided to do preliminary tests before the stuff had dried completely. The results far exceeded my expectations. I then left the rest of the batch of Black Powder to sun dry for the rest of the afternoon. I had decided to do a second test on the completely dried Black Powder. These test results were even more surprising.

I ran the second test late that afternoon; the burn rate: barely 70cm/sec.! Something was wrong, but what? I ran some more tests and achieved burn rates varying between 60 and 85 cm/second. Why the discrepancies? And why were none of the results close to the 105 cm/second test?

I then tested another batch of Black Powder which I had made a couple of months before. My original tests had consistently measured burn rates of about 90 cm/second. The latest test clocked a slightly slower rate but still close to 90 cm/second. Now I had a real mystery on my hands: why the incredible discrepancies?

It took quite a bit of further experimenting and consulting of the Black Powder literature to arrive at what I now believe to be fairly logical explanations. I now also realized that another issue was at stake - one needed to be careful not to compare apples with pears in comparative burn rate tests.

The first conclusion which I arrived at was that completely dried Black Powder (i.e., moisture free) burns at a marginally slower rate than slightly moist Black Powder. The Black Powder literature seems to bear this out. This would certainly explain why Black Powder which had been stored for a few months burnt at a slightly slower rate than the same Black Powder just after manufacture. This factor, however, could not adequately explain burn rate discrepancies ranging from 70 to 105 cm/second. There had to be other factors involved.

I cast my mind back over how I had performed the tests. One factor stood out very clearly - ambient temperature. The Black Powder used for my late afternoon tests was at a significantly lower temperature to the Black Powder used in my midday tests. This was because the Black Powder tested at midday had just been taken out of the sun and was actually warm to the touch. Thus the energy required to ignite this Black Powder was lower than that needed to ignite Black Powder which had actually cooled to the same temperature as its surroundings. Other factors also started to emerge during further tests.

Consistency is the name of the game in properly conducted comparative tests. Where this is compromised, the test results are also compromised. My Black Powder moisture contents and ambient temperatures had failed to meet consistency criteria. The further tests highlighted others.

Black Powder formed into granules burns at a significantly faster rate than the same Black Powder as fine powder. The size and shape of these granules play an important role in determining the Black Powder's burning characteristics. I found that one reason for the slower burn rates I was experiencing was due to my not properly sifting out all the fine powder. Comparing properly sifted Black Powder with Black Powder still containing fine material showed significant differences.

Another factor was the amount of material used in the tests. When I used a generous amount of Black Powder for a test I got a faster burn rate than when I used significantly less. It was almost as if I was being rewarded for my generosity! The light suddenly dawned on me: the first test I conducted when I measured a rate of 105cm/second had used a generous amount of Black Powder, the others quite a bit less. I had actually made a conscious decision to use less, in order not to waste any of my batch of valuable fast-burning Black Powder! But why the differences in results?

I found the answer to this question through repeated experiments. Proper testing required that the line of Black Powder being tested contain enough Black Powder to ensure that most of the granules were actually physically touching their adjacent granules. This meant that when each granule ignited it virtually simultaneously ignited its adjacent granules. Thinly spread Black Powder however, created numerous tiny gaps between granules. The flame from each granule igniting had to thus "leap the gap" to the adjacent granules. Each leap took a finite amount of time, contributing to the extra time needed to ignite all the Black Powder.

I believe that I have found some satisfactory answers to explain the discrepancies in my tests. There may, however, be other factors which I have overlooked. I would be interested in feedback from fellow pyros on this matter. IvM

BLACK POWDER DOESN'T NEED MACHINERY

It is possible to make a respectable black powder without expensive industrial equipment. Any schoolboy with basic laboratory materials and a recipe book can whip up a batch of meal powder. Fireworks people have been making their own for hundreds of years.

In the beginning stages, a homemade mixture may be as good as that of any commercial enterprise. It is the subsequent processing which makes the difference between powders manufactured today and the stuff made by settlers in the early 1800s.

There have been developed several "cottage scale" processes which will yield a functional black powder. They all start out the same: weigh the three ingredients and pulverize them separately. Mix any two together and combine wet with the third. Then the pyrotechnic authorities diverge.

One process works its way around the necessity for use of a high tonnage press. The dampened meal is rammed, layer by layer into a cardboard tube with a mallet and a close-fitting ramrod. Quite a high pressure can be developed with the smack of a hammer, because like with a punch press, there is a lot of compressive energy released within a very short time in a very concentrated area. The idea is to build up a slug of powder within a tube, set it aside to dry for several weeks, then peel off the paper; it is then crushed and screened. The grains can be swirled with some graphite in a saran-wrap covered bowl to finish.

A technique related in *Foxfire 5* is even simpler: flatten the dampened mass with a rolling pin on a stone slab and set it out in the sun to dry. Crumble the dried powder and use it! Results are probably quite similar to powder manufactured in Europe after the 1300s and very much like the powder homemade by settlers.

The CIA has revived and simplified a precipitation method devised in 1875 by Edward Greene and adapted at Frankford Arsenal by T. J. Hennessy in 1967. This technique shortens drying time to a day or two and eliminates the compression step altogether. The procedure starts the same as before: measure and combine charcoal and sulfur with the intent of embedding as much of the sulfur within the porous structure of the charcoal as possible. If you have access to a rock polisher, throw in the ingredients along with some brass, or lead or stainless steel balls and let the machine do the work. When the mass looks uniformly black and very fine, it's time to combine with the potassium nitrate. This step gets a little tricky. All ingredients are placed into a sufficiently large cast iron fry pan or pot and are doused with a measure of water. The mass is then boiled and stirred. The inherent danger with this process should be obvious to anyone who has ever played with matches. An electric skillet takes out some of the worry of the open flame.

The trick of this process is to get around the necessity for compacting the ingredients in order to achieve intimate incorporation. While the dough is boiling, it is dumped into a bucket of isopropyl alcohol. The sudden shock of the temperature change, in conjunction with the possible dispersal of the potassium nitrate in solution over the super-wetted surface of the sulfur-embedded charcoal, does almost as good a job of intimate mixing as does the heavy tonnage of hydraulic presses. Potassium nitrate crystallizes directly out of solution and onto the suspended charcoal particles, much like rain attaching to silver nitrate particles used in cloud seeding. The whole mass precipitates to the bottom of the bucket. The alcohol can then be strained through a piece of bedsheet or muslin into another container. The precipitate (gunpowder dough) is caught in a pocket of the sheet where it can be wrung out like a dishrag.

Wringing out is a big step toward drying since most of the water used in boiling is dissolved in the alcohol which has already been strained off. This meal cake is partially dried for several hours but not to the point where it will crumble into dust. While it is still tacky enough to hold shape, it is forced through a piece of window screen, or fruit strainer or whatever will provide the desired grain size. A finer mesh is better (something that will pass grains more like 3Fg rather than like Fg); the cake is squeezed through with a wooden spoon, or manually if the person doesn't mind getting charcoal under his nails.

The grains should drop into a receptacle without adhering to each other. If they crush into dust, it's too dry. If they clump back together, it's still too wet. In this instance, the screen is used to create the grain size rather than to sort it out. The granules are layered not deeper than 1/4-inch in a cake pan or similar container and set in the sun. Properly finished powder will be relatively dust free and the grains will hold up to a moderate amount of physical abuse without crumbling.

A less expensive and possibly less messy procedure departs at the alcohol point. According to an AFN source, the nitrate can be precipitated out onto the charcoal by just effecting a fast temperature change. That is to say, if the boiling mass is dumped onto a large cold surface, like a marble slab or a sheet of metal, the nitrate will drop out of solution and directly onto the charcoal just as in the previous method. I haven't tried it. From there, it is flattened out with a rolling pin, set out to dry, crushed and then screened to separate the grains. TMcD

TISSUE PAPER TIPS

I'd like to pass on a tip about tissue paper. In this country there is a cheap, available source of strong tissue paper. It took years for it to dawn on me what it is, but since getting some, it has worked beautifully. It won't even breakdown in HOT water! Guess what it is? TEA BAG paper! I got an end-roll from a local tea company and this will probably last me a lifetime.

There are many types of tea bag paper, some natural, some with synthetic fibers, and some impregnated with chemicals. It also comes in different widths, according to the size of the tea bag being made. The roll I have is about 9 1/2" wide, used for restaurant-size iced tea brewing, and I don't know the composition of it, but it burns cleanly. It's sold by paper suppliers by the pound for about $6.50.

It's heavier than Chinese fuse paper, but nonetheless, I can make firecracker-size fuse (honest) with a 1/4"-wide strip of it and fine black powder and roll it so tight it will double-back on itself without tearing! It makes fine touch paper and would probably work in any application where the Japanese paper is preferred.

I encourage fellow green men to check it out.

RB

PERFECT PAPER TAPE TUBES

It's a real pain to roll paper tape evenly. I'm pretty good at it, but I've never been satisfied with the appearance of the tubes that result. No matter how you try, they're always "off by a bit at the ends. Now I've found a way that's not only faster, but is as perfect as you can get. This example for preparing tubes for experimental rocket motors will illustrate:

Tools and Materials:
* Tape:
  1) Fiberglass reinforced, brown paper, gummed, 2.75" wide.
  2) Plastic packing tape, 2" wide.
* Mandrel: 1/2" plastic or metal rod or tube.
* Pressure cooker.

Procedure:
First, some tubes are rolled as follows:
Cut pieces of the paper tape approximately 20" long. Place a piece of the cut tape on a dry surface with the glue side up. Roll it DRY onto the mandrel. Square up the ends and twist the paper on the mandrel to tighten it. Secure the tube by wrapping it with 1 - 2 turns of plastic tape. Take it off the mandrel.

Now for the trick...
All the dry tubes are put into a basket in the pressure cooker with about 1" of water in the bottom. Don't let them get wet! Heat up the cooker with the lid on and the valve open until it's steaming well. Turn down the heat and close the valve. Continue cooking for around ten minutes (time will vary depending on tube thickness). Remove the cooker from the heat, open the valve, take off the top and remove your tubes. Allow the tubes to dry.

Any sort of paper tape with water activated glue should work. Tubes prepared in this manner are as hard and strong as those that are commercially available, the ends are perfectly aligned, and the i.d.'s are exact. You can make sure that they've been cooked long enough by cutting one open to reveal the layers. They should all be securely glued.

Different colors of plastic tape may be used. Monokote or PVC contact paper used for lining shelves should also work, and would cover the tubes completely. FH

SILK SCREENED FIREWORKS

Simple silk screening methods can be used to produce complicated fireworks effects. This method normally used for printing low volume items such as T-shirts, can be used to print pyro compositions. A screen is employed usually of extremely fine mesh stretched taunt on a ridged frame hinged to close down onto a removable surface to print on.

Pyrotechnics will need a coarser mesh. A very fine pyrotechnic mix will work with a screen made of women's nylons, but plastic window screening is to be preferred for most applications. Areas not to be printed are painted shut with a thick paint or lacquer. A thick mixture is prepared and then pushed through the holes in the mesh onto wood, paper, plastic or aluminum foil surface.

As with normal silk screen printing, several different screens are used to place different colors or in this case mixtures precisely where they are required. Dozens of "sparklers" could be printed in seconds and after drying, fusing printed right into place. Several printing and drying cycles can be used to deposit thicker coats and coatings that will resist ignition from neighboring sparks. Elastimors can be added to make flexible assemblies. Larger devices can be fused into the printing to fire batteries, fountains, candles, etc.

I initially tried this method as a means of producing a printed small firecracker. A fusing matrix was printed. It looked very similar to how all the fuses in Chinese firecrackers are tied together. A salute mixture was formulated that would work with a water-based adhesive. Lastly, an adhesive is screened onto all the areas not printed and a closing sheet is placed on top. After the sheet has dried, I make cuts around each individual firecracker cell so that it could fall away and explode without damaging the yet ignited crackers. CD

SIMPSON'S SPARK SPINNER

After reading several articles about the spark effect of burning fine steel wool, I decided to try it. WOW! But my arm got tired, so I decided on mechanic advantage. Even though I'm not into sadism, the cat-o'-nine-tails came to mind. Why not put the principle of leverage to a use that children could enjoy?

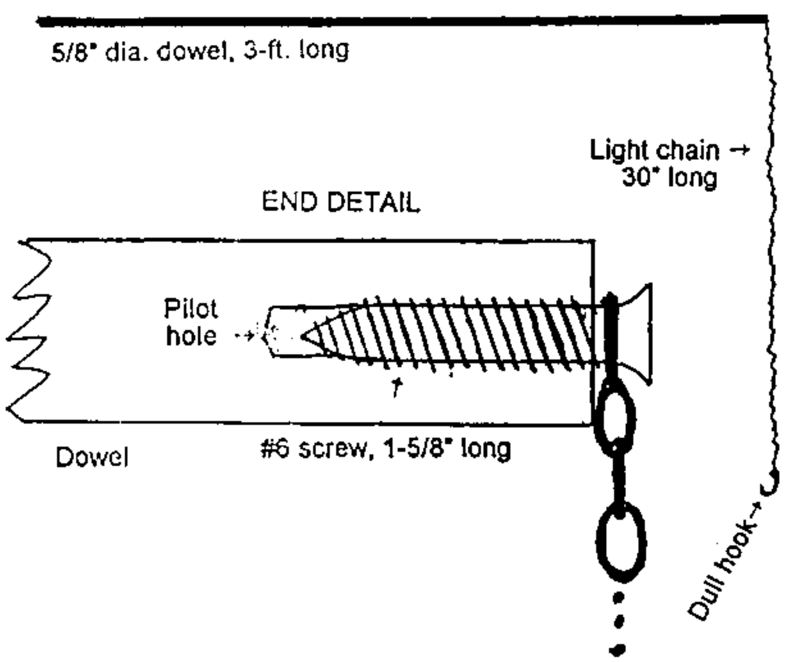
I bought a 5/8" dia. hardwood dowel and three feet of decorative type unwelded light chain from a building supply store. I had a box of #6 x 1/4" drywall screws. I drilled a pilot hole into the center of the dowel so that the screw wouldn't split it. I used a drill a little smaller than the unthreaded diameter of the drywall screw.

I made a hook out of some steel wire. I made the hook about two inches long and wound it around one end of the chain. I resisted the temptation to use a razor sharp, barbed fish hook as being too dangerous. I cut the chain into thirty inches, put a flat washer against the dowel to prevent wear from the rotating chain (totally unnecessary unless you own a steel wool factory) and screwed the chain to the dowel. I drove the screw as far in as possible without hampering the free rotation of the chain on the dowel.

I attached a chunk of 0000 steel wool to my creation and waited for dark, not expecting too much. I was wrong! No, it wasn't the Apollo 17 night lift-off, but after lighting the bottom of the steel wool and rotating it over my head, I did manage to illuminate my rear yard with a 40-foot in diameter ring of sparks. All that oxygen does make a difference. If you really spin it, you'll think it's dawn, but the wool will be consumed rapidly. My chow did his usual "fire! run!" routine.

The spinner is NOT something I let unsupervised children play with. Even without the burn hazard, the chain or hook can inflict serious eye injury, and any chain is a strangulation hazard for children.

A mixture of 0000 and 00 steel wool should be interesting. I might even try mixing some aluminum flitter into the wool. BS



MINI FOUNTAINS/SPARKLERS

These fountains/sparklers produce very nice yellow gold sparks with an occasional gold puffball effect. I recently made 150 of these for my wife's pre-4th of July picnic shoot. They were a hit with both the kids and the adults.

Casing: I begin with a 36" by 1 1/2" strip of Kraft shipping or packing paper, then run a 1/4" wide line of glue along the edge of the 36" side of the paper. Then a 1/4" diameter dowel is placed at a 45° angle across the non-glued short corner of the paper. As the paper is rolled onto the dowel, the glue will attach to the already rolled paper and form a tube. Care must be taken so that the glue line attaches to the Kraft paper already wrapped around the dowel and not to the dowel itself. As the operator works, he keeps sliding the finished tube off the end of the dowel. This allows the use of a much shorter dowel than the length of the finished tube.

The result is a paper tube that is one to two layers thick and 20-30" long depending on how much you overlap the paper. This tube is cut into 7" lengths.

Seven inches of tube is slid back onto the dowel, leaving about an inch off the end of the dowel. This extra inch is twisted to form a closed bottom for the tube (adding some glue to ensure closure, if desired).

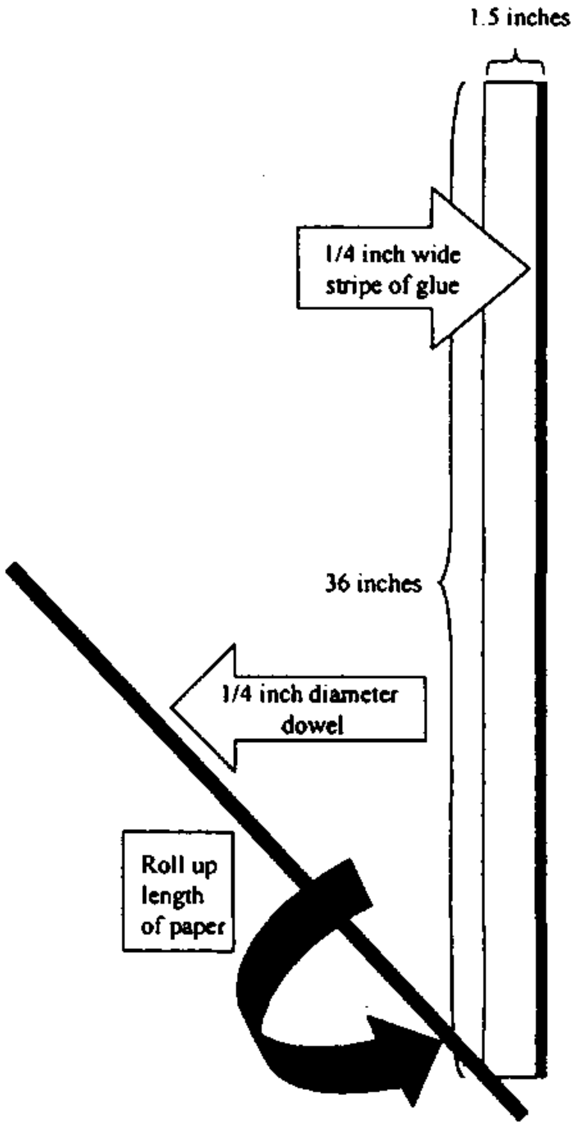
Mixing: The following ingredients are screened together two or three times through a 50-mesh screen. When properly mixed the comp is a dirty medium gray in color:

Ammonium perchlorate	5
Hexamine	1
Iron powder, 50 mesh or finer	4

Loading: A handful of tubes is gathered and tied together to form a bundle (masking tape does a good job). The comp is spooned into the tubes and the bundled is rapped on the table periodically to force the mixture to pack. The casings are filled tightly and completely but not compressed.

Finishing: A couple of turns of packing tape are used to close the open end. A fuse can be added if desired but it is not necessary if they are lit with a torch.

For ease of handling (i.e. no burnt fingers), we recommend that the completed mini-fountain/sparkler be hot glued to a bamboo cooking skewer. This mixture may drop hot iron, so must not be held vertically. RW



SMOKING CAP STIX

Recently, an article in the *Best of AFN III* detailed plans for building Easy Sun. As a by-product of this construction, components of the Cuckoo fountains were removed and discarded. Each Cuckoo fountain contains two whistles, two empty paper tubes, and a plastic base that were not needed for Easy Sun. Chances are the base can't be saved, but if you're like me you'll salvage what you can. Don't discard the whistles and the tubes; they can be used in some nifty projects.

SMOKING CAP STICKS

If you're in my age group (mid-forties), you probably used these when you were a kid. They were fun then, and they still are. My two daughters) dispatched every one I made recently. In case you haven't seen these before, what they are is a small tube about four inches long by 3/8"; you can strike the tip against a match scratcher or hard surface to ignite. Once lit, they would smoke for a minute or so before exploding with a loud report. Here's how I made mine.

Materials required

- 16 empty 4" paper tubes from the Cuckoo fountains
- 16 1 1/2" firecrackers (Big Bomb brand is a good fit)
- Nitrocellulose lacquer (shellac may be substituted)
- 1/8" X 6" rammer (dowel rod)
- 16 Strike anywhere (SAW) kitchen matches (Ohio Blue Tip or Fire Chief brand)

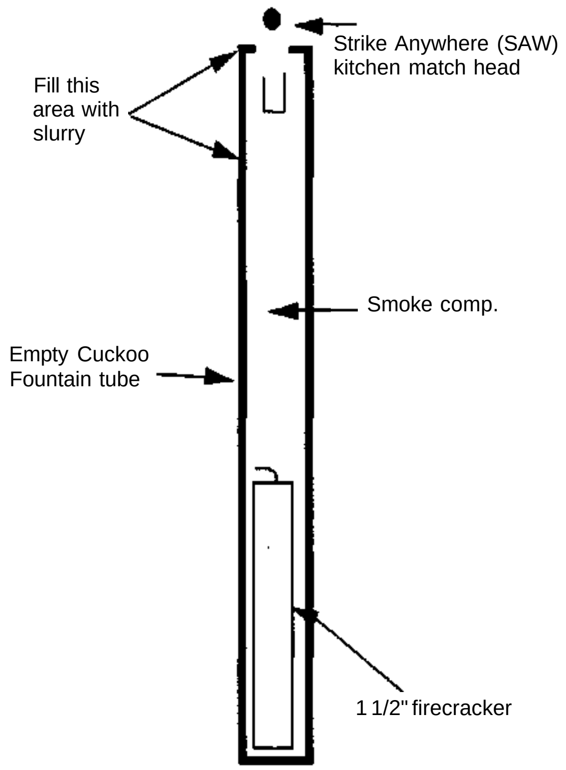
I begin by mixing the smoke composition. All parts are by weight.

I slide a firecracker (fuse end first) into the end of the empty tube, then fill it by thirds with the smoke composition.

Between each charging, I use the small rammer to consolidate the smoke composition; hand pressure is all that's required. The tubes are charged to within 1/2" of the top. This operation is repeated with all remaining tubes. Refer to the following drawing.

I cut the top off a SAW match, leaving about 1/4" of bare wood below the matchhead. Some of the smoke composition is mixed with the nitrocellulose lacquer until it is a thin slurry. Then I use one of the cut off matchsticks to place the slurry into the open end of the cap stick, and then press one of the cutoff matchheads, with the striking tip exposed, into the slurry. If any slurry is displaced just pack it around the matchhead. Caution must be observed not to strike the tip of the matchhead with a fingernail or you may strike fire. It is allowed to dry in the sun about two hours.

Once these have dried, the cap stix can be scratched on any hard surface to ignite - enjoy! Oh by the way, we must be careful because these cap stix are capable of ignition if they are accidentally dropped and happen to land on the exposed matchhead. For a safer, less versatile version, regular strike on box kitchen matches may be substituted for the SAW version. BS



EASY FIRECRACKER MORTAR

The early twentieth century was the golden age of small fireworks in the United States. Innovation was rampant, and is reflected in the large number and variety of fireworks-related patents issued during the first four decades. In addition to fireworks per se, many fireworks toys were made and used during the period — torpedo canes, toy pistols, toy cannons, and many others. One popular item was the cast iron firecracker mortar. The particular ones with which I am most familiar were made by the Kilgore company, a firm that mainly produced caps and cap guns. The Kilgore Firecracker Mortar came in two types that I know of — both of cast iron with bores of 1.375 inches. One type was a rather fancy model mounted on a swiveling base which allowed adjustment of the trajectory of one's projectile. The other was a more modest, common, and inexpensive model that rested on three stubby support legs. Both types had a 0.375 inch hole molded at the rear into which a firecracker could be inserted.

The Kilgore Firecracker Mortars came packed in individual cardboard boxes, each supplied with a foam rubber ball as the intended projectile. Over the years, of course, most of the foam balls have disappeared from the few mortars to be found on the antique market. Presumably other balls or makeshift projectiles would have been fired once the original foam balls had disappeared into the distance.

Over the past several years I have acquired a few of these mortars, which I have enjoyed having in my collection for their aesthetic value as antiques, and for the fun of shooting them off now and then. Lacking the original foam balls, the modern, hard rubber "Super Ball" has proved a more than adequate substitute. These balls are available in a 1 1 1/2" size that tightly wedges into the mortar and will shoot over the treetops with an ordinary 50mg Chinese firecracker, and to amazing heights with an old 2 grain cracker. Needless to say, caution must be exercised to prevent these balls sailing through neighborhood windows like an errant baseball.

Of course, one problem limiting the potential popularity of the Kilgore mortars among pyro hobbyists is the limited supply and relatively high cost usually encountered in the antique market. However, one can very simply make a "clone" of the Kilgore Firecracker Mortar from easily obtained materials. This is one way I have done it.

My local hardware store carries a pretty wide selection of plumbing supplies. Among them is a selection of schedule 40 PVC fittings from which I initially selected a 1 1/4"-inch slip cap, along with a 1-inch coupling. I'm not a pipe fitter, so I can't tell you exactly why the 1 inch coupling is really 1.375-inch inside diameter, let alone why the 1.25-inch slip cap is really 1.625-inch inside diameter. Yet it appears to be so. In any case, these fittings slip right together with a tight friction fit. With my drill press I drilled a hole 0.281 (9/32") diameter toward the rear of the slip cap. This will easily accept most 1.5-inch Chinese firecrackers. The 1.375-inch "Hi-Bounce" brand "Super Ball" from the local dime store slides right down the barrel, neat as a pin. The bottom of the cap is close enough to flat that the mortar will stand up unaided in the dirt of my front lawn. I insert the cracker, light the fuse, then watch as the ball goes nearly out of sight. It may not be Kilgore, but the cost of materials was about $2.50 (including several balls), and the performance was spectacular.

Since making the original mortar, I have also made a smaller 1 inch bore version, as well as a larger 2" bore version for firing the smaller and larger "Hi-Bounce" balls. PVC couplings and caps can be had at nominal cost to produce each, and all of these home-made mortars are loads of fun when used with caution. WK

KATYDIDS- REPEATING FIRECRACKERS

A quick device is a variation on the time-honored Grasshopper or English cracker. This is like a repeating firecracker - a tube that contains an explosive composition that has been folded back and forth several times to give a series of chambers connected by a pinched-off section of pipe. When the fuse is lit, each chamber gives off an explosion, causing it to hop around. Meanwhile, the fire is slowly transferred through the fold, until it reaches the next chamber where it explodes again. Thus you get a series of staccato pops as it hops around. These devices are banned in some areas because of this hopping nature. Yet they are an old fashioned firework, and many people who have a nostalgic nature want to make them. And people who have never seen them also find them to be fun. Weingart has a complicated-sounding procedure that involves wooden formers, rods, hammers and an intricate stringing pattern. I know a number of people who have tried to follow those instructions without success. The following process gives a hopper that isn't as good as the few commercial ones I have seen, but it can be spiced up with added effects. I call it a *katydid* to distinguish from the real grasshoppers. One nice thing is that "this isn't rocket science". I have seen these made with tremendous variations and they all work. Some jump higher, some have nicer effects, but they all do something fun!

The first step is to make a tube, much like a quick match tube. The diameter isn't strictly important - anywhere from 1/4" to 3/8" seems to work fine. The stouter it is, the more the katydid hops around. Two turns of 30 pound Kraft paper gives a fairly sedate katydid, while three turns of 50 lb. Kraft afford some really energetic hops! The tube is rolled with a liberal application of slightly diluted white glue, and allowed to dry.

After it is dry, a length ranging from 14" to 24" is cut. Then a single strand of black match is passed through the length of the tube. Multi-stranded black match doesn't provide much of a delay between *POPs*, and so single stand is definitely indicated. The black match is trimmed so that it hangs out about 1/2" on each end. One end is folded, and taped shut with either masking tape or 1/4" nylon strapping tape. The latter seems to give slightly better results. The tape covers the match and helps prevent it from taking fire accidentally. A little tape is used on the other, open, end to prevent the black match from disappearing down the hole.

It can be filled with many different compositions, but I have found that simple variations on Black Powder compositions work best. Flash compositions are too brisant, and cause huge hops or simultaneous explosion of all the chambers. A very simple starting project is to mix 25% (by weight) of a metallic spark producer (such as brake turnings, titanium granules, sponge zirconium, coarse aluminum, etc.), in with 3Fg or 4Fg Black Powder. Enough of this is scooped into the tube to loosely fill a section which is about 1 1/2" long. Then an empty section of the tube is bent sharply back on itself just beyond the filled portion, and flattened lightly with a mallet or pressed with an arbor press. This crimps the paper around the single strand of match, affording a short delay. This flat crimp is then wrapped with masking tape or 1/4" nylon strapping tape to retain the crimp and the delay action. The next section is then filled, and the bending, crimping, pressing and taping is repeated. This is done until the whole tube is filled. Of course the last chamber can simply be taped shut after a length of visco is added. This gives a loose accordion shaped like "WW", where each leg stands slightly aloof of its neighbor (grasshoppers are tightly bound).

Such a katydid will give a series of explosions while hopping around and showering sparks in every direction. Caution must be exercised because while they do tend to hop around in a confined radius, there is nothing saying that a larger one couldn't travel more than a dozen feet in a straight line - possibly right into your audience.

Very small stars can be added to a larger katydid to give a series of colorful showers. I have seen one made with red, glitter, blue, white, green, orange, and yellow segments - a kind of 7-break ground shell. TIP

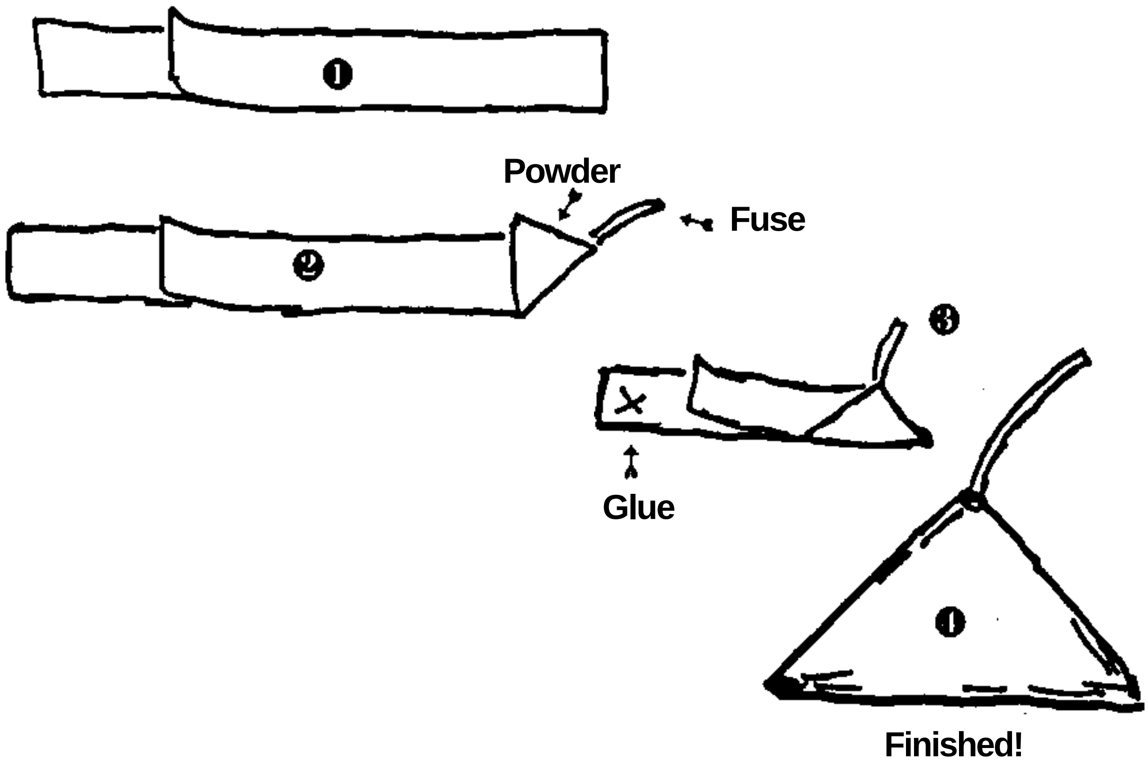
TRIANGLE PYRO CASES

Cylindrical pyro cases are expensive, and if hand made are very time consuming to make. Also, the mechanical integrity of the end plugs is very small in comparison to the cylinder portion. It has been my observation that stronger containers produced louder, sharper reports. A triangle salute case is a mechanical marvel with respect to utilizing the paper's entire tensile strength.

Triangles are charged with a pyro mix of the builder's choice, wrapped, fused and glued, all in one step! The basic design is an interesting design for smoke bombs, salutes, fountains and flying triangle rockets with a little imagination.

I start with a good strong brown Kraft type paper. Paper grocery bags are saved for this purpose! I cut into strips about 1 3/4-inches wide with a straight edge and razor knife, then cut strips around 24-inches long. They are folded about 6-inches off center from in half. I crease this fold on a hard surface with the edge of a pen, then fold this crease across the paper to form a triangle and again crease the paper fold (which helps keep the powder from leaking out). Then the triangle is bent open and a favored salute or other mix is spooned in, along with a piece of visco fuse in the upper corner. Then I tightly wrap the remaining paper around the triangle and glue the end. They are ready to use immediately.

These packages throw well, can be tied in strings like Chinese firecrackers, loaded in shells and mines. They pack quite densely in cylindrical cases and fly oddly when loaded with a fountain/colored/rocket mix. These packages are excellent when loaded with a bullet sensitive mix and placed on steel silhouette targets. CD



YOURS, MINES, AND OURS

A few months ago I put on a charity show for my local community. One of the donations was a pair of mine walls. Later, the mines were one of the things that were almost always mentioned by the people of the village. Similarly the memorable segment entitled "Dreams" at the Amana PGI convention relied heavily on mines. Mines are clearly a crowd pleaser.

The question often arises - "How do you make mines". Well, I knew the ways I had been taught, and I had learned several more complicated ways. Recently, there has been a small literature storm debating the best way, and that debate sort of culminated in a challenge at the Amana PGI convention (each side claimed victory). Thus, I became interested in learning which was "the right way".

I began by experimenting with five ways. All of them had the following similarities for the purpose of this test. Each was made with an outer casing consisting of three turns of 60# Kraft paper, wrapped on a 3" case former. The paper was held with glue, and the bottom was sealed with a well glued tongue fold. The lift was 1 ounce (±2%) Goex 2FA, and 100 grams (±1%) of Snowball Glitter stars were used. Commercial quickmatch was used. The tops were all closed via a clove hitch which was used to gather the case around the quickmatch. When end disks were used they were 0.125" thick. The finished mines were all placed in standard 3" guns, and fired by hand. The differences are as follows:

1) ***The lift-powder bag method.*** In this method the lift powder was placed on a 8" square of tissue paper, and the paper was gathered to form a tissue bag, and the quickmatch was piped right into this bag. The bag was then placed in the case, and the stars were placed on top of the bag, and the mine was finished as above. In this method the burning gases of the lift charge are supposed to ignite the stars.

2) ***The star-bag method.*** In this method, the lift powder was placed loose in the case. The stars were placed in the center of a square of tissue paper, and this was gathered to make a bag. The quickmatch was piped into this bag, and the bag was sealed with string and clove hitch around the quickmatch. The star bag was placed on top of the lift powder, and the mine was finished as above. In this method the fire from the ignition of the stars is supposed to break through the bag and light the lift charge. This is supposed to assure better ignition.

3) ***The disk method.*** A 5/16" hole punch was used to punch seven holes in an end disk, with one central hole and six holes around it. A 3" length of black match was threaded through the center hole and held with a small piece of masking tape (this is almost certainly not needed). The lift powder was poured into the bottom of the case, and the perforated disk was placed over the lift powder. The stars were then placed over the disk. The bare end of the quickmatch was nestled into the stars, but not more than one-half of the way to the end-disk. This was then finished. The purpose of the disk is to prevent the stars from commingling with the lift powder, and to help force the stars out of the mine.

4) ***The piston method*** (published as the *Meinhart* method). In this method a clever little piston is designed to push the stars up and out of the mine. This is supposed to eliminate the possibility that the single disk might simply tip on its side and lose effectiveness. The piston is made from two end disks that have a central hole, and which are spaced by gluing three small cardboard tubes between the disks. The dimensions on these tubes do not seem to be critical, and these tests were conducted with 1.5" long by 9/16" o.d. spiral tubes. White glue was used for the tests reported below, although hot melt seems to hold up equally as well. The pistons of both types were generally recovered intact, demonstrating that these dimensions were adequate. After the glue hardened a length of quickmatch pipe was inserted through the two holes in the end disks, and a 5" length of black match was threaded through the pipe.

The piston was held against the end of a case former, and a casing was rolled around the piston and the former. Lift powder was poured into the open end (this is "down"). This was then pleated over using a tongue fold. The case was then removed from the former, and the stars were placed in the upper end. Quickmatch was then nestled into the stars, and the mine was finished as above.

NOTE: The appearance of both methods 3 and 4 can be improved by using a final end disk with a central hole that sits above the stars. The quickmatch goes through this central hole. This top end helps to define the shape of the top of the mine, giving it a more pleasing appearance. However, no visible difference in performance could be detected.

5) ***The can method.*** People who have reloaded shotgun shells will find that this method is very familiar. The idea is to use a split cup that holds the stars in a cluster while they are accelerating in the gun, but which peels away when the unit leaves the muzzle of the mortar. Kastners sells cardboard shell bodies that consist of a cardboard tube (roughly 2 1/2" dia. and about the same height), two end disks and two end caps that fit over the end disks. If one assembles one end of this "can", one obtains something that resembles a Quakers Oat can (before they started using plastic ends). For each mine one of these one-ended cans was taken and six slits were made in the wall of the can parallel to the axis. These slits were cut about three-quarters of the way from the open end to the bottom of the can. A 1/4" hole was punched in the bottom of the can, and a 3" length of black match was threaded through this hole, and held in place with a small bit of tape. This can was then butted up against the bottom of a case former, and a case was rolled over the can and the case former.

Lift powder was then placed in the open end of the casing, such that it rested against the outside bottom of the can. This was sealed with a tongue fold, and the case was pulled off of the case former. The can was then filled with 100 g of stars, and the mine was finished as above.

TESTING THE MINES

These five types of mines were then subjected to a number of different tests. In all of the tests the responses were gathered in a blind fashion - a series of different mines were fired, and the evaluators did not know which type of mine was being shot. The tests reported here were:

Preliminary - A set of ten mines, two each of all five types, were shot in front of a small audience of local pyrotechnicians. These mines were made less accurately than stated above, and used a mixture of red and gold glitter stars. The results were communicated verbally. These were not blind tests.

FFFF - A set of eight mines, two each of types 2, 3, 4 and 5 were made during a seminar, and shot for a small audience of judges. The results were communicated verbally, and no numerical scoring was attempted.

Tri-State Shoot - A set of eight mines, two each of types 2, 3, 4 and 5 were brought to this shoot. Questionnaires were given to members of the audience, primarily builders and shooters of mixed experience levels. The test was run double blind, in that the shells were shot in a random order, the types were not announced, and the data analysis was performed without knowledge of which mines were of which type. Twenty-two people turned in their questionnaires. One was eliminated due to textual rather than numerical responses. The questions for each mine were *height, breadth, fullness* and *comments.* The questionnaire also asked the people to select their favorite.

Video tests - a set of eight mines, two each of types 2, 3 ,4 and 5 were shot in front of video camera. The camera was set to manual focus, and was placed approximately 125' from the mortar. The same mortar was used for each shot. The focal length was set so as to be able to capture the tallest mine. The tape was then subjected to a frame by frame analysis to determine the relative heights, breadths, and in an attempt to count the stars. The heights and breadths were measured by placing a ruler against the TV screen. All numbers were converted to relatives values by dividing by the largest values for height and breadth. Thus, the numbers range from 0.5 to 1.0.

TEST RESULTS

The preliminary tests indicated that there were going to be noticeable differences between most of the methods. The two bag methods seemed to be essentially identical. Thus, method 1 was not examined for the other tests.

The results of the FFFF shoot were perplexing at first. The audience clearly saw the differences in the various methods, but they were NOT in concurrence as to which mine had been the best. Initially I ascribed this to poor note taking and poor memories. I subsequently revised this opinion (see below).

The Tri State Shoot gave me a chance to gather some statistics. The mines were shot in random order, and the data were collected without anyone knowing which test shot was which construction method. The results for the Height, Breadth, and Fullness scores are shown here:

	H	B	F
Method 2, star bag	7.7	7.9	7.6
Method 3, disk	7.9	6.7	6.5
Method 4, piston	8.1	6.5	6.3
Method 5, split can	8.7	5.5	6.2

The video experiments verified these results. The video results agree surprisingly well with the human panel. Relative numbers were used since the camera wasn't calibrated to an exact scale. The fullness was determined by using Adobe Photoshop to determine the number of pixels that were brighter than 20% white. Thus, the relative numbers are (1.0 = the biggest, and 0.5 was half as large as measured on the screen):

	H	B	F
Method 2, star bag	.71	1.0	1.0
Method 3, disk	.81	.76	.86
Method 4, piston	.88	.73	.85
Method 5, split can	1.0	.70	.86

There are several trends that can be seen. There is an inverse relationship between height and breadth, and between height and fullness. Those mines that went higher were less wide, and seemed less full. The star bag produces a short bushy spray, while the can produces a tight shot pattern of stars that flies high into the sky. Comparison of the disk and the piston methods reveals a similar tradeoff - the disk produces a shorter, more bushy spray, while the piston produces a higher tighter bunch.

Another question on the form was, "What do you like in a mine?". The answers were wide ranging. Some people said that they preferred wider, more bushy sprays, while others said they wanted tall, narrow columns. This helped to explain the diversity of answers obtained in Florida. The people had different preferences. Of those people at the Tri-State Shoot who responded to which mine they preferred, the responses were (15 respondents):

Method 2, star bag	(4)	27%
Method 3, disk method	(5)	33%
Method 4, piston	(4)	27%
Method 5, can	(2)	13%

What does this mean to the mine maker? Well, first of all, the ease of construction is 2, 3, 4, 5. It is far easier to make a bag mine than a piston or a can. The perforated disk seems to be a good compromise of effort versus results. However, if the maker desires a more bushy or a taller mine, the other methods can be used.

But what about esthetics? My interpretation is that no single method is the best. People have individual preferences, and no single method was viewed as being best by anyone. However, the good news is this... none of the methods produced "bad mines". People liked them ALL. So, why worry about it? My motto is, let's go out there, make mines, have fun, and wow the crowd! TIP

THE CONSTRUCTION, CARE & FEEDING OF THE CAJUN PYROTECHNICAL SAWED-OFF SHOTGUN MINE

What is it? Is it impressive looking? No. Is it traditional? No, but it is easy and cheap and makes one helluva mine wall. Unlike the conventional mine which uses a much longer tube, this mine effect can most readily be described by using the analogy of the differences between a full choke and a sawed off barrel on a shotgun. With a full choke the shot does not spread out and can travel a longer distance. The Cajun shotgun mine gives the effect of the sawed off barrel in which the shot pattern spreads readily, but doesn't travel as far.

When these mines are fired in walls the effect is a fuller horizontal effect than with a conventional mine. Because of the short exposure time to the lift, created by using a short tube, the operator can much more easily obtain a star layering effect. If a mine wall of red, white & blue is needed for the 4th of July show and the colors sort themselves at three separate heights (as opposed to variegated) it is simple to put the blue stars in the bottom of the bag and layer red stars of a larger diameter on top of the blues and finally top them with the larger white stars. When the mine is fired, the blue stars will be at the lowest altitude followed by the larger stars, again followed by the largest diameter stars at the highest altitude. If inserts, such as small salutes, festival balls, etc. are used, they will gain quite a bit of altitude, such as that imparted by a longer tube.

As a testimonial to this mine, I would like to add that the device described in detail below won first place in Advanced Mines at the Fargo convention, beating out the individual who won Grand Master for that year.

CONSTRUCTION

1. 1/4" and 3/4" exterior plywood.
2. One 13"x13" plastic milk crate.
3. Adjustable circle cutter.
4. Wood or decking screws.
5. Drill press.
6. 3" i.d. cardboard tubes.
7. Table saw (Skil saw if the builder is good).

The most difficult item to acquire is the crate. The type I am referring to are the plastic crates in which milk is delivered to the local supermarket. They can be identified easily as they have the following printed on the sides. "Warning, use by other than registered owner punishable by law". The sixteen crates which I use were procured from the local landfill at no cost. It would be wise to make sure they sign a piece of paper as a certificate of origin. Please note that the author is not suggesting in any way the "Midnight Requisition" option from the local supermarket. I once saw some plastic crates at Sam's or Walmart for filing documents which were of similar construction, however most important, the crates must be designed so that they have a protruding foot on the bottom of the crate such that one crate can be stacked on top of another while locking in place.

I usually stack the crates four high. It takes two people to transport four crates each to the shoot side giving us five walls of eight mines. The mine tubes can be easily obtained free at any industry or company who uses shrink-wrap plastic film for packaging. The tubes are generally standard in size. These tubes are spiral wound and measure 20 3/4" long, 2-7/8" i.d., 3-5/8" o.d., with a 3/8" wall thickness. Other lengths of tube are available depending on what type of shrink-wrap machine they are using. By the way, these tubes make excellent guns for 3" shells. I have seven racks of five guns which I use for my 4th of July finale.

With all the necessary components collected, construction may begin. A section of 1/4" plywood is cut to fit snugly in the bottom of the crate. This serves to equally distribute the shock as each mine is fired. Should this bottom plate not be used, any overlifted experimental mines might break the waffle weave plastic on the bottom of the crate.

The next step is to construct the tube guides. Two pieces of 3/4" plywood are cut to fit the inside of the crate snugly. One piece will serve as the tube guide in the bottom of the crate and the other will be positioned at the top of the crate. Five equidistant points are geometrically laid out and marked, which will allow cutting out holes slightly larger than the mine tube diameter. These holes are not too snug, that would cause trouble removing the tubes for cleaning and maintenance.

Once the five holes are marked and centered, the two pieces of 3/4" plywood are fastened together with decking screws and marked or indexed so they can be positioned properly in the crates after cutting the holes. This indexing is most important, as the tubes may not be properly aligned when assembled. Now using an adjustable circle cutter on a drill press, the first hole is cut slightly larger than the tube o.d. (I have also discovered that a 4" hole saw works quite well). When the first hole is completed it will be found that the circle cutter has made a drill bit mark on the second piece of plywood. After drilling the five holes is completed, the two pieces are unscrewed, at which time marks will be on the bottom piece of wood showing exactly where to drill the next five holes.

With the foot and two tube guides cut, assembly can proceed. The 1/4" plywood piece is positioned in the bottom of the crate and immediately the bottom tube guide is inserted directly on top. Using wood or decking screws the bottom tube guide is secured to the four sides of the crate by screwing right through the solid sections of crate plastic. Notice that the crate will have handle holes built into the sides of the crate near the top. Just below the handle holes the second tube guide is inserted and secured with screws. If the guides have been properly aligned, they will readily accept the mine tubes.

The last step consists of cutting the mine tubes to fit the crate. The tubes are cut to a length that is only long enough so that when inserted into the guides, the length of the mine tube will not be so tall as to interfere with the stacking feature of the crate. This is important; if the tubes are too long the crates cannot be stacked on top of each other. When the tubes are cut, 1 1 1/2" kiln dried plugs are inserted with hot melt glue and secured with three or four decking screws drilled through the cardboard tube into the pine plug. I get my plugs from Midwest Wood Specialties. Now the five tubes are inserted into each crate. If all the measurements were properly done, all the tubes will fit snugly and the crates will be stackable.

CARE:

Very little care is required after construction other than cleaning after use by dumping the crates upside down to clear out debris. One of the notable attributes of this mine system is that the mines or walls can be shot "Wet" or "Dry". My mines have been in the pouring rain for up to 6 hours and still fired when requested. Immersing the entire tube in a couple of gallons of Thompson's Water Seal will waterproof it. It is also advisable to waterproof the wooden guides. This waterproofing treatment also has the advantage of discouraging de-lamination of the spiral wound tubes. Some of my tubes have been fired over 40 times and still show no signs of peeling.

FEEDING:

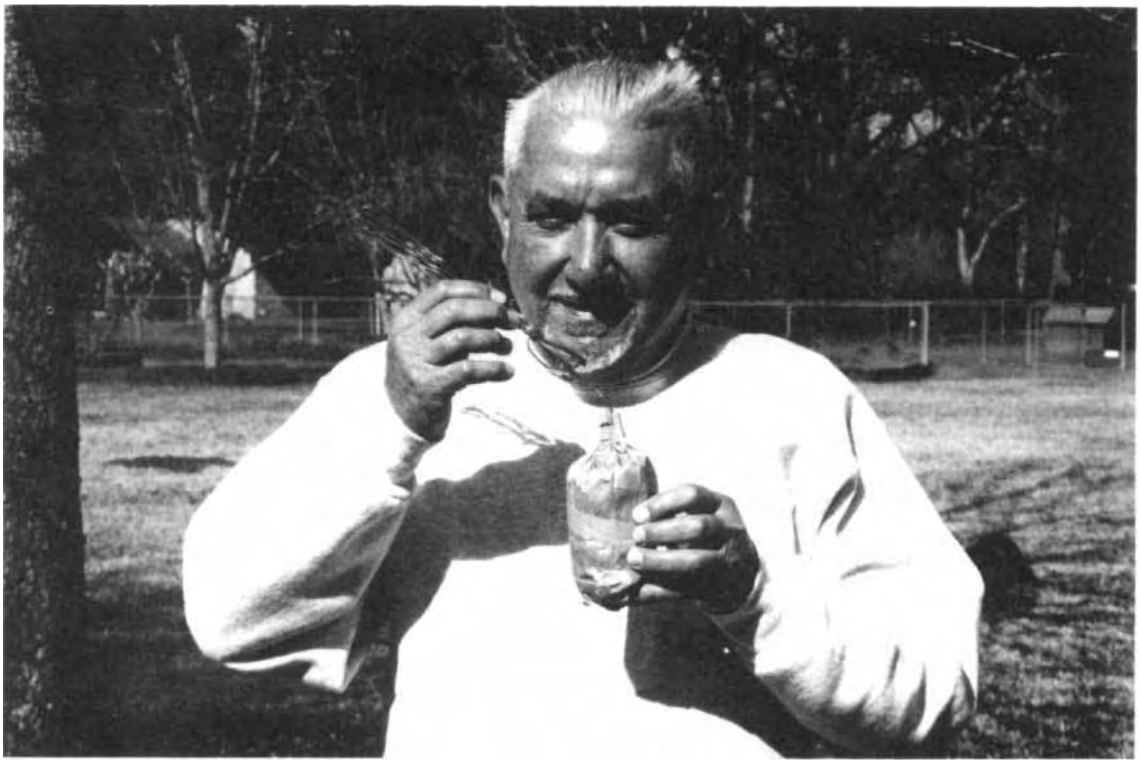
Now comes the fun part. The only limit is the imagination when considering what type of pyro effects to produce. Some of my favorite stars include:

1. Chrysanthemum #8 (Shimizu)
2. Winokur 39j glitter (Pyrotechnica II)
3. Electric spreaders (Weingart)

Yes, even Dragon Eggs, Jumping Jacks, and many other consumer items can be used. Some may be used as inserts along with the usual charge of stars.

Items Needed:

- Black Powder, 4Fa
- *Baggies* sandwich bags (the cheap kind to fold the sandwiches into, not the zip type)
- Masking tape
- Electric match, or quickmatch & visco for hand firing.
- Kraft self-opening paper bags, 1 lb. size.
- A glass tumbler measuring approximately 5 1/2x2 3/4", or a full coke can to be used as a case former.
- Transparent plastic drinking cups, 10 or 12 ounce.



Author Jerry Marino with finished mines.

Completed Shotgun Mine assembly.

Crate and tube stabilizers

The Kraft paper bags can be purchased from the local tobacco wholesaler. They stock about 8 sizes, the smallest being 1 lb. self-opening. They measure 6 1/2"x 3 1/2" when they are flat and not opened. They come 500 to a bundle and are inexpensive. Several sizes larger may be purchased at the same time for future use. To use, they are double bagged (one opened bag placed inside another), the glass tumbler or full coke can is inserted, the excess paper is crumpled or folded around the case former, and then three or four turns of masking tape are made around the bag. The makeshift case former is removed and the lift bag is complete.

Lift Charge Construction:

17 grams of 4Fa (a lesser amount will be required if Fg is used) are weighed and dropped inside of a plastic baggie. An electric match is inserted (or quickmatch and visco to hand fire individual mines), the baggie is twisted until it forms a small ball around the powder, masking tape is applied above the powder and finally the bag is cut above the tape line.

The next step is preparing to fill the mine bags with stars, inserts, etc. To make a wall of 8 mines, a 1400 gram batch of stars (double if using heavy zinc stars) is needed. In my procedure, I lay out side by side on a counter top eight 10 or 12 ounce transparent plastic drinking cups, then equally distribute the stars between these eight cups. Next I take the mine bag, insert the lift charge into the bag and dump in the cup of stars, then twist the top of the mine bag together and secure with several turns of masking tape. This is repeated until the mines are finished.

The mines are loaded into the crates, marking each location by effect. When all the crates are loaded with five different wall effects one step further is required. Each mine tube must be covered by a piece of heavy duty aluminum foil, secured by a rubber band to insure that slag and stars from one wall do not ignite elements of subsequent walls. It should be obvious at this point that any compositions selected must be fast burning compositions or else the effect will be what I call "Colored fireflies in the grass".

GOLD LAMPBLACK STAR MINES

On the 4th we shot some 3" mines using a gold/lampblack star mix that was a combination of Bleser's lampblack and Allen's gold star compositions:

GOLD LAMPBLACK STARS	
Potassium chlorate	39
Potassium nitrate	4
Barium nitrate	6.5
Sodium oxalate	3
Air float charcoal	20
Lampblack	15.5
Dextrin	5.5
Red gum	6.5

All the oxidizers were "hand milled" to -60 mesh. Then all components were diaper mixed and the comp was dumped into a Ziplock freezer bag for wetting. I used approximately 20% water/ethanol (50/50) to wet, kneading the bag in the usual manner. Then the comp was formed and cut into cubes of about 10 mm.

The mines used about 60 grams of stars, with about 25 grams of Elephant brand Cannon powder.

Mine bags were rolled of 3 turns of newsprint over the required former, and the stars were dumped in. The Black Powder was contained in a tissue bag, with quickmatch. The mine bag was clove-hitched around the quickmatch. Plenty of bare match was left for a safe retreat.

The effect is a gold head with trailing charcoal/lampblack sparks (or fire dust). The fire dust looks more gold than a regular lampblack star, but that could be an artifact of the gold head. BD

DON'T MIX IT!

I burn all the trash and leftovers from my hobby in a 55-gallon "fire barrel" in a field behind my shop. During the past couple of weeks, in an uncharacteristic frenzy of shop-cleaning, I tossed out several small containers of unlabeled compositions (probably left over from the last club meeting here, when one of the rocketeers had made up a batch of some blue strobe rocket comp). There was probably 6 - 8 ounces of various stuff. I tossed it all into the trash can.

Later that week, I dumped the trash into the fire barrel. Now I can tell you that this particular barrel has seen some interesting flames come out of it, as have the neighbors' kids, who love to watch me burn stuff. So, I should have remembered what was in the contents of the trash, as I leaned over the barrel with my trusty propane torch to light the papers laying on top of the pile. No sooner had I lit the pile and moved my head from over the barrel, than FWOOOOSH ! went the barrel ! A bluish flame shot up out of the barrel about ten feet in the air. Not even singed, I was nevertheless startled, to say the least. I walked back into the shop and just sat down to cool it for a few minutes. That was a VERY close call. My face had only been inches from the conflagration. Another second or two earlier and I would have had a different looking face for a long time. I made a stupid mistake and almost paid for it.

Moral to this: Don't burn stuff all in one pile--make a thin line of the stuff and ignite one end. Ignite it with something that puts some distance between you and the material. And DON'T MIX IT WITH THE OTHER TRASH!

AP

A HERETIC'S GUIDE TO ROMAN CANDLES

There is the so-called right way to make Roman candles. Classic pyro writers such as Weingart, Lancaster and Brock tell you how to do it the right way. Other pyro writers follow suit. But - "right way" Roman candles are in fact just boring!

Sure there have been many innovations such as exploding stars, color changing stars, and humming stars or "bees". But these have reached (in my mind) the bo-o-ring stage. The classic device which shoots a series of stars which fly to the same height and then extinguish is just one big yawn. Ah - but there are ways to make Roman candles more exciting!

My first thoughts at challenging the orthodox doctrines making came with my early experiments in this area. Watching how low cost Class C performed only strengthened my convictions. These did not perform according to the books which described how "good" Roman candles should be made - but they sure did some unexpected fun things.

The "proper" way to make Roman candles is to ensure that the propellant is adjusted in such a way as to project each star to exactly the same height. Ideally each star should extinguish just as it reaches maximum height. We are told by the Roman candle high priesthood that to achieve these goals is a measure of one's skills in the pyrotechnics arts. Failure to achieve such automatically assigns one to the ranks of lesser mortals.

In addition to the above goals, a "good" maker of Roman candles must pay careful attention to the ramming of the "candle comp" or fuse. A mortal sin is to ram in such a way as to cause too short a burning time. There is (supposedly) something just proper and decent about having a respectable pause between each star being shot. And no one has even dared to consider firing more than one star at a time from a single tube.

Well there are more fun ways to make Roman candles and the sky's the limit when you start to consider all the many variations and possibilities.

I must confess that in the early days of my pyrotechnic endeavors I was steeped in orthodox Roman candle beliefs. I got rather annoyed every time I witnessed a Roman candle shooting its stars to different heights. The cheaper Class C candles almost inevitably dropped the first star on the ground. The second star would often extinguish just before ground level. The other stars would improve on this until finally the last star would perform more or less correctly. I really felt cheated by these "below spec" candles.

My own attempts at making Roman candles ended up being better than the cheaper Class C items and this gave me a certain amount of satisfaction. It took me quite some time to more-or-less perfect them and I started asking a lot of questions along the way.

My first question concerned the right type of propellant to use. I had no source of Black Powder in those early days and had to try and find an alternative. I opted for some (shock! horror!) flash powder. With some drawbacks, this worked pretty well. Number one drawback was trying to find the right amount of flash. Even a tiny amount would send the star into orbit and would often cause it to blow out blind. The second drawback was that the flash lived up to its name by producing a blinding flash of light. This would frazzle the eyeballs and thus diminish one's enjoyment of watching the star fly through the air.

A third drawback was flash was good for only two stars per candle. This was partly because, for safety reasons, I opted to press the components gently into each tube, rather than ramming them. I used a less violent flash than that normally used for flash crackers; it was made with potassium permanganate and atomized aluminum powder.

I wasn't too happy with my flash candles and looked around for an alternative. Someone I worked with offered to trade some nitrocellulose used for charging cartridges for some firecrackers. She wanted the firecrackers to scare some pesky bark-in-the-middle-of-the-night-at-nothing dogs belonging to her neighbor. The firecrackers worked better than expected. After a while, she just had to appear at her window to stop the dogs barking. Unfortunately, the nitrocellulose powder didn't perform as well.

Yes, there are many dire warnings about the dangers of using nitrocellulose. Even a tiny amount of this stuff is enough to propel a heavy bullet many hundreds of feet, so imagine what it would do to something projected from a Roman candle! And there is always the danger of the tube bursting! The dangers were highly exaggerated.

Yes, nitrocellulose confined in a tight space will explode violently. Thus only a small amount is needed in a sealed cartridge case to send that bullet flying. In Roman candles, however, the situation is different. Even a large amount packed tightly produces a minimal amount of propulsion. So nitrocellulose in my Roman candles was just one big flop. The remainder of my nitrocellulose was used as a binder for stars.

Eventually I managed to make some Black Powder which did a good job of projecting Roman candle stars. But the question still remains in my mind: are there any other propellants out there which could do the same job cheaper or better?

The next major question is: should all the stars be projected to the same height? My answer: no, not necessarily!

Projecting the stars to different heights creates a certain delightful diversity for the audience. Having each star travel higher than its predecessor creates the feeling of something getting better and better. Is it a sin to let the star fall before it has extinguished? Well, this happens with other fireworks so why not with Roman candles. It can be quite fun to watch flaming stars hit the ground, being sure of course that no other ignitable materials are around. You can naturally opt for stars which extinguish just before hitting the ground.

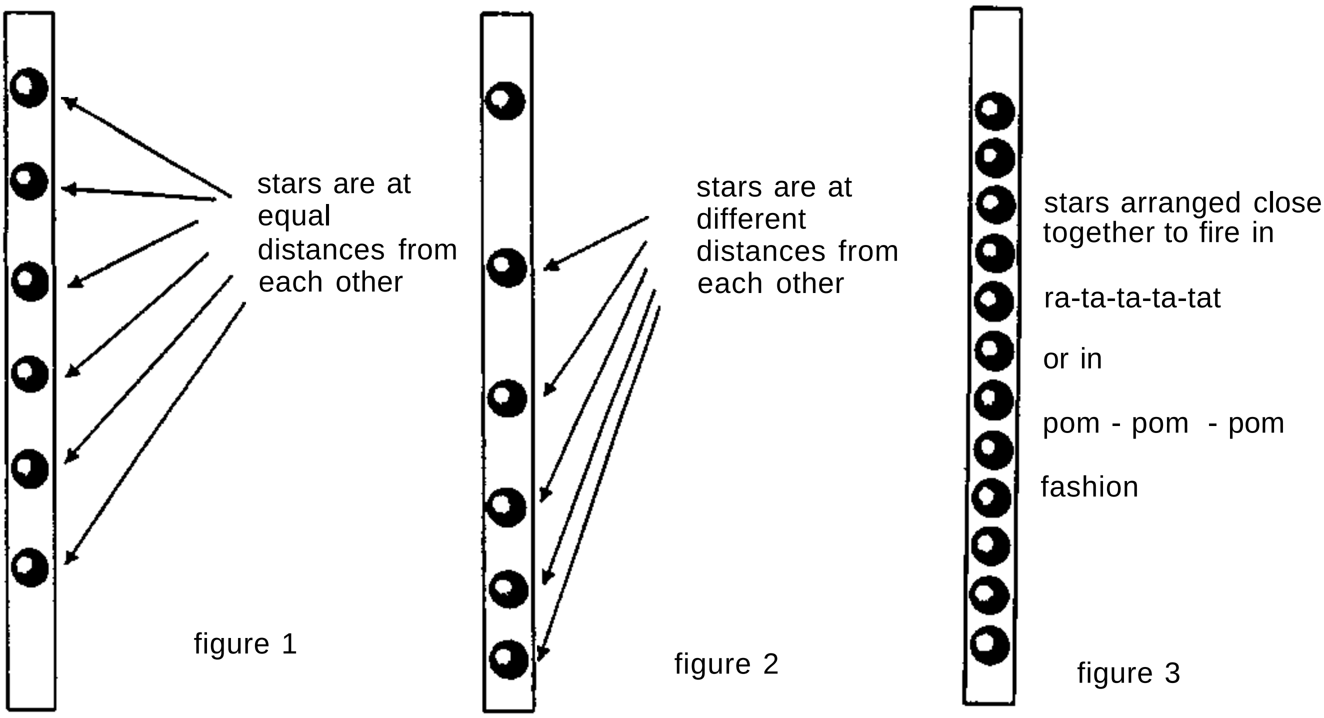
Here's another thought. Why not add to the diversity by having stars of different sizes? Brock describes some pyros who did just that but finally abandoned the idea. The thought behind this idea was to make stars of different sizes and keep the Black Powder projecting charges the same size. This, in theory, would result in all the stars being projected to the same height. Manufacturing practicalities aside, a perceived disadvantage with this scheme is each flaming star differs in size from the others.

To a heretic a perceived disadvantage can actually be an advantage, and a good one. Stars of different sizes create different flame sizes and have different burning times - two interesting diversities. One can naturally combine these two diversities with each star being projected to a different height. So you see where just a little bit of heretical lateral thinking can lead us!

While popular folklore accepts the concept of having different size propelling charges, it hasn't gone as far as entertaining different fuse burn times. Why not progressively shorten the fuse after each star? Here the candle will start off at a leisurely pace and quicken as time goes by. Figures 1 and 2 illustrate these two conceptual differences. For clarity, these drawings show only the stars and omit the fuse and propellant. A variation on this theme is to add a dramatic climax such as having the last star behave differently. For example, this could be an exploding star where the others are not. Another surprise variation is to make the fuse time for the last star longer. Here the audience thinks that the Roman candle is finished when suddenly a surprise last star is shot!

It's great fun having the stars being shot in quick succession. This "machine-gun" effect first came to my attention with a Chinese Class C candle - all the stars were out of the tube before the first star extinguished! Unusual, but great. This has given me a few good ideas.

Idea number one was to replicate the performance of the device which gave me the machine-gun candle idea. Here the stars are packed tightly together and the aim is to fire them all in one quick burst. The effect is a ra-ta-ta-ta-ta-ta-ta-tat, just like in the gang-



ster movies. (See Fig. 3.) Idea No.2 calls for a slower firing rate, a pom - pom - pom - pom like an anti-aircraft gun. (See Fig. 3).

Idea number three has a more purist infantry outlook. Here it is not proper to fire long bursts from an automatic weapon but rather short three-round bursts. A Roman candle can be modified to do just that by firing stars in groups of three, as shown in Figure 4. Of course, one can experiment with the three concepts I have outlined above by combining two or all three of them in a single candle.

Doctrinal purity in Roman candles demands that only one star is fired at a time. Even our deviant machine-gun candles conform to this dogma. Well if we can have candles which behave like machine-guns, we can surely have shotgun type candles. The fireworks world already has these in the "sawed-off single shot" variety - we refer to them as mines. Now imagine a mine which has a longer tube and can fire more than once. *Voila!* A mine which evolves into a special type of Roman candle - a shotgun candle! Fig. 5 shows one shot of such a candle.

A final word about a heretic's approach to Roman candle stars, and good news for many pyros. Yes, you *can* use cut stars in Roman candles! You don't have to restrict yourself to pumped or laboriously made round stars. Cut stars will work with a bit of extra propellant. This extra propellant is needed to make up for the loss of efficiency due to the cut stars not sealing properly in the tube. But if you can afford the extra propellant, cut stars might be your way to go.

So much for stars. On now to tackling the next sacred cow, the revered "candle comp".

Candle comp is treated by most manufacturers of Roman candles as just another type of fuse. In many Roman candles that's all it is - fuse. As such, with few exceptions, the burning of candle comp is boring. A few makers of Roman candles have, however, by accident or design, created candle comp which actually burns in an attractive manner. I have noted some candles which have been pretty little fountains as well as projectors of stars. This is really the way to go - and it shouldn't be too difficult to achieve.

A lot of attractive fountain effects can be achieved with variations in just the three main candle comp ingredients: potassium nitrate, sulfur and charcoal. Here the most important ingredient is the charcoal. Different types of charcoal can give different ef-

stars arranged in
groups of three
to fire in short burst

ra-ta-tat

fashion

figure 4

fects. One can cautiously venture further by adding other ingredients to the candle comp. I say cautiously because many fountain compositions are not suitable for ramming. And the ramming process in Roman candles has its dangers under even ordinary circumstances. But does one always need to ram Roman candles? Here is even more food for deviant heretical thought. IvM

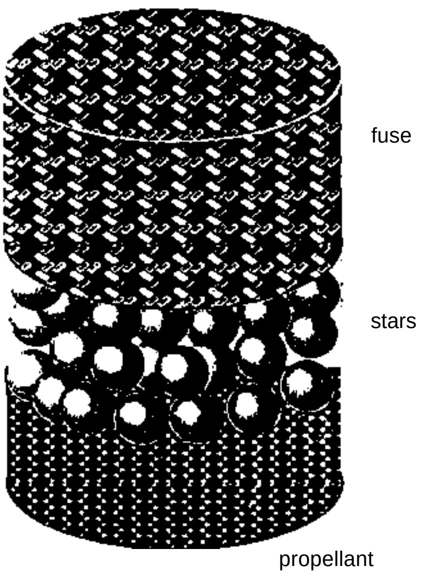


figure 5

KEEP THE KIDS HAPPY WITH THIS

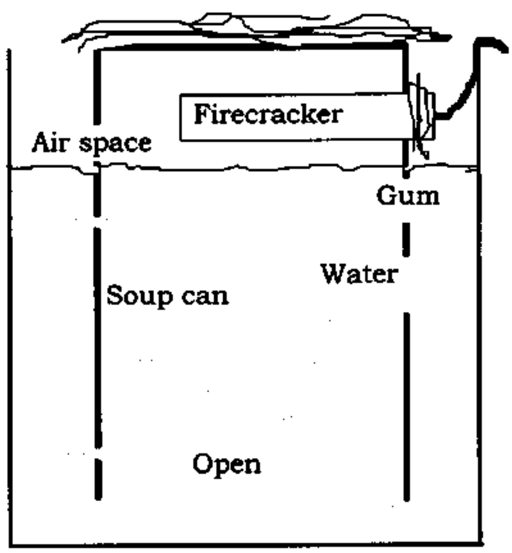
Some people launch parachutes, bombs, vegetables, candies! Well, I use reusable fireworks. (You know, recycle, reuse and re-elect.) It's simple to make with the kids and relatively safe. Stuff needed:

1 - chewing gum
1 - pop or soup can open on one end
1 - 2" cotton cloth
1 - firecracker
1 - coffee can (open on top)
1 - chemical light stick (cylume, glow sticks)
1 - book matches
Some water.

I fill the coffee can half-way with water and set it outside. Then I drill a hole in one side of the soup can small enough to fit a single firecracker. I place the chewing gum (or glue) on top of the inverted can to hold the cotton cloths. I cut an activated light stick open to allow the chemical light to soak onto the cloth. I try different colors, like red, green, blue, and yellow. Then I light the fuse.

Results: The firecracker will explode and push out the water. The can with the glowing cloth raises up quite high; spinning and glowing, flying around and landing, with no chance of starting a fire. I then put in a new firecracker and water and reuse over again.

LJS



MY FIRST GIRANDOLA!

For those of you who may not know, a girandola is a horizontal wheel. When ignited, drivers (rockets) around the periphery of the wheel set it spinning on a central spindle. As the wheel comes up to speed, vertically-mounted drivers are ignited which lift the spinning wheel, and it slowly and majestically rises into the sky in a crown of sparks like a pyrotechnic flying saucer. Optimally, upon reaching maximum altitude, headings affixed to the wheel are ignited, throwing stars and/or garnitures into the sky, and then the wheel settles back to earth.

This all started when I was lucky enough to attend a seminar at the PGI convention. During the seminar, the speaker demonstrated his building techniques and allowed a few lucky souls to help him build a girandola which we shot off later. I also picked up a copy of the new book, *The Incomplete Book of Girandolas.* I was hooked.

Using his book, I created a jig and ordered tooling to construct the drivers. Unable to find a bamboo supplier, I was initially concerned that the budding project would come to an untimely halt for want of raw materials. However, as my (normally) intrepid wife and I headed out to Charlottesville one day, we passed what appeared to be a grove of bamboo in the median. On an overcast afternoon, I went back with a hand-saw and cut five 10-foot plants from the thousands there.

After a few weeks of drying, the bamboo was still as green as it was the day I hacked it down, so I tried various ways of cutting it, finally resorting to using a table saw to cut it in strips. Eventually I ended up with some serviceable raw bamboo.

Making the drivers figured to be a formidable task, as I have had mixed success at making my own Black Powder fuel without Lloyd Sponenburgh's mill. I compromised by using commercial Meal D, and pressed my drivers using a 1-ton pyro press. Three trips to various auto stores eventually located the required left-working snap-action torque wrench with a range of 20-120 lbs. of torque. After pressing 20 drivers at its max of 120 lbs., my right arm was a mass of tendonitis.

Balancing this lopsided girandola was a constant worry to me, but I located some Velcro with adhesive backing and experimentally attached the drivers to the hoops. Balancing was, at it turned out, a snap.

Waxed linen string was also a potential problem - luckily the local WalMart had a cheap supply in 25-yard spools in the craft section. The waxed string is essential for strong, light-weight attachment of bamboo supports and drivers. As I discovered, it also very nicely cuts your hands, thereby adding injury to the tendonitis insult.

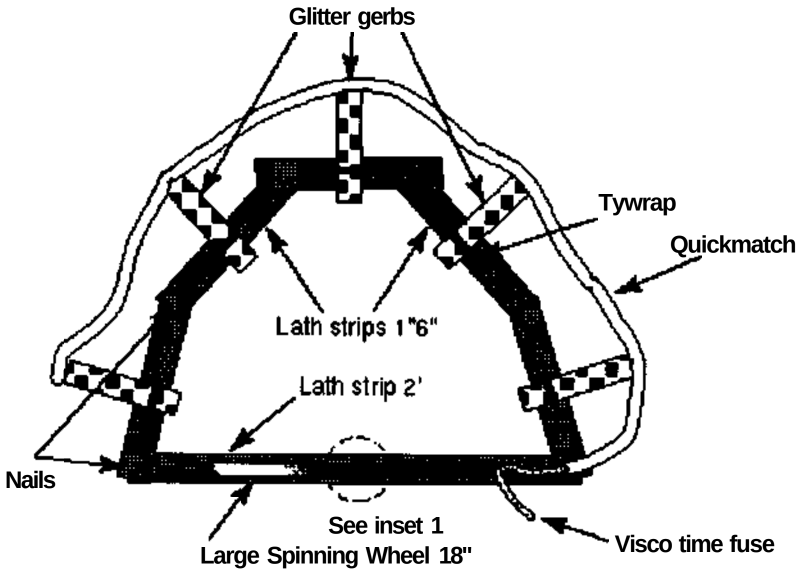
Fussing over this project for about 40 hours made me reluctant to send it up. I was still in pain from the string and torque wrench, and having invested that much in it, I wanted to enjoy it longer. Too soon the big day arrived - Super Bowl Sunday. A dozen friends came over and for three hours we enjoyed each other's company, if not the lack-luster football game. Finally it was over and we trooped outside for the BIG show.

Then the big moment came. I lit the fuse and gave the device a quick kick-start spin. The horizontal drivers picked up the lateral motion and spun her up. At just the proper time, the tapped and fused horizontal driver fed the bucket of vertical driver fuses and they roared to life. Scant milliseconds later she rose majestically into the night, exploding one of her headers (a leak?) and attaining a height of about 150 feet. She then dropped back slowly to the ground, where she bounced along, finally rising again to shoulder height and exploding the remaining headers of star shells! Super! Fantastic! A whoop of joy from me and the onlookers!

Yeah, it could have been better - the next one will stay up longer and explode the effects properly at the top, but for my first girandola, I was satisfied. No, more than satisfied - gratified. Prayers had been answered and a labor of love justified. What more could you ask for? WWG

GLITTERING SUNSET

My family and I spent the last Fourth of July at home in North Carolina. The state has only recently relaxed its fireworks laws to allow the sale and discharge of a limited amount of fireworks. The only items that are allowed are fountains, sparklers, smoke balls, etc. In other words, if its exciting or noisy, forget it as it's sure to be banned. In order to comply with the local ordinances, and yet put on a show that would be entertaining, I decided on building set pieces for our display. Several of these pieces were given rave reviews by all in attendance. One piece in particular, *Glittering Sunset,* seemed to be a real crowd pleaser. This project is simple to construct and is fairly inexpensive.



The glittering sunset is constructed on a lath frame in the rough shape of a semicircle. Between five and nine glitter gerbs are placed equidistant around the periphery of a frame, and a large 18" Spinning Wheel Saxon is placed in the center of the semicircle. All of the gerbs and the Spinning Wheel are quickmatched together to fire quickly. The effect is spectacular as the Spinning Wheel begins to spin and send out a silver spray. After a short delay, shimmering gold flitter begins and extends out between 4' to 6' feet beyond the silver Spinning Wheel. The drawing shown uses only five glitter gerbs to cut down on clutter. It is possible to use nine for a spectacular piece.

Construction

I begin by cutting the lath to length as shown in the drawing, Figure 1. The lath pieces should be arranged so that no interference is possible between the large Spinning Wheel and the semi-circle upon which the glitter gerbs are mounted. Also at this time, I determine how the piece will be mounted for firing. I use a portable cart with a 1"x6"xl2' board mounted on one end with right angle hooks mounted on the board for holding the set pieces. You've seen these right angle hooks at the hardware store by the cup hooks and other miscellaneous hardware. This cart and hook assembly makes for rapid installation and removal of the fired pieces. Mounting needs a screw-eye on the back of the piece to hang on the hook and maybe a couple of TyWraps or tape to secure the assembly to the board.

The lath pieces are joined together with glue and small nails or staples to hold the frame securely. One of the glitter gerb cases or the case former is laid across the frame where the gerbs will be mounted. Pencil marks are placed on either side of this to indicate where to drill for the TyWraps. This is done for each gerb and a mark is made for the hole for the Spinning Wheel, being careful not to interfere with the mounting hardware. When finished marking, a 1/4" drill bit makes the holes.

Glitter gerb construction

I rolled my cases out of Kraft paper on a 5/8" former. A piece of paper 12"x6" is more than adequate for this purpose. The paper tube only has to be glued on the outside edge as strength is not critical. I used clay for sealing the end of the gerb, although plaster or any other cheap material may be used. Fig. 2.

The glitter composition is really a modified glitter star formula that I found in Lancaster's book on page 161 *(Fireworks Principles and Practice).* It is important to be careful to ensure the ingredients are well mixed, and to use hand charging to consolidate the composition in the tubes. Ramming or pounding this is not required and would probably split the lightly wound paper casing.

Within about 1/2-inch of the top of the gerb I placed a 2" piece of black match, secured in place with tissue paper and tape. This should not be so secure as to cause the gerb to explode, just to hold the match in place.

Completing the piece

I pay careful attention to the hardware stacking arrangement for the Spinning Wheel hardware. See Figure 3. I want to be sure this will turn freely. Also, when matching the device, I'm careful to make sure that the tape holding the visco to the Spinning Wheel fuse is not excessive and does not block vents in the Spinning Wheel case.

The glitter gerbs are mounted to the frame with TyWraps; one per gerb is all that is required. The gerbs are quickmatched as shown in Figure 1. To do this I cut a "V" shaped notch in the quickmatch near each gerb and insert the blackmatch from the gerb into the notch, then finish securing the match to the gerb by placing a strip of tape over the gerb and match. An excessive amount of tape is unnecessary.

Finally, the fusing is finished by running a 6" piece of visco to the Spinning Wheel and the end of the quickmatch. The idea is to get the Spinning Wheel going before the glitter gerbs ignite. To make sure the visco gets to the Spinning Wheel first I allow at lease 3" of visco from the Spinning Wheel fuse until the visco gets to the quickmatch. BS

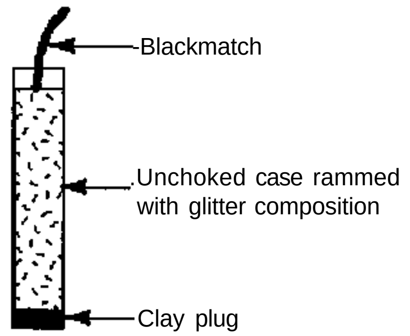
GLITTER GERB COMPOSITION	PTS. BY WT.
Antimony sulfide	14
Sodium oxalate	11
Bright Aluminum*	7
Meal gunpowder	68

*Note:The bright aluminum may be 100 mesh or finer. This formula is not fussy and works great!

Materials required

9 Kraft paper tube cases 5/8"x6" *(Can be rolled out of Kraft paper or paper grocery bags. They don't have to be too strong as they will be used unchoked.)*
Quickmatch, about 8'
Visco fuse 6"
Lath about 10'
TyWraps (about 9)
Tape
(1) 3"#6 machine screw
(2) 1" fender washers
(2) #6X32 nuts
(1) aluminum spacer 3/8"
Nails and glue for lath frame
(5-9) glitter gerbs
Blackmatch
Spinning Wheel Saxon or similar

Fig. 2



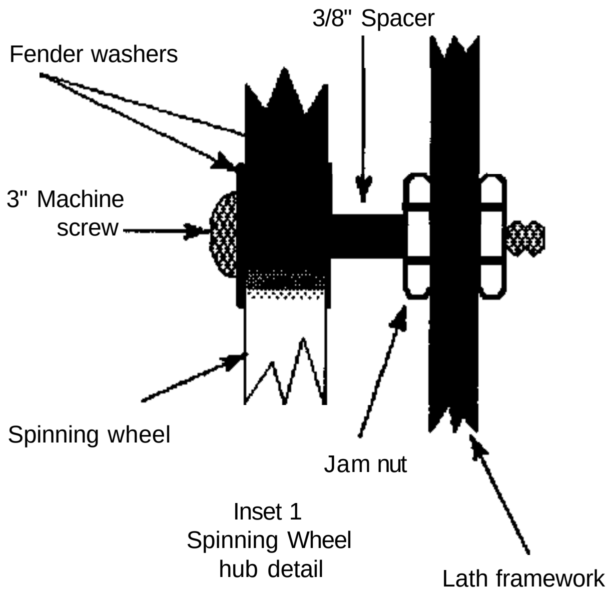


Fig. 3

GLITTERING THUNDER AEROLITES

Lancaster calls them comet bombs. Weingart refers to them as aerolites, but many at the Crackerjacks October shoot just called them spectacular. What are they really? Quite simply an easy to construct comet with an explosive finish.

When it comes to fireworks, I'm a traditionalist. I like willow stars with long duration lampblack streamers, glitter effects, simple proven formulas, and easy construction techniques. This project combines all these elements; and best of all, these aerolites can be used in Roman candles, mines, small mortars and as shell inserts.

I have produced these in various sizes, and in this article I will describe an aerolite of 3 1/2" X 3/4". Even though this is small in size, it still produces a beautiful display and ends with a thunderous report.

Procedure:

1. I begin preparing the tube by sawing to the required length, 3 1/2".

2. Next I prepare the rammer by placing a tube over the ramming base and inserting the rammer until it bottoms out. Then I mark the rammer where it meets the top of the casing. I then raise the rammer one inch and using the marker draw a heavy black line around the one inch mark.

3. I then prepare the composition. Refer to Table 3. The important thing to keep in mind with any of these mixtures is to make sure they are well mixed. I usually screen the composition three times to get a uniform mixture. When this is done I add just enough water a little at a time so that when a handful of the composition is squeezed tightly it holds together.

4. Once the composition is ready I use a wooden spoon to pour composition into a tube that I have placed on the ramming base. I consolidate the composition with two or three good raps from the mallet. I continue to fill the tube and consolidate the composition until the black line on the rammer is visible at the top of the casing. It's important not to try and fill these cases too quickly. I add only enough composition to raise the rammer up about one third of an inch with each spoonful of composition.

5. After I have all the cases filled to the proper depth I place the filled cases in the sun or a warm location to dry out. It's well to keep in mind that these cases are filled with 70% Black Powder and are extremely flammable. I keep these well away from any sources of ignition.

6. I then prepare the cherry cups. I use one complete set for each aerolite. These cups come in two bags. One cup has a larger diameter to fit over the other smaller cup. In the large cup, I punch a hole for a piece of visco fuse. I use a 1" length of visco; on the convex side of the cup I let the visco extend about 1/8". I glue the visco into the cup on the concave side using hot melt glue.

7. When I have prepared the large cups, I take one large cup, and using the brush I paint the sides of the cup with white glue. I then take one of the filled aerolite casings and slide the convex side of the cup down into the casing so the short fuse rests against the dried comet. I use the small brass tube to ensure the cup is pressed hard against the comet. Then I fill the rest of the tube about three-quarters full with flash powder. I then take the remaining small cup and paint white glue around the edges. I then slide the concave side into the tube to a depth of about 1/8" from the top of the filled aerolite. I repeat this procedure for each aerolite.

8. I use pyro adhesive to secure the tops, and ensure a good seal and pour it into the cavity at the top of each aerolite. Refer to Table 4. This adhesive will set up to a rock hard consistency in a couple of days. Refer to Figure 1.

9. ***IMPORTANT.*** I place a bead of white glue around the glitter composition where it intersects the casing. This prevents fire from the

Figure 1

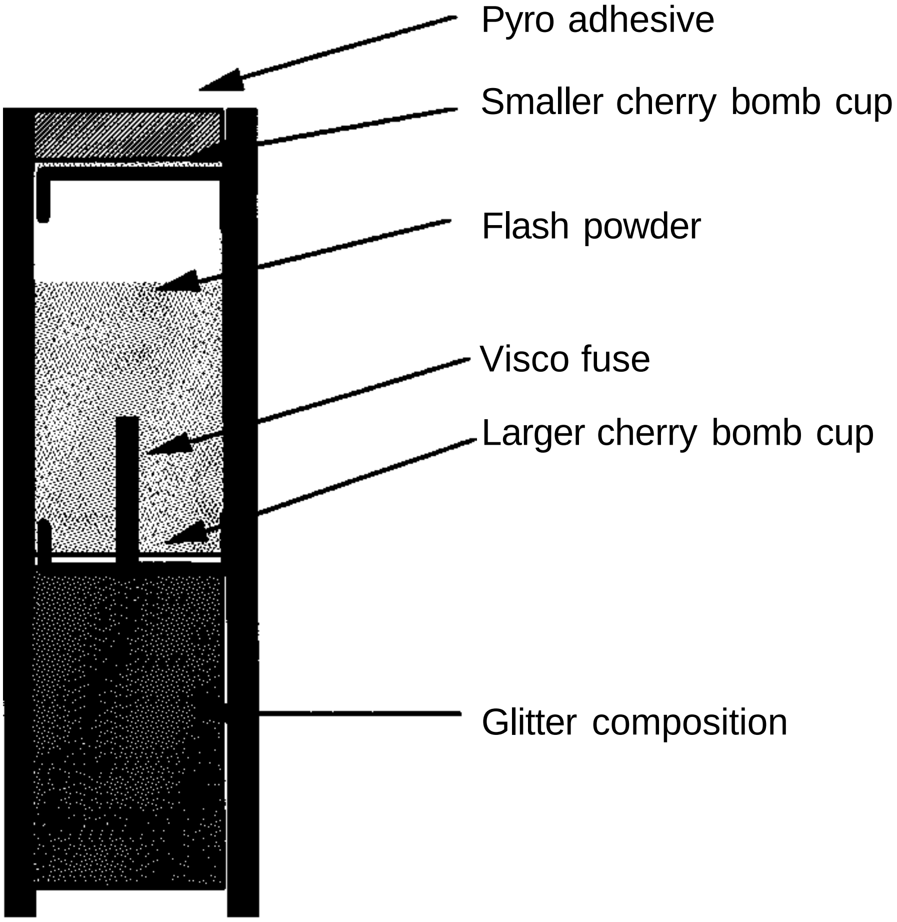
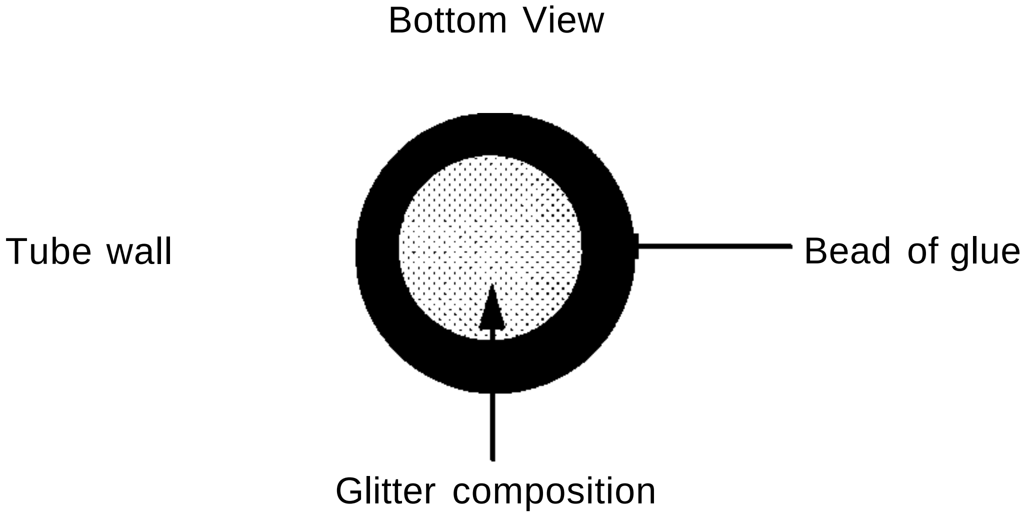


Figure 2



lift charge from getting in behind the comet and igniting the flash powder prematurely. Refer to Figure 2. I allow a couple of days for the glue to dry.

10. When these aerolites are complete they may be placed in the #2 mortar and lifted with 2FA Black Powder. I use approximately 15% of the weight of the aerolite in lift charge to send these up about 100 feet.

The effect is spectacular as the glitter comet heads skyward and begins to arch back to earth. Just as it begins it's drop it explodes in a brilliant flash and deafening report. I have constructed 1/2" version aerolites for Roman candles and for use in mines. The largest I have constructed is a 2 1/2" version for use in a standard 3" mortar. The effect of multiple comets and reports is even better. You can also use these in shells as they require no priming. I hope you enjoy these as much as I do.

Addendum: Several readers suggested improvements to this Aerolite article. They pointed out that there was no need to add dextrin and dampen the mix. They said they had success dry ramming the glitter compound. They also said that they did not need the bead of glue around the perimeter of the comet since there was no shrinkage with a dry rammed star.

I have yet to give this a try but it sounds reasonable. I am tempted to add a little stearin just to ensure that it packs well, and I don't think that the same percentage of stearin as dextrin would upset the glitter.

One final note on the Aerolites: I found the fuse absolutely necessary between the star and the salute. A reader suggested that I didn't need the Visco between the star and the salute. All I can say is that the number of duds just using a hole punched in the cherry cup was greater than 50%. Bare match can be used instead of the Visco as well. BS

Table 1

QUANTITY	MATERIALS
1	Parallel wound tube 3 1/2" x 3/4" with 3/16" wall, similar to Skylighter #137. This tube is 30" long and may be sawed to length yielding 8 tubes with a little left over.
1	3/4" cherry cup set, Skylighter #203
1	#2 mortar, Skylighter #155
1	#2 plastic base, Skylighter #215
As needed	Visco fuse
As needed	White glue
1	Small brush for glue
As needed	2FA Black Powder, or your favorite lift powder
1	Hot glue gun and glue sticks

Table 2

QUANTITY	TOOLS
1	Rammer 3/4" and ramming base
1	1/2" brass tube
1	Scissors
1	Saw
1	Ruler
1	Permanent marker or equivalent
1	Rawhide, wood, or small brass mallet (non-sparking)

Table 3

GLITTER COMPOSITION	PARTS BY WEIGHT
Water	as needed
Meal gunpowder	70
Mixed aluminum, 50-150 mesh, Skylighter #6	7
Antimony sulfide	8
Sodium oxalate	10
Dextrin	5

Table 4

COMPONENT (ADHESIVE)	PARTS BY WEIGHT
Calcium Carbonate (whiting, precipitated chalk).	1
Zinc Oxide (zinc white).	1
Sodium Silicate (water-glass)	1

MAKING PLUGS THE HARD WAY

Recently there was an article about a great little firework device called an *Aerolite.* In a nut shell, this is a comet pressed in a tube with a salute finish. The article deals with only one aspect of the device. I would like to share with you how I made the plugs for them (they called for paper cup sets — I did not have them).

What to do about the paper cup sets when you don't have any of them? I guess you could purchase them. However, if you have a few hours to spare, you can try making them like I did. This I accomplished by using the cardboard [or chipboard] backing of those desktop calendars that sit atop every desk at work in North America.

Since my tubes were 1" i.d. x 3 1/2" long, I needed to make plugs that fit. Looking around the house for some kind of high-tech measuring device, I found the top of a Tropicana juice bottle - you know, those half-gallon plastic bottles that are collecting in the recycle bin - the top is a perfect size (1 3/4) for the 1" i.d. tube. All I do is trace a circle around the cap (concave side face down) on the cardboard backing or similar chipboard, for a perfect circle. I cut them out, (or they can be punched if lucky enough to have a punch this size) but 100 took me about 3 hours to cut! - enough for making 50 Aerolites.

The next dilemma I faced was how to shape the plug from the cutouts. All seasoned pyros probably have an efficient method to do this -- if so tell me about it, PLEASE!

Here's how I did it. I make a 15/16" hole in a piece of 1 x 4 x 4" pine using a wood boring bit. The hole should NOT go all the way through the board -- I leave about 1 1/4 - 1/8-inch of wood at the bottom of the hole. Next I cut a piece of 3/4" dowel about 6-inches long to use to shape the plug.

Now I take some white glue and squeeze a fair amount out in a disposable paper bowl or some other container your significant other won't mind you messing up. I add some water to the glue to water it down a little and mix it well. I want the mix to be wet enough to absorb into the cardboard cutouts.

Next, I take a cutout, dip my finger in the glue mix and rub it on both sides, making sure its evenly coated. It doesn't have to get sloppy wet, but just a light and even coat. I set this one aside, and continue coating another four or five. This is a good amount to manage because by the time I get to the 5th or 6th cutout, the first is soft and ready to shape.

I center the first cutout over the top of the hole cut in the 1x4x4 board (hint, I made some alignment marks on my board so that I could estimate the center of my cutouts). It doesn't have to be perfectly exact, but it does need to be close to make a well shaped plug.

I place the dowel over the cardboard cutout that is centered over the hole center, and hit it a few times with soft little blows. The cutout should slowly pound into plug shape, conforming to the hole in the board. I pull this plug out with my finger nails (might be tough at first until the hole sides get slippery with the glue and water).

Now I shape the remaining moistened plug cutouts. When done with that group of five or six, I start the next batch. I found after drying for about 10-15 minutes, the newly formed plugs start to lose their shape and try to become flat again - what nerve! This is easily fixed by going through a second reshaping procedure. I don't wet them again, but just force them back in the hole and kind of roll the dowel around, forcing the shape. This will produce a shaped plug that will nicely fit the 1" i.d. tube. I let the plugs dry overnight and reshape if necessary.

Wow! — All that for plugs!? At the going rate of $5 to $7 per 250 plugs, this procedure hardly seems worthwhile, and you're absolutely right! But you know what? If ever you need some plugs in a pinch, or you have some odd sized tubes, you will be able to make the plugs to fit them. SK

AERIAL FLASHLIGHT SALUTE CANDLES

If you're like me you find that having a regular day job gets in the way of more enjoyable pursuits such as building fireworks. However, I can usually find some time on the weekends for a quick project. One item that lends itself to quick weekend projects are the ubiquitous 35mm film cans. I only use the plastic (HDPE) versions in any of my projects. I never use the older aluminum or even older steel film cans in any firework project.

I should also point out that not all film cans are alike. Some film cans have caps that snap over the top lip of the can. Some have caps that snap inside the can and have no outer lip. This is the type that is best suited for this project. Some like the new Advantix containers are oval in shape and will not fit in a round tube.

For this project, I have used the 35mm film cans as salutes, and placed them in a Roman candle. These Roman candles may be shot as either a day, or night item. Over the years, I have noticed that Roman candles have gotten away from using candle composition between shots to using Visco. This may be economical, but it really detracts from the beauty of the candle since there is no gold spray between shots. These are really exhibition candles and when fired in groups the gold showers are truly spectacular.

If you want to economize, and use these in the daylight; you may replace the candle composition with wood meal, and use Visco as the delay mechanism. Sky lighter sells an inexpensive Chinese uncoated Visco for cross matching purposes that works well (Skylighter #250). They also have the regular Visco but it is a little large and may produce difficulty in working the salutes down the tube with it in place. One other drawback is that the regular Visco is coiled and has a memory. The small thin Visco tends to lay flat and is easily worked with in this project.

One note of caution: As with any project involving energetic materials, it is always wise to follow all safety rules and work with the smallest practical quantities.

Procedure:

1. I begin preparing the salutes by cutting a 3/4" piece of Visco for each salute end cap.

   Next I punch a hole in the center of the end cap and slide the Visco into it so half is inside and half is on the outside of the cap. Using a hot melt glue gun, I fill the recess on the inside of the cap with hot melt glue. This secures the Visco and prevents the lift from igniting the flash powder prematurely. Refer to Figure E.

2. Using a knife I split the Visco on the outside of the cap and paint it with a slurry of nitrocellulose lacquer and meal powder.

3. I fill each film can approximately 3/4 full with flash. I then paint epoxy around the lip of the can and the lid. I press the lid into the film can using a press with a blast shield. I do this with as many salutes as I intend to use in the candles. I can get between six to seven shots in the 24" candles and three in the 12" candles. Caution: I always wear eye and hearing protection, and use extreme care when assembling salutes or any potentially explosive components. See Figure D.

4. Next I glue the end disks on the top and bottom of the film can using epoxy. I use an awl or hole punch for the disk that I place on the bottom of the can over the fuse so that the fuse and priming are not obstructed. These disks prevent the plastic can from softening due to the burning candle composition and lift charge. Refer to Figure C.

5. Once the epoxy has set I wrap the salute with a couple of layers of filament tape. This increases the size of the salute for a better fit in the candle and greatly strengthens the casing, thereby substantially increasing the report. See Figure B.

6. The final step in preparation is to cut a 3" length of StickyMatch® and center the salute vertically on the match. I wrap the

Figures A~E

Figure A

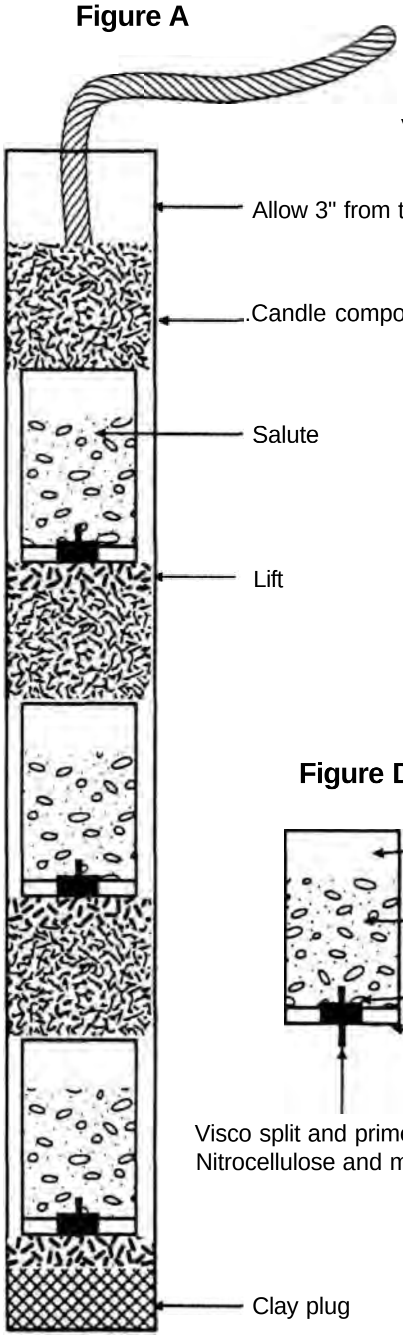


Figure B

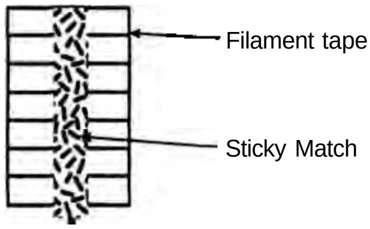


Figure C

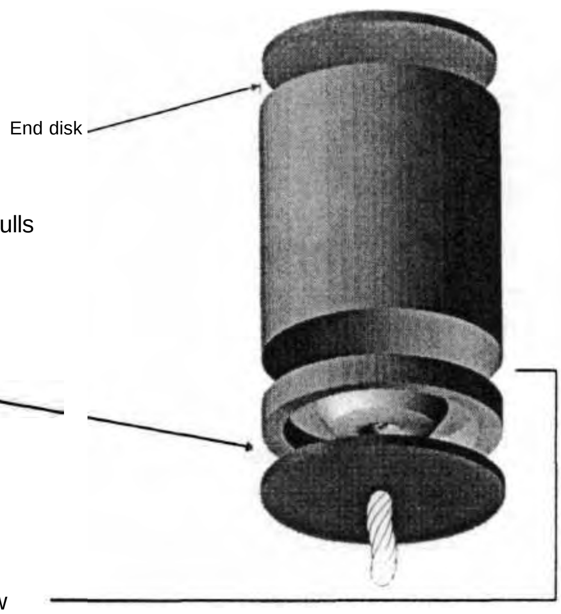


Figure D

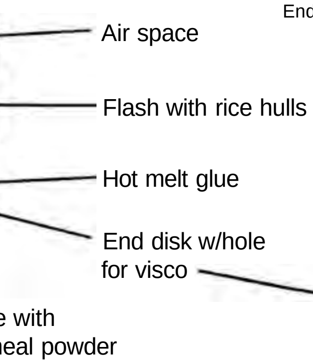
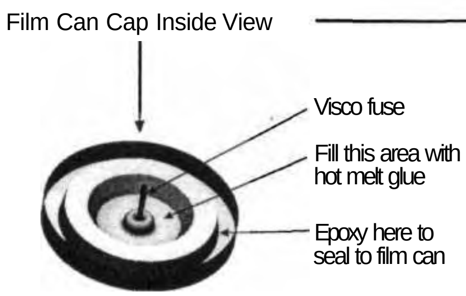


Figure E



match over the top and bottom of the salute for about 1/2", ensuring that it will take fire from the candle comp. and communicate the fire to the lift charge. Refer to Figure B.

7. Then I place one of the 24" tubes on the ramming base. Using an empty film can as a measure I put a couple of scoops of clay in the tube and consolidate it with seven good blows on the rammer. I weigh the salutes and use approximately 5% of the weight of the first salute in the tube for lift charge. I increase the amount of lift for each salute until the last one, which I give 20% of its weight in lift. This is only a ball park figure and experimentation may be necessary for consistent height and performance. Refer to Figure A.

8. Next I place the lift in the tube and drop the salute (fuse end down) on top of it. I use the empty film can and pour two measures of candle comp on top of the salute. I consolidate the candle comp between measures by lightly tapping the rammer with a rawhide mallet. There is no need to heavily ram these nor is that a very good idea. All that is required is to pack the candle comp consistently. Two scoops will give about 1" between shots.

9. I repeat this operation for the remaining shots. When finished I have about 3" of space above the candle comp over the first shot. I place a 6" piece of Visco in the cavity and a wad of tissue paper to hold it in place.

10. This completes the candle construction. As Shep would say, "Place upright in a clear unobstructed area. After igniting, stand well back. Not recommended for children. The manufacturer assumes absolutely no responsibility for this device."

Suggestions:

I have also tried the following with these candles:

* Mixed salutes comets
* Solid color ending with salute
* Red, White, and Blue stars ending with salutes, "Union Battery" configuration
* Five shot salute repeaters
* Glitter comets and salutes

The variations are endless and limited only by your imagination.

For large stars of this caliber 1/4" I use a Rich Wolter comet pump. This works well and the best way to join the star to the salute is with a couple of turns of Kraft paper. BS

List of materials:

Table 1

Quantity	Materials
1	Spiral wound tube 24" x 1 1/2" with 3/16" wall Skylighter #185.
6	35mm film cans (no lip type)
12	1 1/4" end disks Skylighter #165
As needed	Visco fuse Skylighter #279
As needed	Epoxy glue
As needed	Nitrocellulose Lacquer Skylighter #66
As needed	Meal powder
As needed	Sticky Match® Skylighter #306
As needed	2FA Black Powder, or your favorite lift powder
As needed	Bentonite clay Skylighter #29 or kitty litter
As needed	Filament tape

Table 2

Quantity	Tools
	Rammer 1 1/2" x 30" and ramming base
	Hot glue gun and glue sticks
	Small brush for epoxy
	35mm film can for a powder measure
	Knife
	Rawhide, wood, or small brass mallet (non-sparking)

Table 3

Candle Composition	Parts by weight
Saltpeter	5
Sulfur	1
Charcoal 100 mesh	2
Charcoal 40 mesh	1/2
Charcoal 12-20 mesh	1/2

Table 4

Flash Compositions	Parts by weight							
Ingredient	1	2	3	4	5	6	7	8
Aluminum, dark pyro dust	3	2.3	26	1	3			23
Antimony Trisulfide (dark pyro)		3.4					33	
Magnesium powder (100 mesh)			34					
Magnesium powder (400 mesh)						1	17	
Barium Nitrate								68
Plaster of Paris						1-1/3		
Potassium Perchlorate*	7	6.4	40	4	7		50	
Rice hulls				1 1/4	1 1/4			
Sulfur		0.9		1				9
Titanium shavings					1			

* .01 parts Cabosil added to the potassium perchlorate prior to mixing.

NIAGARA FALLS - 4TH OF JULY FAVORITE

Back in the days when I wasa kid, fireworks displays were not limited to aerial shells. The Legion usually kicked off the display with several aerial flashlight salutes. I'm sure they were probably just three inch salutes, or nine inchers as they used to call them back then. But they were loud enough to silence the cherry bombs and M-80s that were being shot off. The ground display began with line rockets that never really seemed to work as intended. For some reason the rockets wouldn't travel all the way down the wire or, if they did, they wouldn't return. I think in all the years that I watched the fireworks there, I saw those line rockets work right only once drawing a standing ovation from the assembled multitude.

After the line rockets came what I remember best, a large Niagara Falls. I was always awed by the shimmering silver streamers and the tremendous cloud of smoke that it generated. I remember thinking back then, "How did they get the entire falls lit so quickly?" I remember asking my dad about it. He told me, "They use a special fuse." I know now that it was quick match that made the rapid ignition possible. I used to watch that mammoth cloud of smoke drift gently across the lake and up the distant shore toward the city. At that moment I could see the shooters lighting fusees, and the aerial bombs would take to the sky.

Last year, I was thinking about those early days spent with my folks down at Powder Horn watching fireworks, and I decided to build my own Niagara Falls for our Fourth of July display. For the last six years, my brother Bob and I have put on a neighborhood fireworks display. Each year we try and out-do the previous year's display and last year was no exception.

Since we have a very limited shooting area, we scale our displays accordingly.

This meant that we wouldn't be putting up a 50- or 100-foot Niagara Falls like the Legion did. Rather, we settled on one 12-feet long, suspended 12 feet off the ground. Despite its rather modest proportions, it still got rave reviews from all in attendance. We constructed an improved model for this year's display. I hope you enjoy this project as much as we did. I think you 11 find that this is fairly inexpensive to construct and well worth the time and effort.

Note: In this project I use potassium chlorate as an oxidizer. Those concerned about sensitivity may wish to substitute the perchlorate, and increase the aluminum about 20%.

Procedure

I cut the Kraft paper for the casings. If the Kraft mailing paper is used, the plastic wrapper is left on. I use a permanent marker to mark off 6" lengths on the roll. One roll should yield four 6" by 24" lengths.

Using a hack saw , I cut the roll into four 6" rolls, then use the paper cutter to cut the paper into 6" by 12" strips. For a twelve foot long waterfall I'll need 36 casings. The ideal spacing for this composition is one casing every four inches.

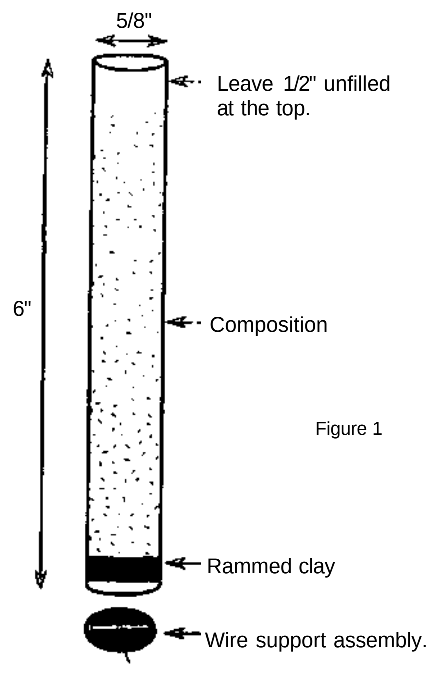


Figure 1

CONSTRUCTION MATERIALS	
QUANTITY	**ITEM:**
1	roll of 60 lb. brown Kraft paper, available at Walmart or any office supply store. Paper grocery bags also work well but be prepared to do a lot of cutting.
1	sheet of thin cardboard (a shoe box lid is ideal)
1 or 2	rolls of 20 lb. picture hanger wire.
1	box of 5/8" brads. These are small nails. Toothpicks could be substituted
as needed	powdered clay or kitty litter
as needed	white glue
as needed	black match
20"	Sticky Match® or quickmatch
4"	Visco fuse

TOOLS	
QUANTITY	**ITEM:**
	scissors
	hot glue gun and glue sticks
	hacksaw
	permanent marker
	paper cutter
	5/8" punch
	ramming block with 5/8" peg protruding 1/4"
	5/8" rammer
	rawhide, wood, or small brass mallet (non-sparking)
	teaspoon measure
1 per casing	Magic whip or dragon egg rope 2" or longer for each falls casing.

COMPOSITION (PARTS BY WEIGHT)	
QUANTITY	**ITEM**
3	Potassium chlorate
2	Aluminum 100 mesh, such as Skylighter#6
0.5	Red gum or Vinsol resin
As needed	Alcohol

Before rolling the falls casings the former must be prepared by wrapping a layer of Kraft paper over it and taping it in place. This will facilitate the removal of the former when ramming the composition.

Next I roll a casing around the former. The last inch of the casing is glued. This is done with as many casings as I wish to make, keeping in mind the three-casing-to-the-foot spacing. When finished rolling the tubes, I remove the layer of Kraft paper from the former. Then I place one of the finished casings over the ramming block and pour in a level teaspoon of clay or kitty litter. I slide the former into the casing and give it a couple of raps with the mallet. It is necessary to keep in mind that these casings are very lightweight and too much pounding will split them. The purpose of this clay plug is to insulate the composition from the hot melt glue. This is repeated for each casing.

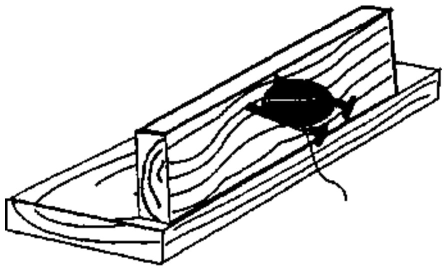
I have used the composition shown above for several of these projects with great success. It combines quick ignition with a very smooth burn and lots of hot dross. I have never had to prime them; they are extremely flammable and will easily take fire from bare match inserted in the end of the casing.

Each casing will hold approximately four ounces of composition. Hence, if I am going to construct a 12-foot waterfalls with 36 tubes, 111 need about nine pounds of composition. I mix the composition in a plastic

Niagara Falls Construction Details

Disk, brad, and wire support assembly. Place dab of hot melt over the hole in the middle to secure the brad.

Figure 2



A simple jig for holding the disk assembles. This saves on burned fingers when applying the hot melt glue used to secure the brad and wire to the cardboard disk.

Figure 3

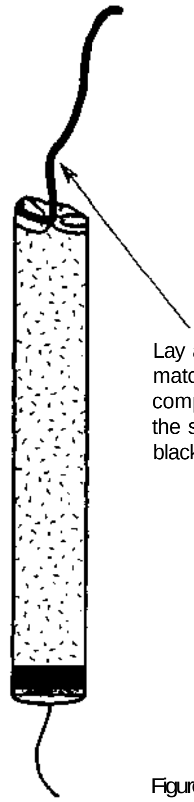


Figure 4

Niagara Falls

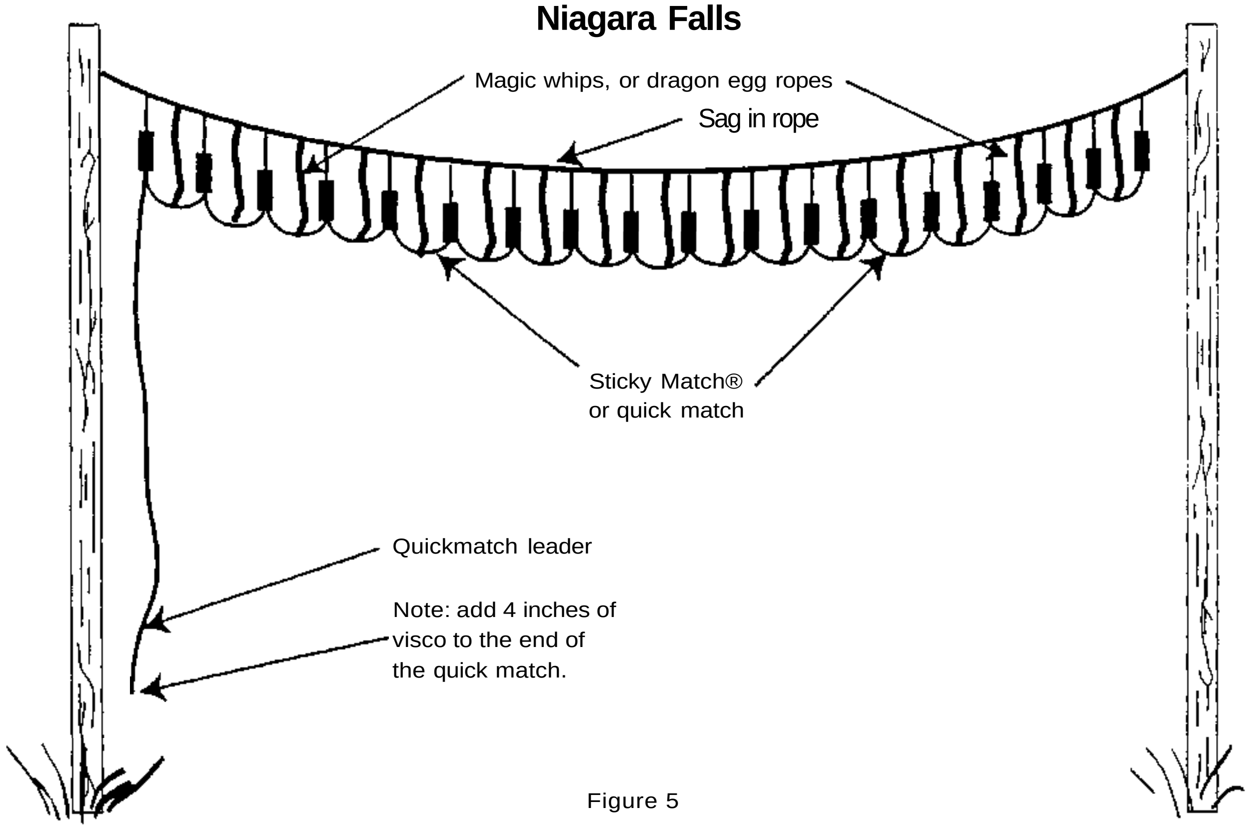


Figure 5

bucket with enough alcohol added that when a handful is squeezed it sticks together.

The casings are filled with the damp composition. I add only a couple of teaspoonsful before consolidating with the rammer, again keeping in mind that these casings are very lightweight so they will burn away with the composition. The casings are filled to within 1/2" of the top. This empty space is needed to secure the fuse. It's a good idea to make a heavy black mark on the rammer 1/2" from the end so as to know where to stop. This not only ensures the casings have the proper space for the fuse, but also have a consistent load so they all burn out about the same time. Refer to Figure 1.

After the casings are filled they will need to dry out. I do this outside in the sun away from any possible sources of ignition. I have found that a week outside is usually sufficient to dry these out. Keep in mind these casings are extremely flammable and contain a chlorate. I generally keep these items segregated in an airtight plastic container with a drying agent like Damp Rid® (calcium chloride) to keep them dry. I also store them away from other combustibles.

I have found that the best method for displaying these casings is to suspend them with a wire about 6" long fixed to the end of the casing. This wire in turn can be attached to a heavy wire or non-flammable rope to suspend the waterfall. This allows the casings to move as they burn, adding greatly to the effect of falling water. Also, the sag in the supporting rope adds realism to the waterfall.

The best method I have found to suspend the casings is by punching out a cardboard disc and passing a wire through the center of the disc. The lightweight cardboard from a shoe box lid is ideal.

I take the end nearest the disc and fold it back on itself, forming a loop. I put a small brad through the loop and secure it to the disc with a dab of hot glue, then repeat this procedure with the remaining discs until they have all been wired. Refer to Figure 2.

Note: I have trouble manipulating the wire, brad, disc, and glue gun at the same time, so I made a jig to hold the disc while it is glued. I made it with two blocks of wood nailed together to form a right angle, with 10d nails in the back of the board about 1/4" apart. If the disc with the brad is set through the loop on top of the nails it can be pulled down on the wire and the glue applied without burning the fingers. Refer to Figure 3.

After all the discs are wired I pick up a filled casing and run a bead of hot melt around the clay plug, then press one of the wired discs into the glue. I usually run another bead of hot melt over the top of the disc as well. This doesn't take very long and I have never had a casing break loose using this method.

Fusing these casings is easy. I cut a 4" length of blackmatch for each casing, then bend over one end of the match and press it down and across the hardened composition. Then I fold over the opposite side of the casing wall, pressing the match on the composition. The remaining sides of the casing are folded down to finish securing the match. Refer to Fig. 4.

To complete the finishing of the casings and to provide a nosing for the match I usually roll the casing up in tissue paper. This is a good way to get rid of all that left over Christmas wrap. This step is unnecessary but does give a professional appearance.

Final assembly begins by marking the support line at four-inch intervals with a permanent marker. After the line has been marked, I wrap the wire from the casing at each mark and secure with a small piece of masking tape. This will keep the casings from sliding on the support line.

Once all the casings are attached, I tape Magic Whips or Dragon Egg ropes between each casing. How to ignite the casings depends on the ignition method chosen for the waterfall. If quickmatch is used, I can simply tape the free end of the whip to the falls casing. If Sticky Match® is selected, I simply match them in as I do with the waterfall. Refer to Figure 5 for a completed assembly drawing. BS

THE POOR MAN'S WATERFALL

Items needed:

1. Morning Glory Sparklers
2. 75 feet of rope or flexible wire
3. Newspaper cut in 5x3" pieces
4. Quick match
5. Cotton string
6. Masking tape.

Probably the first decision to be made is the length of the waterfall. We make ours 60-foot long which requires about 75 feet of rope to allow you to string it between two uprights. The most important thing to remember is to buy good quality Morning Glories (there is some real crap out there). A good quality Morning Glory will start with a red fire emitting voluminous charcoal sparks, which then changes to a Dragon Egg effect (without lead) and finally ends with a white flame emitting charcoal sparks. The unique thing about this waterfall is that it gives three events instead of the traditional, single event given by a Niagara Falls. Also of note is that this device is very inexpensive considering the effect that you can get. I recently bought a case of Morning Glories for $41.00. They came packaged 15 boxes of 24 bundles of 6 Morning Glories, for a grand total of 360 bundles of 6. It takes 120 bundles of 6 to make a 60-foot waterfall since we space them 6 inches apart. Three waterfalls can be made from a case for a cost of less than $15 each plus the cost of the connecting quickmatch. Now let us get to the description of the construction of this unique device.

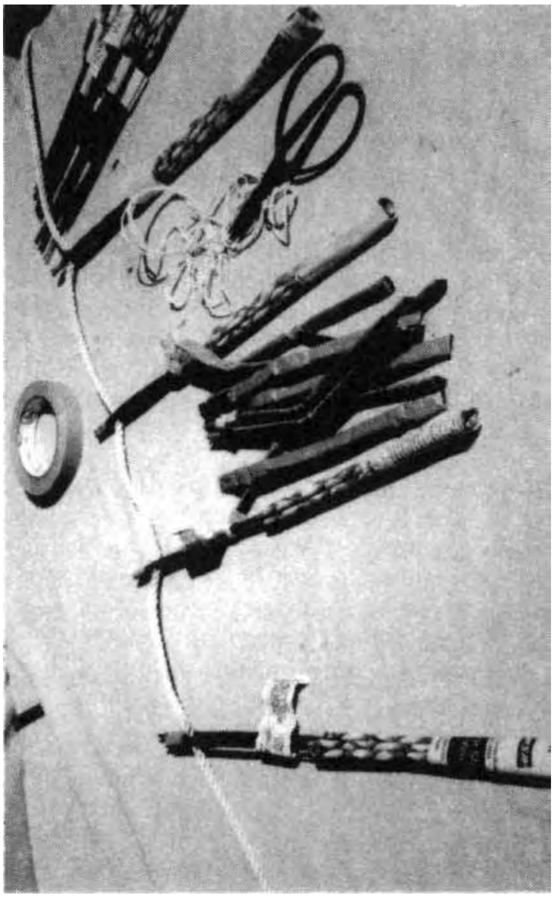
The basic unit of this waterfall is the bundle of 6 Morning Glories which are bound together by Scotch tape on the end with the composition, and a warning label device on the end with the 6 bamboo sticks. The warning label device is removed because we need to be able to separate the bamboo sticks at a later time to attach them to the rope; however the Scotch tape that is left near the composition end is not cut as it is needed to hold the device together. Next the decorative colorful paper streamers which are on the ends of the bundle are removed by twisting them off and exposing the end of the composition of the Morning Glories. Next the newspaper strips are pasted so they can be rolled on the bundle to create a *bucket;* the buckets are made such that there are 1/2" inches to be used as the bucket while the other 1 1/2 inches of the strip are rolled around the Morning Glories.

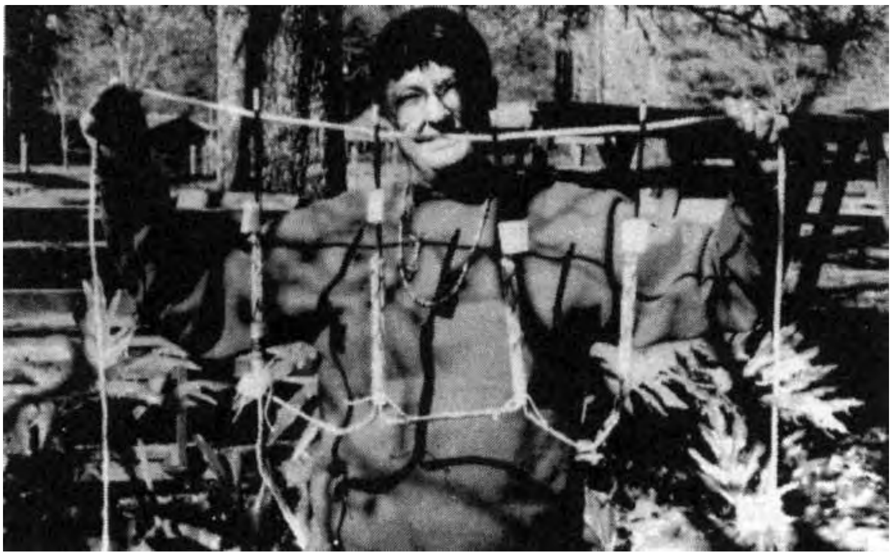
After the buckets are rolled, the rope is stretched out and marked at 6" intervals with a permanent marker (the same marks will be used the next time this device is constructed). The same amount of rope is left on each end to allow suitable rope to attach the falls to two upright devices.

A 60-foot falls is quite heavy, so I usually screw two eye-hooks and attach pulleys to assist in lifting the device between the supports.

Now that the rope is marked, it is time to attach the Morning Glories. On the end with the six bamboo sticks, separate them into three sticks each and slide them onto the rope at the appropriate 6" marked intervals. Immediately secure the ends with several turns of masking tape. After all 120 Morning Glory bundles are attached, the buckets are tied off with 10-inch lengths of quick match. When completed the device should look something like the attached picture. When lashing the waterfall to the supports, some binding along the buckets might occur. The binding is relieved by sliding the Morning Glory bundles to the left or right at the top where they are attached to the rope.

Please note that if this falls device is ignited on one end only, with the number of buckets it will take too much time to ignite the falls on the other end. I normally use four electric matches suitably spaced to give equivalent burn distance in all directions. J&BM





FROGS

Ever since our triumphant show in Muske. gon, countless people have asked about how I did the floating gerbs we used in the show. Well, here it is.

The concept behind frogs', also known as floaters' or 'nauticals', is really very simple. Put a float on a gerb and shoot it out into the water. The execution is only slightly more complicated, but there are almost as many variations in design as there are manufacturers who make them.

One important rule in making frogs is: test, test, test. There are many elements in a frog that depend on others, such as the lift charge, float size, counter weight (if any), weight of the gerb, and delay time. It's a good idea to make an inert gerb and experiment with it until a combination is found that works, and then use that on the real ones.

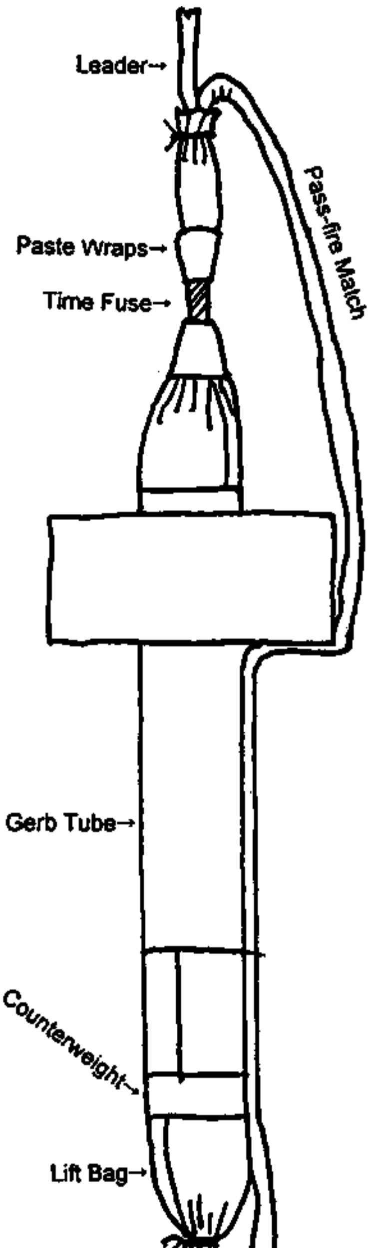
To start, any kind of gerb is made as it would normally be made if it was just a gerb for a wheel or other effect. I have seen many different types and sizes used, from 3/4" i.d. steel gerbs to 2" i.d. aluminum gerbs. I've also seen people use a flare composition instead of a fountain comp. This creates floating bengal lights.

After the gerb is finished, a counterweight may need to be added to the bottom of the gerb to keep it upright once in the water. The only way to know if a weight is needed on the bottom is to experiment. Some people choose not to put a weight on, letting them lay on their side once they hit the water. If the gerb is on its side, it will have a tendency to 'stand up' once the gerb ignites, with the thrust of the gerb keeping it vertical. A bunch of gerbs standing up at once is an interesting effect. I prefer to add a weight to the bottom of mine because I like the effect of the gerbs igniting while they are vertical. For a weight, I use a piece of tube the same size as the gerb tube (in this case 3/4" i.d.) and about 2" long, filled with pressed clay. It is glued to the bottom of the gerb tube and then to hold it on securely, wrapped with a couple of turns of pasted 30 lb. Kraft paper about 2" wide. Remember, if a weight is used, it needs to be heavy enough to keep the frog upright before it ignites, but not so heavy as to cause it to sink once lit. I make mine so the frog is barely kept upright in the water.

Once the weight is attached (if one is being used), the gerb is nosed with three turns of 401b. Kraft about 3" wide. Also nosed is the bottom of the gerb, like the top. This will act as the bag for the lift charge. There are two ways of doing the lift bag on the bottom. It can be done as described above, or later in the process and the pass-fire quickmatch can be done along with the gerb, so the match enters the bag at the top, instead of at the bottom. This method gives a slightly cleaner look, but it is more difficult to wrap the match and the gerb once the float is attached. It is much easier to roll the gerb without all the other stuff attached.

A good quality time fuse about 4" long is pierced and cross-matched about 1/2" from each end. Using Chinese fuse, this gives about 9 seconds of delay from when the frog is launched to when the gerb ignites. I use about 1 1/2" of crossmatch to ensure that the fuse gives and takes fire easily. The fuse is tied into the top of the gerb so the crossmatch touches the top of the gerb comp or prime. It may be necessary to bend the crossmatch so it fits into the tube. I always put a few bits of black match in with it so there is plenty of fire to light the gerb. A 'Bucket' or coin wrapper is tied to the other end of the time fuse. This is where the pass-fire match and the leader will go. Once the fuse has been tied in, a pasted piece of 301b. Kraft about 2" square is wrapped around the time fuse at the joint between the fuse and the gerb nosing and at the joint between the fuse and the bucket. This has the effect of sealing one end of the fuse off from the other end. Sometimes, when the fuse lights, fire from the leader match spits through the bucket, down the side of the time fuse, and through the joint between the nosing and the fuse, igniting the gerb prematurely.

Now comes a part that requires a lot of experimentation, the floats. Floats can be made from almost any light material. I have seen them made out of Styrofoam, cork, balsa,



A FROG

even injection-molded plastic. I use Styrofoam because it is cheap and easily available at any home improvement center. About 10 bucks will get more Styrofoam than can ever be used for floats, unless they are being produced in volume. (The leftover Styrofoam from the PGI show is now insulating the roof at Greg's shop.) I used two pieces of 1" thick foam instead of one piece of 2" because the 2" wasn't available at my store. A piece of the foam 2" thick by 3" square is cut. This is sufficient to hold up a 3/4" i.d. aluminum gerb. The foam block is wrapped in two pieces of pasted 701b. Kraft about 3"x24" long, one piece set at 90° to the other, completely covering the Styrofoam. This paper has the effect of protecting the foam from the fire of the lift charge and also allows the float to be glued to the gerb. Paste doesn't stick to Styrofoam too well, but with the paper encasing the float, the paper can be glued to the gerb, holding the float in place. A hole is cut through the center of the float slightly smaller than the outside diameter of the gerb tube. A snap-blade razor knife works fine. I used a hole saw made from a piece of thin wall aluminum tubing with teeth cut into one end and a shaft that allows it to be put into a drill press. It doesn't have to be too sharp to cut through the paper and foam.

Some white glue is smeared around the gerb tube about 1" from the top, about 2" down the side. The float is slid down the tube from the top onto the glued area, then rotated a couple of times to make sure the glue is spread evenly. Then a bead of glue is applied around the edge of the hole in the float on the top and bottom to further secure it. It is easier to put the floats on once the time fuse is in. The taper from tying the fuse in keeps the edges of the nosing from getting caught inside the hole.

To attach the pass-fire quickmatch, a piece of quickmatch is cut long enough to run from the bucket at the end of the time fuse, around the float, down the side of the gerb, and into the bottom of the lift bag. The quickmatch needs to follow the side of the tube closely because the gerb has to fit inside the mortar and go all the way to the bottom. I recommend using commercial quickmatch for the pass-fire as it is usually flatter than homemade, allowing the frog to fit in the mortar more easily. Now I may tie the pass-fire match and a piece of leader quickmatch or an electric igniter into the bucket on the time fuse, again adding a couple of bits of black match to ensure ignition. When using commercial quick-match, I put a 2" or so piece of good quality match into the match pipe at each end. This keeps the knot from cutting off the fire since sometimes commercial match tends to crumble.

The lift charge is put into the bag at the bottom of the frog and tied in the other end of the pass-fire match. For a lift charge, I used 9 grams of Goex 2F for a 3/4" i.d. gerb. This will kick the frog about 75-100 feet from a tube at a 45° angle.

The frog is basically done at this point. The operator can wrap the bottom part of the gerb tube and pass-fire match in another piece of paper as a cosmetic touch, but it is not necessary. Waterproofing the frog is not really necessary because the gerb only sits in the water for about 30 seconds before it is burned out and the water never has a chance to get far enough into the gerb tube or the top of the gerb to do any harm.

To make a mortar for the frogs, I take a length of PVC pipe (1 1/2" schedule 40 x 8" long in the case of a 1 1/4" o.d. tube) and glue an end cap onto it. It is possible to get scrap PVC for next to nothing from a local irrigation company, and end caps only cost about 75$ apiece from the home improvement center. The mortar should be long enough so that, when the frog is bottomed out in the tube, the top of the mortar is just below the float. The fit should be snug but not tight. I attached four tubes to a board with zip-ties and put legs on it, then fan out the tubes a bit to get a good spread when the frogs are fired. I make sure the tubes are far enough apart so that the floats on the frogs don't interfere with each other.

Once done with that, I take one out to a local pond and try it out. DD

PAPER FREEBIES

A source for tubes that make outrageous 6" paper mortars: shops that use rolls of Fiberglas, such as a boat works or auto customizing shops. These tubes were 6" long, with 3/4" (or better) spiral-wound walls. (A matched six-inch plastic ball shell slides through it perfectly.) They were being thrown out.

Carpet roll cores make dandy 3" or 4" mortars if they are of thick-wall (1/4" or better) spiral construction; most are. Available from carpet stores or a friendly carpet-layer. I haven't checked out linoleum cores yet, but they are probably pretty substantial, also.

Medical facilities can provide a cornucopia of usable goodies from exam table paper cores to disposable hemostats, (similar to small, needle-nosed pliers). You usually need to know someone "inside"; but if you do, there is lots to be had.

There are an abundance of textile mills. By simply getting permission to raid the trash, I have found an unbelievable supply of paper cones, which make great fountains. Thick-walled core tubes are also abundant.

One rocket guy has been known to re-use rocket tubes and sticks many times over by knocking out the old clay.

My friend the chemist offers the following: He says that research labs routinely throw out certain chemicals when they become "old". Two such are cuprous chloride, used in organic synthesis; and potassium biphthalate (potassium hydrogen phthalate, an analytical standard - yeth, I thed phthalate).

Cuprous chloride, in contact with moist air, slowly converts to copper oxychloride, rendering it useless for the lab. Its pyrotechnic values are unaffected. FP

TENNIS BALL GAS CANNON

I grew up in Southern California, and as a teen-ager in the early 70's, I remember the "safe & sane" stands that used to carry BIG BANG (calcium carbide) cannons. Back in those days, the small 9" 60mm cannons cost about $10.00, and the larger 17" 105mm model cost $21.95. Alas, those days are gone! The stands don't carry them any longer. They really should, because they are a safe, non-hazardous method of making a real bang, which is a lot much safer than M-80s. They are still available from some mail order firms.

There was an article about Black Powder cannons in the December '93 AFN. I would rather use a BIG BANG cannon. I feel they are much safer. They may not produce smoke and create thunderous sound like some Black Powder cannon aficionados prefer, but they are much safer! There is one method that I use to make a large boom that I feel is comparable to a Black Powder cannon: I make my own BIG BANG cannon! Here's one method I use.

I get five tin cans, either soup or dog food cans (I just have to make sure that they are the correct size for a tennis ball to fit snugly). Using an electric can opener, I remove both ends from three of the cans. With the 4th can, I remove just one end and leave the other end. I make a hole about half way on the side of this can. This is the can that goes on the bottom of the cannon.

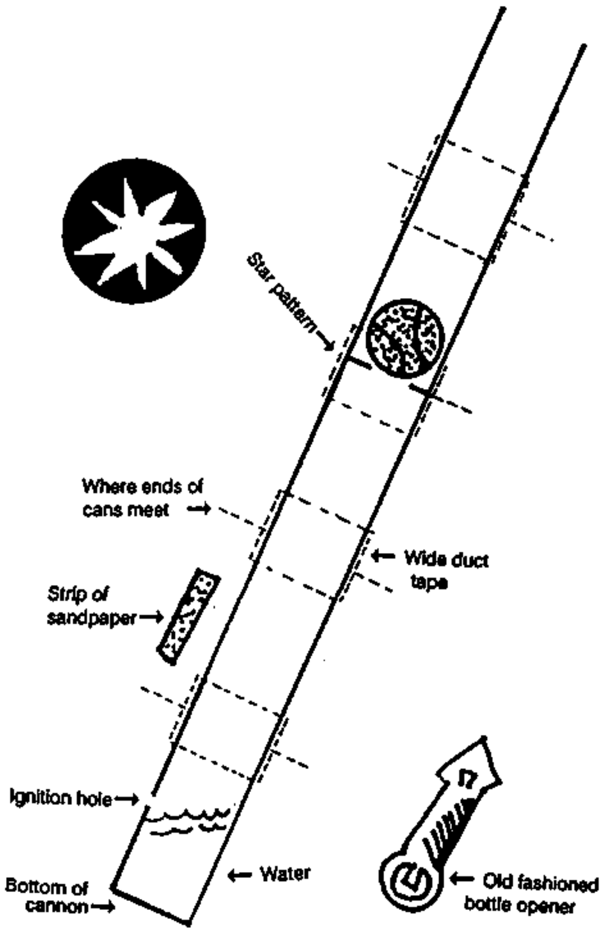
I remove one end of the 5th can and then, instead of using a can opener, I use an old fashioned bottle opener and cut the other end around in a circle, making a star-like pattern per drawing. This can will be the 2nd can down from the top; it supports the ball and will keep it from falling into the water.

Heavy duty duct tape is used to tape the cans together. Masking tape won't do. I tried and it holds up for only about 20 shots or so. After the cans are taped together, I tape a piece of sandpaper to my cannon. This is used to strike stick matches on.

I assume everyone knows how to use BANG-SITE carbide. Just add a small amount to the water, wait a few seconds for the gas to generate, then hold a lighted match to the hole. It doesn't take much carbide to do the job.

I always use some sort of eye protection when I fire my cannon, just in case. I try to keep my head off to one side and use ear plugs. These cannons are loud!

I never look into the business end of the cannon or allow anybody near it when it's ready to fire. The first time I fired it in the front yard, neighbors came running, wondering what all the commotion was about! Some kids thought I was shooting M-80s - that's how loud these cannons are! RS



DRESS UP THOSE SPINNING WHEELS WITH LEFT OVER CUCKOO FOUNTAIN WHEELS

Recently, an article in the *Best of AFN HI* detailed plans for building Easy Sun. As a by product of this construction, components of the Cuckoo fountains were removed and discarded. Each Cuckoo fountain contains two whistles, two empty paper tubes, and a plastic base that were not needed for Easy Sun. Chances are the base can't be saved, but if you're like me you'll salvage what you can. Don't discard the whistles and the tubes; they can be used in some nifty projects.

Those popular spinning wheel saxons can be improved by using the discarded whistles from the Easy Sun project. The spinning wheels come in several sizes. The one I used was 18", but the 12" version could be used just the same.

Refer to the following figure. You will note that the spinning wheel is a saxon with firecracker fuse running the length of the casing. At several points the fuse enters the case to ignite the driver and the color compositions. As the fuse reaches the center of the case it passes through and does the same on the opposite side of the case. This device relies on the paper covering over the firecracker fuse to cause it to act much like quickmatch so both sides of the casing are ignited quickly. In the following procedure we do not remove the paper covering the fuse.

Chemicals	Yellow	Olive	White
Potassium nitrate	5	1	12
Sulfur	2	1	16
Antimony Sulfide	3	1	
Meal powder		1	
Charcoal, dust			1
Realgar		1	

Materials required

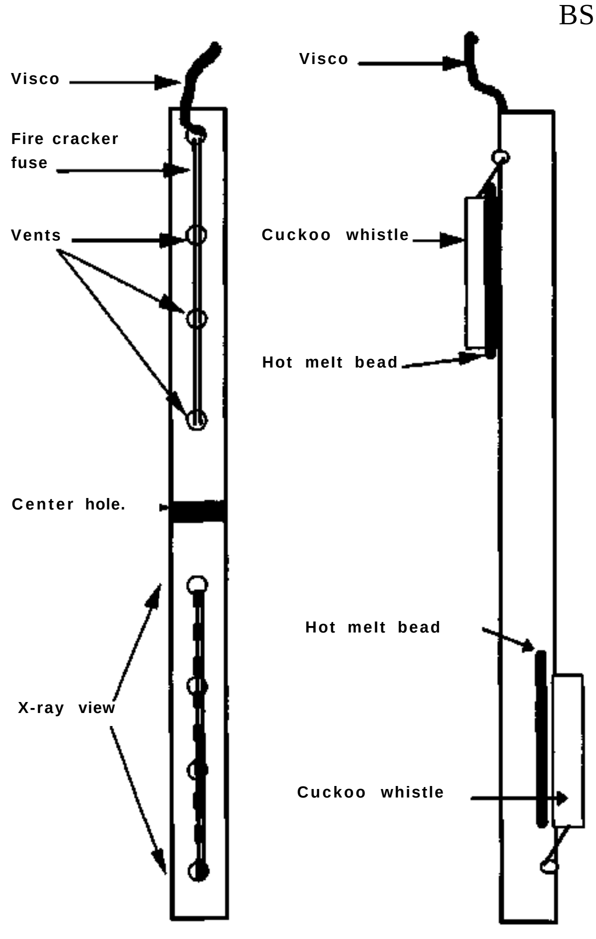
- Two left-over Cuckoo fountain whistles
- Spinning Wheel firework
- Scratch awl or other pointed tool
- Hot melt glue gun and glue sticks

Procedure

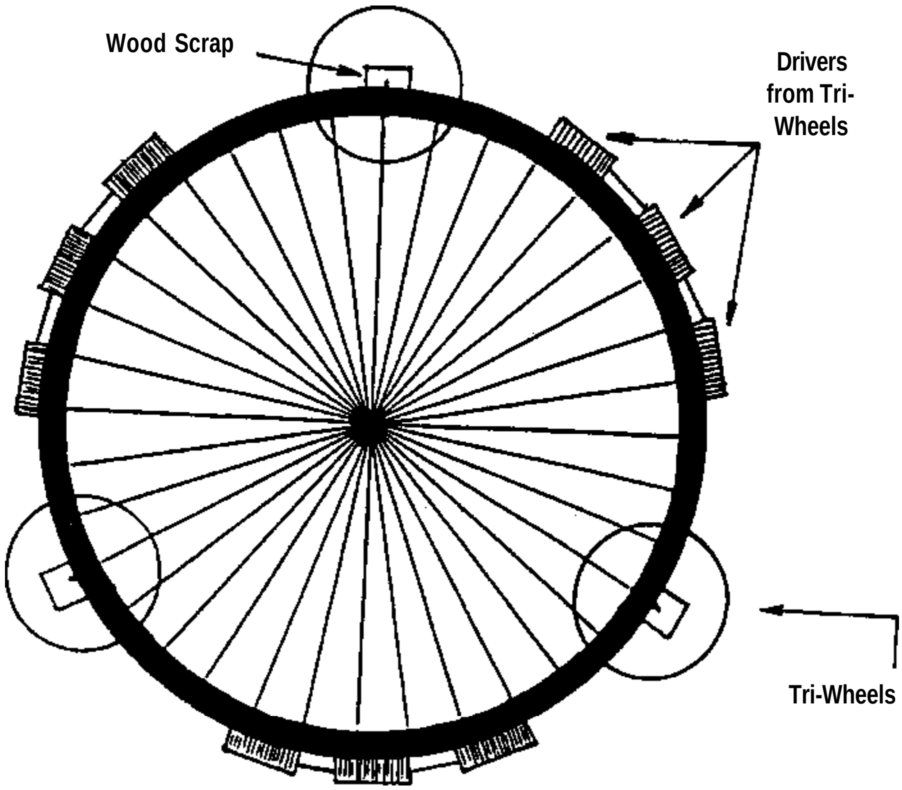
The fuse at the end of the case can be located by running a finger down the side of the case. It can be felt beneath the paper wrapper. Once the fuse is located, an awl is used to punch a hole in the paper wrapper that will allow the whistle fuse to fit under the wrapper. Then the whistle is positioned off to the side of the case. Remember, the case has several vents in it and we don't want the whistle to be blown off when these fire.

Once a good location has been found a bead of hot melt glue is run down the side of the whistle. Then the whistle is held in this position until the hot melt sets. Now it is repeated on the other side of the whistle, and this procedure is done on the opposite of the Spinning Wheel case for the other whistle.

BS



WILD ABOUT WHEELS



This is based on a 26" bicycle wheel hung on a post or pole with a bracket, nuts and bolts. Good posts can be made with 2" PVC pipe in 5-ft. sections with screw fittings. It's light and easy to handle.

I get a couple of dozen Tri-Rotating Wheels. They are cheap and work well. I take three wheels and cut the wires that hold the drivers on, but take care to leave the drivers fused together as they are removed from the frame.

Next I divide the bicycle wheel into thirds by counting the spokes and dividing by 3. I mark the thirds on the rim with a Magic Marker. At these marks I fasten on the wood scraps, using plenty of fiberglass strapping tape, twisted wire, or both. Now I attach a complete, unaltered Tri-Rotating Wheel to each of the wood scraps, using the usual mounting nail. I take care to support the rim and wood scrap while attaching the wheel, and watch that I don't pound the nail in so far that the wheel rubs.

Now I take the three sets of drivers that I had removed from their plastic frames, and securely tape them on the rim, centering them between the wood scraps. I'm careful to make sure they are all pointing in the same direction!

The entire array is now matched with quickmatch. A short piece of visco will provide a little running-away time. Sometimes I'll remove the whistles from the Tri-Rotating Wheels. Six whistles going at once will wake up the neighbors! FM03

STEEL WOOL REDUX

It seems to me that the whole country is missing out on a pyrotechnic effect. It is as safe and simple as a sparkler and as beautiful as the biggest consumer ground items. It is steel wool.

I buy some fine grade steel wool at the hardware store, unroll it, light it, and swing it around my head. It makes a 20-foot radius of dazzling orange sparks! Alternatively, it can be attached to an electric motor, or swung on a weighted string. I'm not claiming this is the pyrotechnic discovery of the century, but it's cheap and lots of fun for any occasion. *DB*

[For a more detailed look at the burning steel wool effect, see *Fun With Steel Wool,* Jan. '92 AFN, and *Steel At It,* April, '93.]

DRIVER BASICS

Drivers are the most important part of a successful wheel as they provide the thrust which turns the wheel. A driver is very similar to a rocket, the main difference being that a driver is end-burning while a rocket burns from the center out. End-burning keeps the surface area of the propellant constant throughout the duration of the burn, providing an even thrust as opposed to the violent start and diminishing strength of a rocket. A good driver must have a sturdy casing, preferably a convolute Kraft paper tube. A good standard size for a driver is 1/2" inside diameter by 6" long, with a minimum wall of 1/8".

The first step in constructing a driver is to ram a sturdy clay choke into one end of the tube. I prefer to space the choke approximately 3/16" from the end of the tube. I do this by placing the tube over a base constructed with a 3/16" x 1/2" protrusion (see illustration A). The choke is spaced 3/16" from the end of the tube in order to prevent it from being easily expelled. Upon ramming, the tube expands at the choke, preventing the choke from passing through the end of the tube which retains the original 1/2" diameter. Granular bentonite clay makes an excellent choke, as does fire clay. I place the loading base on a solid surface and with a 1/2" rod, "loading drift" (preferably aluminum or brass), I hand ram the choke approximately 75% of the diameter of the tube. I pound the drift with a mallet until the choke is hard-packed and expands the tube slightly. The container in which the clay is kept should be left open so that the clay can absorb moisture from the air. This slight amount of moisture is all that is required to bind the clay together. Once it has been determined the adequate number of blows to pack the clay hard, that number should be used to pack the clay in any other drivers that are made.

The next step in constructing a driver is to load the fuel. Fuel should be loaded in increments which do not exceed, when packed, one diameter of the tube. All increments of fuel should be the same and small enough to prevent erratic burning. The same number of blows used for packing the choke should be used to load each increment of fuel. The very first load of fuel should consist of straight Black Powder to avoid the possibility of sparking when the driver is drilled. Enough fuel should be loaded to allow for a 6 - 7 second burn duration.

Among the many possible fuels, I will discuss three basic effects widely used in drivers. The first effect is the charcoal driver, which is simply a Black Powder fuel with the addition of coarse charcoal. This continues burning after being expelled from the nozzle, giving a soft charcoal scintillation. The second is the steel/cast iron effect. This, again, is a Black Powder base with the addition of steel or cast iron filings. I use 16 mesh size. This creates a stream of golden sparks similar to that which is produced by a cutting torch. Third is the titanium driver, which again is Black Powder based with the addition of titanium flakes/grains. Different size particles produce different effects. Finer particles produce a thick cloud of silver sparks close to the driver, while coarser particles will produce a much longer, less dense trail of silver.

After the fuel is loaded, a nozzle must be created by properly drilling the choke. My drivers are typically drilled 9/64", a size determined purely by trial and error - experience! If the choke is drilled too small, the driver will explode or expel the choke; if drilled too large, the desired thrust will not be achieved. The base I use has a small protrusion in the center which provides a guide for drilling. Drivers should be drilled completely through the clay choke. A small amount of fuel should then be packed into the drilled hole. This prevents the possibility of explosions due to increased surface burn area.

Priming is the next step. I prime my drivers with a nitrocellulose meal prime thinned with acetone. Proportions of meal powder and NC are usually not specific. I try to use as much meal powder as possible, but it must remain firm when dry. Using a plastic squeeze-type ketchup bottle, I thin the prime with acetone

DRIVER FORMULAS		
CAST IRON	TITANIUM	CHARCOAL
80% - Meal D	93.5% - Meal D	90% - Meal D
20%-16 mesh cast iron (or steel)	6.5% - titanium, 16-40 mesh sponge or flake	5% -charcoal, 36-80 mesh
		5% - lampblack

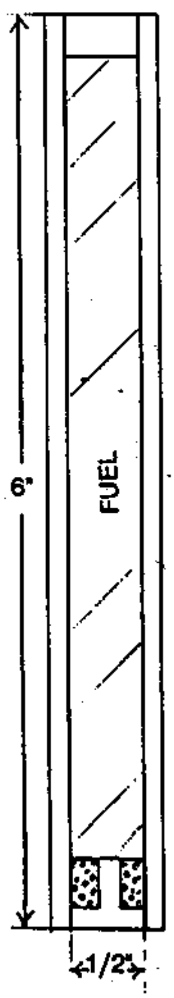
	CAST IRON	TITANIUM
75.3%	25 - Meal D	25 - Meal D
18.3%	6 - homemade Black Powder	6 - homemade Black Powder
6.3%	2 - steel 16 mesh or cast iron	2 - titanium -10 to +40 mesh sponge

NOTES	
Meal D	GOEX commercial Meal powder
Homemade Black Powder	75/15/10 ball milled
Cast Iron	Brake turnings -16mesh. Must be treated with wax or oil if stored for any length of time

to the consistency of maple syrup. In use, I squeeze enough prime into the choked end to cover the clay, and then place a small piece of match into the center of the nozzle through the moist prime. It dries overnight.

The final step in driver construction is nosing, which provides a means of connecting piped match or fuse to the driver for ignition or transfer of fire. Typical nosing consists of 30 lb. Kraft paper rolled three turns around the tube, with two inches extending beyond each end. A small dab of paste is applied to the tube as I begin rolling, and the final turn is secured by a 1/2" strip of wheat paste or glue applied to the edge of the paper. GD

1/2" DRIVER



BASE
1/2" DRIVER

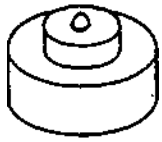


Illustration A

THE TOURBILLION REVISITED

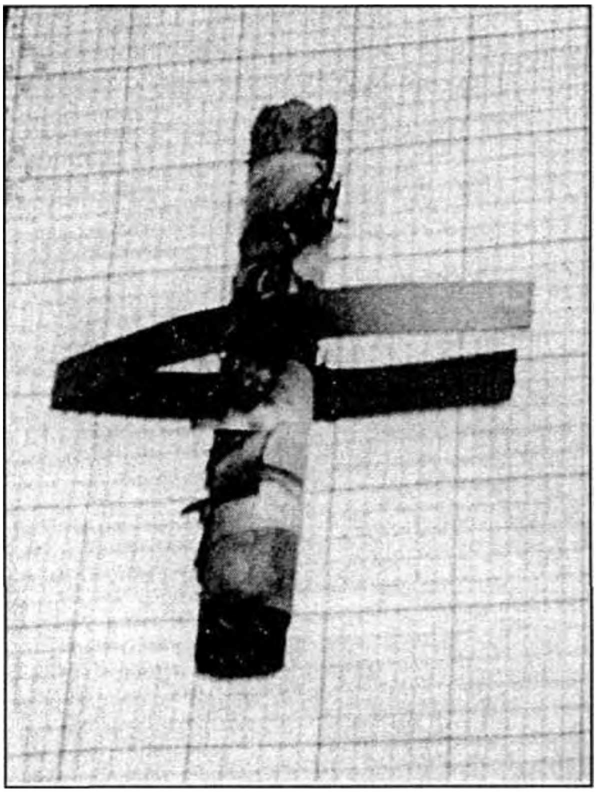
The classic tourbillion, along with skyrockets, has disappeared from the American display scene. There are several reasons; the principal one is the spent case with hot sparks being uncontrolled in direction, possibly falling off-limits on property or people. This same drawback has limited the use of the girandola in U.S. shows.

This restriction was not always the case. Prior to WWII and just thereafter, large tourbillions were used in limited ways. For effective display, the tourbillions were large and heavy, equal in weight to one-pound skyrockets. But without a stick to guide their return to the ground, they were more erratic than rockets.

Tourbillions of all sizes were popular in Europe late in the 19th century. Kentish gave detailed directions for construction, including recipes for propellant mixes. [*The Complete Art of Firework Making*, available from AFN].

Some years ago, through the courtesy of W. R. Withrow, I obtained some display tourbillions that had been in the collection of the deceased pyrotechnician, Mr. Engelke. For historical purpose, I will list the size of these samples.

- Lap-rolled paper case: 9" long
- Outside diameter: 1 1/4"
- Inside diameter: 3/4"
- Vent diameters (all four identical): 1/8"
- Vent orientation: Two, 1" apart on bottom of case, astraddle the wing. One on each end of case at 90° from bottom vents, 1" from end of case. Vents connected with heavy blackmatch to fire simultaneously.
- Match was not piped but was covered with a wrap of blue Kraft paper around the entire body.
- For safety's sake the vents should have been drilled before loading the case. This was not confirmed.
- For display effect, several tourbillions were matched together for launching in salvos from a flat surface.
- End plugs: Rammed clay.



- Wing: Curved piece of hardwood cut with bandsaw. Nine-inch span. Nailed to center, bottom of case with two common 1 1/2" steel nails after filling the case. It is interesting to note that Brock attributed a serious accident in one of the English factories to a worker driving a wing nail into a tourbillion case. We hope the manufacturer over here was more fortunate. The wing nailheads served as bearings for the rotating body prior to lift-off. Kentish also advocated placing tourbillion wings in a position above the body to improve aerodynamic stability. His advice was not taken by this manufacturer.
- Manufacturer: Unknown. The device was not intended for over-the-counter sales. It is suspected that the Rozzi firm made such pieces in the immediate post-WW II era.

The Test

Age and weather exposure were cause to rematch the entire piece. Masking tape covered the bare match and assured near-simultaneous ignition. Take-off was from a large plywood surface.

Departure was better than expected (no tip-over), probably helped by the wing position on the undersurface.

Visually the spark spray seemed to flitter, suggesting the use of a comp. more complicated than mere black powder. This was confirmed by yellow-orange antimony stains in the case after recovery. Obviously, iron or steel, if used, would have succumbed long ago to internal oxidation while in contact with the saltpeter. Certainly the piece pre-dated the use of titanium by many years.

The test can't be classed a complete success, as both end-plugs gave way from internal pressure before the intended height was reached. Success was sweet and it was best demonstrated in action.

* The untimely passing of W. R. Withrow brought regret to his many friends and called for words of commendation by many, something this writer could not find adequate words to express at the time. Discussions between the writer and Mr. Withrow many years ago over the extinct fireworks described here led to an implicit promise that I would someday examine them for posterity. I think he would have been pleased with my investigation. JB

PYROS BEWARE THE MONTH OF JUNE

Accidents happen in the fireworks industry this month. A tray of green stars made with barium nitrate, barium chlorate, red gum and dextrin ignited *while wet* at high noon at my plant. Temperature was 75° and the stars were drying directly in the sun. It started a grass fire which we quickly put out. No casualties. I've been using this formula for over 30 years. Bill B.

EASY TO MAKE FUSE FOR BETTER ROCKET IGNITION

I was very much interested in the article *Priming Gives Positive Ignition.* I've also had problems igniting rocket engines, but I came up with a solution that doesn't involve the use of such expensive materials as nitrocellulose lacquer, smokeless powder, collodion ("New-Skin") or Mantitor igniter cord.

My chemistry students and I had trouble igniting our rockets with visco fuse or Estes model rocket igniters. They just didn't seem to produce enough flame to reliably ignite slow-burning black powder mixtures. I found the solution in a crafts shop section devoted to candle-making where I spotted some candle wick priced at twenty feet for about two dollars. I realized that this could be used to make black match that was thin enough to fit inside the nozzle of a 4 oz. rocket motor. I buy the plain cotton wick (without a wire core) that is intended for candles of 2" diameter or less. I cut it into 3" lengths, then mix:

Potassium nitrate	15 grams
Airfloat charcoal	3 grams
Sulfur	2 grams
Dextrin	2 grams

The potassium nitrate is ground as finely as possible with a mortar and pestle. Then it is mixed with the other ingredients on a sheet of waxed paper with a spatula. Water is then added in sufficient quantity to make the mixture into a thick paste (about the consistency of pancake batter). The pieces of candle wick are coated evenly with the mixture, stretched out on another sheet of waxed paper, and allowed to dry overnight. By the next day, the pieces of wick are quite stiff. One end of the wick is bent over into a hook and pushed up through the rocket's nozzle, so that it catches on the inside of the hollow central cavity. An Estes model rocket igniter is then taped to the other end of the fuse with a short piece of masking tape.

This system has worked every single time I've used it. Rocket ignition failures are now a thing of the past as far as my students and I are concerned! ST

PRIMING GIVES POSITIVE IGNITION

Visco fuse itself, without primer on one end, will not ignite (or will with difficulty) a rocket! There are several different ways to prime the fuse. Here are a few:

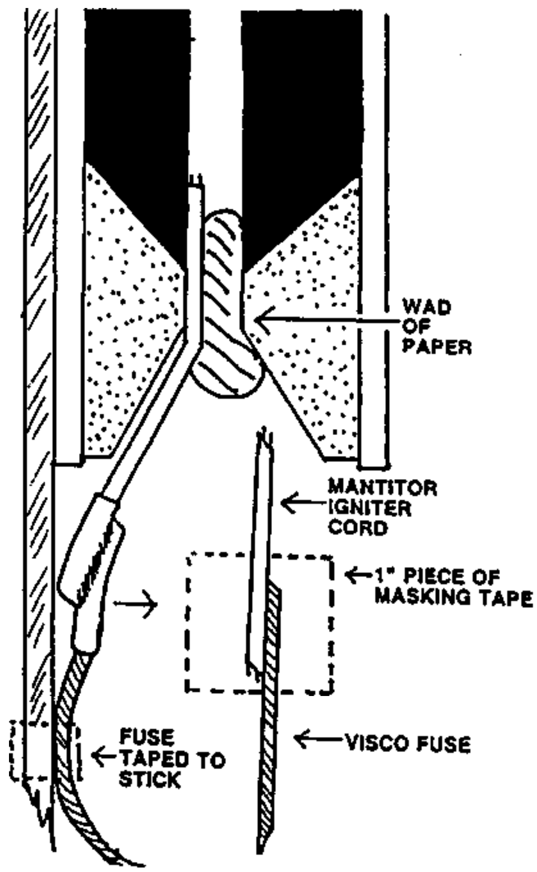
Very simply, I dip the visco tip into some nitrocellulose (NC) lacquer, then rub it around in some 4Fg black powder to make a blob. In about 15 minutes it's dry and ready to use. Anyone unwilling to pay the high prices for HazMat shipping and UPS charges can make his own. Here's how I do it:

1 A can of acetone can be obtained at the hardware store, and from the gun shop it's possible to get a can of smokeless powder [single base - not the nitroglycerin-containing double base powder!]. It looks like broken pieces of pencil lead. In a glass jar I put about an ounce of acetone and add 4 - 5 teaspoons of the powder. I stir it once or twice a day. In about 3 - 4 days the powder will be completely dissolved in the acetone. Now's the time I experiment. I can add more powder to make it thick, but I really want to make it into a syrup. Using this, I just dip the end of the fuse into it, and let dry.

2 Here's another method: At the drugstore, in the area where they sell bandages, there is a liquid bandage product called "Nuskin", which I believe is composed of collodion, or pyroxylin. This is the stuff in the bottle, not the spray kind. Donning safety goggles, and with a mortar & pestle, I carefully grind some 3Fg black powder into a fine powder. I put the collodion in a small glass jar, and using a wooden stick (bamboo skewer, etc.) I mix in the fine black powder until it is the consistency of syrup. It's used the same way - just dip the end of the fuse to form a nice blob. One problem is that the collodion evaporates very quickly and the stuff will harden. It can be put into a small jar with a small opening with a tight fitting lid.

3 The last method uses Mantitor brand igniter cord which can be obtained from Coonies. It's a grayish fuse with two fine wires in it. It's kinda expensive and burns FAST, so I use it sparingly. This is what I do:

I cut about 2-inches of Mantitor and about 3 - 4 inches of visco fuse. I cut a piece of masking tape about 1" square, and wrap it around the Mantitor/visco, making sure that they are securely touching each other. It is shoved into the rocket choke, Mantitor end first, with a piece of balled-up paper to hold it in place. For added security, I tape the visco to the stick. I don't put the tape over the area where the cord meets the visco, or the wire won't blow out. What happens is that the hot dross may accumulate on the wire and possibly clog up the choke, thus altering performance or causing failure. The igniter cord burns hotter than the visco and spreads some FLAME around! RS



SURE METHOD OF PARACHUTE EJECTION FOR ROCKETS

Most of the books recommend 3Fg Black Powder for ejecting parachutes from rockets. But I found that while the powder charge never failed to ignite, it burned so quickly that the parachute and its attached nose cone were blown completely out of the rocket's body tube. I next tried Pyrodex for ejection charges, figuring that it would burn more slowly. It worked fine as far as ejecting the parachutes was concerned, but often failed to ignite. The solution was to combine the two powders. I'm now using a 50:50 mixture (mixed by volume) of 3Fg Black Powder and Pyrodex RS rifle powder as an ejection charge. It never fails to ignite, but burns slowly enough to leave the parachute attached to the rocket's body tube. (1/4-teaspoon works perfectly for 4 oz. rocket mortars).

The other problem is protecting the parachutes from the ejection charge hot gases. The plastic parachutes I was using were being badly burned and melted, despite the overpriced "recovery wadding" (actually only fireproofed tissue paper) that I had placed over the ejection charges. When I tried adding extra sheets of "recovery wadding", it merely plugged up the rocket's body tube so that the ejection charge ejected the engine instead of the parachute! I began considering alternatives but decided to eliminate the fiberglass insulation that some rocket builders have used, since it isn't biodegradable (not a good example for a science teacher to set for his students). I chose instead to try fireproofing regular "cotton puffs". I mixed up a saturated solution of boric acid in a glass bowl, then soaked some of the cotton wads in this solution and spread them out on waxed paper to dry. It took several weeks for the cotton puffs to dry completely in this damp climate, but when they did finally dry, they proved to be entirely non-combustible. I've since found that three of these fireproofed cotton wads does an excellent job of protecting my parachutes without plugging up the rocket body tubes (or creating a pollution problem). ST

CHAIN FUSING VISCO

I have found the easiest and quickest way to connect lengths of visco fuse together is to split the visco lengthwise with a razor knife. I do this about 1/2" to 3/4" and then place the exposed powder trains together and secure with tape or tie string. If I am doing a splice of two to one, I add a couple of 1/2" pieces of black match just to be sure there is enough fire to transfer.

For a mid-line splice I slit the main line about 1/2" and slice the other piece at a long angle to expose the powder train and insert it in the slit and secure with tape or tie string. Again if you are uncomfortable about enough fire to transfer, add a small piece of black match. JLM

STICKY, STICKY

In *Easy to Make Fuse For Better Rocket Ignition,* in the February issue of AFN thin black match was recommended for reliable rocket engine ignition, which is fine, but then an Estes ignitor is taped to this fuse with a piece of masking tape. Not a good idea! If left in contact with the match for any length of time, the adhesive from the tape can soak into the match, possibly interfering with ignition. I have seen several incidents of stopped fire where masking or ordinary Scotch tape was placed over Chinese fuse, despite the paper covering over the powder core. In these cases the tape had been in place for a few weeks or longer, but it is hard to estimate how long it takes for the adhesive to do damage. Old, deteriorated adhesive (which gets gummy and does not hold well) will soak thru very quickly. One should not rely on adhesive-backed tape for other than short-term use, and it should never be used on fuses, match, or paper collectibles, which it can stain indelibly. HD

EXPERIMENTS WITH MINIATURE ROCKETS

The great task of chemistry is to figure out the universe as exactly as possible, and use that chemical technology to make better use of the universe. Logic is the great tool of the human mind, so with that logic and chemical technology we tear things down to get to the basics, and then might very well get better fireworks.

Quantum chemistry promises some real good fireworks effects and new chemistries. I have played around with some wondrous new toys, but right now let's go back to what was probably the second firework every invented, and see what logic and thinking can do for our old friend, the rocket.

The experimenter takes a really tiny rectangle of cigarette paper and pastes it with rice starch paste, then pastes half of it with powder paste, then lets it dry a little and then rolls it around a pin or needle so that the powder is now inside a tiny paper tube. With a little practice, he should be able to make rockets that are only about 1/8" long and less than 1/16" in diameter, and they will fly a short distance. You might think these are about as simple as a rocket can get.

For more than a thousand years, the way to make a rocket was to place a tube over a mandrel that would form a cavity when removed, then ram clay around that to form a nozzle, and then ram propellant into a solid, strong mass, provide other things like fins or vanes. Now we sit down with the old physics book about rockets and we notice that of all the various parts and pieces of all the configurations of things that flew by rocket propulsion, every one of them had substance, and therefore weight. According to Newtonian physics, we have two things to overcome: inertia and gravity. (Add air drag and turbulence to inertia.) Fundamentally, a pyrotechnist wants to entertain by creating a self-accelerating device that will not only fly, but create interesting patterns of moving light, or as my old friend Orville Carlisle would say, has snort, a little sound and a lot of acceleration.

So our scientific logic tells us that we can boil things down to a minimum system of the sound of escaping supersonic gases and particles in the exhaust from the burning fuel and the acceleration motion. Logic says we had best maximize the light production, next produce pleasing motion of the light, and the sound will probably take care of itself when other aspects are maximized.

We concentrate on the essentials. The clay nozzle is heavy and inert, used to pattern flow and regulate pressure, but it is not the only way to achieve these. It has to go. Then, looking at aerodynamics, we learn that for subsonic rockets, the effects of small drag surfaces is proportional to the area and greatly sensitive to turbulence from non-streamlined surfaces, but for rockets below a foot in diameter, the carefully streamlined nose cone is of no real value because it has inertia effects greater than the air drag effects it was to overcome. Therefore, its only use is as a container for garniture effects, and other container configurations are more effective.

Let's get back to experimentation. Next we dissolve some gelatin or hide glue in water. When this dries it has a film strength of about 5,000 pounds per square inch. When used as a binder, it considerably slows the burning rate of a composition, which is the secret of the new Chinese sparklers that outperform the old dextrin-bound compositions (the long duration of a common match derives from the use of collagen binders). What we need is a strong, well shaped grain of fuel, with a central cavity to furnish a larger burning surface, and a pressure chamber that will vent the combustion products in one direction. So for a tiny rocket we mix up a little powder with the collagen colloidal suspension most people only slightly incorrectly call a gelatin solution, and we paint on little blobs of the stuff on pin tips or needles or carefully shaped stainless steel wire or small diameter rods, layer by layer, and let it dry.

When you get these to fly, you will be down to the minimum for a rocket. They function nicely in sizes down to about half the size of the cigarette paper rockets. At about 1/16" long it becomes a difficult art project, but fun.

If they explode or refuse to fly, they can be made shorter or the powder slowed down. If a big bunch of them has been made and they come close to working, you can fudge a little and give them a casing of painted-on gelatin. These are the second smallest type of rocket-propelled fireworks; the smaller ones get a little high-tech. They require thermosetting, virtually instantly graphitizing coating on magnalium particles that have been coated with a combustible that must furnish part of the energy of the conversion of the thermosetting resin to a microscopically thin graphite casing that is just porous enough to let in air for the fuel combustion. Actually, the purists (people are so picky) might say they were really jet engines four hundred microns in diameter, and not really rockets. These fly only about a foot during the burn, and another three feet or so after. As it happens, they are of great theoretical interest, not only for the funny sound they make, but for the rather peculiar light. They do not crackle like burning magnalium usually does, because the reactions that drive them consume the energy in high frequency vibrational burning.

Once the experimenter has gotten the gelatin rockets flying, he realizes that he could make larger versions work too. A 1/8" diameter tube makes a good mold for a star pump-like device to pump grains about a centimeter long (or about 12mm for a crackling micro-star). A small brass rod can be used to produce grains or stars 21/64" or about 8mm. The grains can be molded with rice starch, and require no casing, but can be painted or rolled on 10% gelatin in water-alcohol suspension, after they have dried. For rocket sticks for these, heavy thread saturated with gelatin and coated several times with more gelatin, makes nice sticks. These rockets should fly many dozens of feet. These can be difficult to light, so very fine nichrome wire can be tried.

The experimenter can try putting just a little spherical titanium on the end for garniture, or perhaps try something like German black aluminum, coarse magnalium, and some oxidizer, in about equal parts. Playing around with maximizing that should inspire you to use triangle diagrams. I like to sneak a little science in whenever I can. Makes for better fireworks.

Now we are finally down to the basics of rockets, a molded grain of pyrotechnic comp. As we scale up to about 1/4" diameter, the fuel experiments start to pay off nicely. At about two grams of comp and up, half or more of the fuel can be spark producing material, but that is another story for another day. LSO

VISCO IGNITION TRANSFER

As a manufacturer of visco and as a consultant to a major visco manufacturer, now extinct, I had thousands of opportunities to splice visco fuse. I can recollect no instance where two pieces of visco, in intimate contact with each other, failed to transfer fire, even if they were just crossing each other. Therefore I would state that knotting, lashing, or bucketing will work fine. If buckets are used, be sure to lash also in the center of the bucket where the pieces bypass. Also, plastic ties are very effective for joining visco.

I would venture the opinion that ignition transfer of visco to visco is more certain than black match because the violent deflagration of the match occasionally disrupts the connection before the arrival of the flame front, whereas visco burns more steadily and has longer contact time for heat/flame transfer and doesn't whip around while burning.

I like TW's suggestion of the plastic sleeve:

"To connect visco to visco, I get a piece of 1/8" or 5/16" dia. plastic tubing and cut a piece about an inch long and then stick the two pieces of fuse into the tubing. It kind of acts like quickmatch in that one inch."

Yes, if you enclose visco loosely, it will often "quickmatch," even with a light paper sleeve.

GG

HOBBY ELECTRIC LAUNCHER

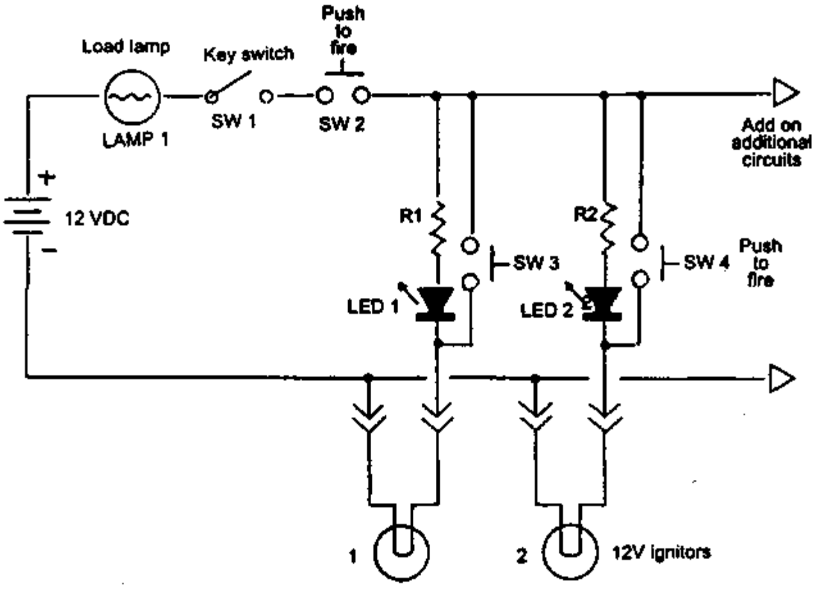
The hobbyist can build for themselves a small launcher panel that can be used to safely set off a dozen or a hundred electrical ignitors individually. My panel uses LED's to indicate that the ignitor is properly connected and that it has actually activated (shot off the mortar). This is really comforting if people have been trampling on your wires all day or a low burst may have disturbed your wiring! However it will NOT tell you if you have your wires shorted together. Use extra care to make sure you won't get shorts. Features also included are a key switch to prevent unauthorized launches, a current limiting bulb that will light brightly and keep the wires from melting if I try to launch on wires that are shorted together and a dual switch set up so I can't accidentally launch anything without using two hands. This is an important feature if you have ever knocked over your beverage container and sent up half the display!

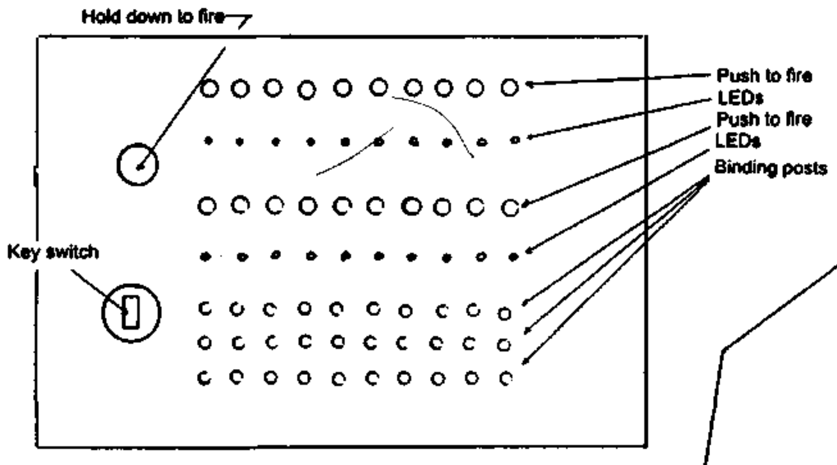
The current required to operate an LED (light emitting diode) is usually around 6 mA (milliamperes). This is not anywhere near enough current to activate any common ignitor. However I always test any style of ignitor with this setup to be sure it will not activate before it's assembled into a device. Also, because the launches I make are during hours of darkness, these LED's are too bright; so I select resistors that will limit the current flow to 3 mA.

LED's have incredible life spans (theoretically forever!) if their current is limited to no more then 10 mA or what ever the manufacturer recommends. Mechanically they will survive a drop from an airplane, unlike filament bulbs which draw many times the current, have a short life span, are as fragile as glass and can not be used safely for this application. Consider the drawing on page 83.

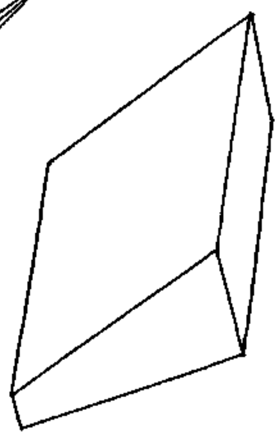
LAMP 1 is a 12 volt automotive turn signal or brake light bulb. Its job is to limit current so if any wires get shorted together this bulb will light and prevent damage to your wires and cables. The SW 1 (contacts OPEN when key is removed) key switch turns off all power with key removed. SW 2 (normally open push to operate) prevents any firing unless it's pushed. Set it up so you use your left hand for this and your right hand (or opposite for lefties) to FIRE SW 3 through XX (normally open push to operate). Current will flow in only one direction through an LED so if it should light and it's not, reverse the leads! Resistors are 1.2k for very bright or much better 3.9k. Quarter watt resisters will work fine for this application. If you are familiar with electronics you can adjust these values for any voltage with the formula E=IR and P=IE or you can build an adjustable voltage power supply so you can adjust the brightness to suit the situation.

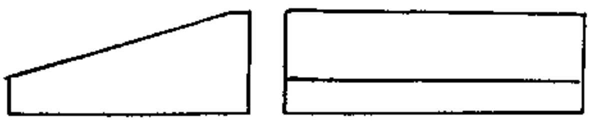
I used a quarter-inch thick piece of *Plexiglas* or *Lexan.* I scratched up the back of the plastic with 240 grit sandpaper, then sprayed it with my favorite spray paint, drilled holes for the switches, drilled a dimple part way through the plastic from the back and *Superglued* the LED into position. This will hold the LED securely while allowing me to view it. I soldered all wires and resistors into position. Any hook-up wire can be used here between 18 and 22 gauge stranded. Epoxy, silicone or hot melt is used to hold parts in position and keep wires from shorting out. Next I select binding posts, barrier blocks or cable connectors and wire them in. This assembly is installed as a cover to a box that can be bought or fabricated. Now you can launch your creations at a safer distance, with a better view! CD





Example of 20-position panel shown





TWO-STAGE WHISTLE ROCKETS

I tried various ways to make 2-stage whistle rockets, and after some successes and failures, came up with this method:

I tried making my own whistle rocket tooling, but the results were poor. One AFN pen pal told me to use the head of a penny nail attached to a dowel, but it often came apart, and the penny nail often got stuck in the fuel. I wrote to several AFN advertisers, finding that there are very few who manufacture whistle rocket-making tools.

The few advertisers who sell tools make them only to a certain dimension. I wanted mine to be custom made to my specifications. One AFN advertiser made some rocket tooling for me and to this day, with close to a thousand rockets made, the tools are still in good condition!

The machine-rolled tubes I bought have an i.d. of 1/2" and an o.d. of 13/16". I cut the tubing down to 2" long. Like model rocket motors, I tried coupling them together and often the 2nd stage would fly erratically, like a ground chaser. To ignite the 2nd stage, I had to make a launching tube and fasten it to the front end of the whistle rockets. I noticed that the i.d. didn't have enough "play room" for the 2nd stage of the same dimension to loosely slide in.

I tried making my rockets so the 1st stage would lift the 2nd stage of the same size dimensions, but that would make it top-heavy. Not only that, but the 1st stage wouldn't have enough power to lift the 2nd stage high enough.

Again, I had tooling made for smaller whistle rockets, with an i.d. of 3/8". When I made these rockets, I found they slid quite loosely inside the Kraft paper tubing fastened to the front end of the rockets.

The small rockets have an i.d. of 3/8", and an o.d. of 5/8". The o.d. of the 1/2" tubing is 13/16". This particular tube barely wants to slide through a 3/4" circle template, so the next size up is 13/16", and that slides through fairly easy. The template says "Pencil allowance on all holes .040". I'm unable to find AFN advertisers who have tubing with an i.d. of 13/16" by 8" long, so I had to roll my own with Kraft paper, wallpaper paste and wooden dowels. It's an old method of making tubes. AFN readers who are new to this can find some AFN advertisers who have info on how to make these tubes.

Another way to make a launch tube for the 2nd stage is to take at least a 10" piece of the machine-rolled tubing (I use to make rockets) and use that to roll my Kraft tube. It seems to have a snugger fit around the 1st stage.

At first I rolled my launching tubes about 6" long. I glued about 3/4" of it to the front end of the whistle rocket. When I tried attaching the stick, I couldn't attach it along the entire length of the rocket because the thickness of the launching tubes would be in the way (see Fig. A). I tried attaching the stick near the edge of the launching tube in this manner, then launched a dozen rockets to test. Some went into a big arc or went helter-skelter! Then I made it so the 1st and 2nd stages were encased in one l-o-n-g tube so the launching stick can be attached to the entire length of the rocket (Fig. B).

Because my 2nd stage is also 2" long, the remaining end of the launch tube has to be at least three times longer than the 2nd stage in order for that stage to be projected in as straight a line as possible.

WHISTLE MIX IS NEVER RAMMED, BUT ALWAYS PRESSED.

When I press whistle fuel in the 1st stage, I try not to put too much whistle fuel "way past" the spindle because it's likely that the 2nd stage will ignite when the rocket has peaked and started to come back down! So I put in small charges of comp. each time, and try not to put too much in the 1st stage.

One problem I had was that some 2nd stage rockets didn't ignite. It occurred to me that priming the front end of the 1st stage, and priming the nozzle end of the 2nd stage (with real Black Powder) would correct this problem. That did the trick!

I make sure my rocket sticks are at least five times the length of the rockets. Thus an 8" long rocket would need a stick 40" long. That might seem like a pretty long stick, but that's the only way my rockets will fly nearly perfect. I glue 1/4" thick wooden dowels to the rockets and reinforce them by wrapping with gummed Kraft paper tape. I also put low temp hot melt glue where the stick meets the Kraft paper and the tubing.

I take a long enough piece of fuse, bend it in such a manner that it comes in contact with the fuel, and then shove a wad of tissue paper to hold it in place. I never put hot melt glue near the opening nozzle end so that it can clog the orifice, but just enough to the spot where the fuse can be glued to the tube. Finished.

I shot about four dozen rockets at the beach on New Year's Eve. All worked nearly perfectly. One was errant when the 2nd stage ignited in a sudden gust of wind. It went toward a crowd of people about a quarter mile away! Luckily, it didn't get too close! RS

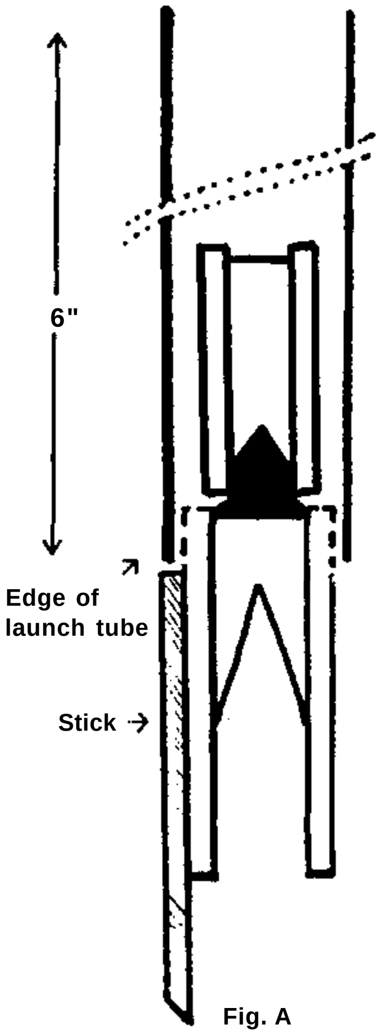


Fig. A

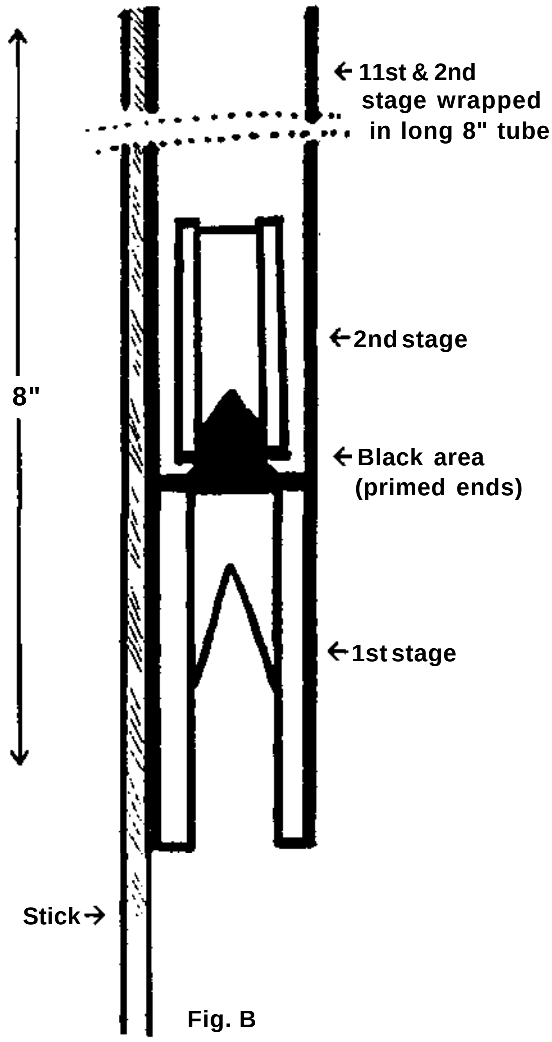


Fig. B

PARACHUTE ROCKETS

At the '91 PGI convention I witnessed one of the most spectacular finales ever. Included in it was a flight of parachute rockets with deep red flares attached. They lit up the Mississippi River and boats below beautifully. It was unlike most pyrotechnic effects because it lasted more than three seconds. Alas, I've learned these beautiful rockets were really commercial signaling flares. But I was so impressed, I set out to make parachute rockets.

The existing literature gives the impression that this is not an effect for amateurs. To my surprise, the challenge proved to be not difficult at all. The information I found in Shimizu's Fireworks, The Art, Science & Technique and in Weingart's Pyrotechnics was very descriptive. But it took about fifty readings of both books to fully understand it, because trying to describe something like folding a parachute is not easy, to say the least. By combining the information found in both books, I came up with a method that was sort of a compromise of the two. I'm sure readers who try this will find themselves reading it fifty times or more.

The material I use for my chute is a waxy-covered tissue paper similar to Japanese Kozo-paper. It's quite easy to find; I go to my local florist and ask for some of the paper they use to wrap flowers in. Most places currently charge 10$ for a piece 24x36". I cut my chute into a 14x14" square. After cutting the paper I ball it up in the palms of my hands and roll it around for a few seconds. This "breaks" the paper and makes it more pliable.

Then I cut five pieces of cotton string to 14" lengths. I twist the corners of the paper a little and tie a piece to each, then bunch the other ends of the strings together and use the fifth string to tie in a knot. Now I have the chute with a leader attached (for the flare).

Holding the end of the leader string in one hand and the top of the chute in the other, I gently pull in opposite directions so that the chute folds itself together as in Fig. la. Now I lay the chute on the table and fanfold each of the four sections, one at a time, as in Fig. lb and lc. I have found that this is the first of two points that determine if the chute will or will not open.

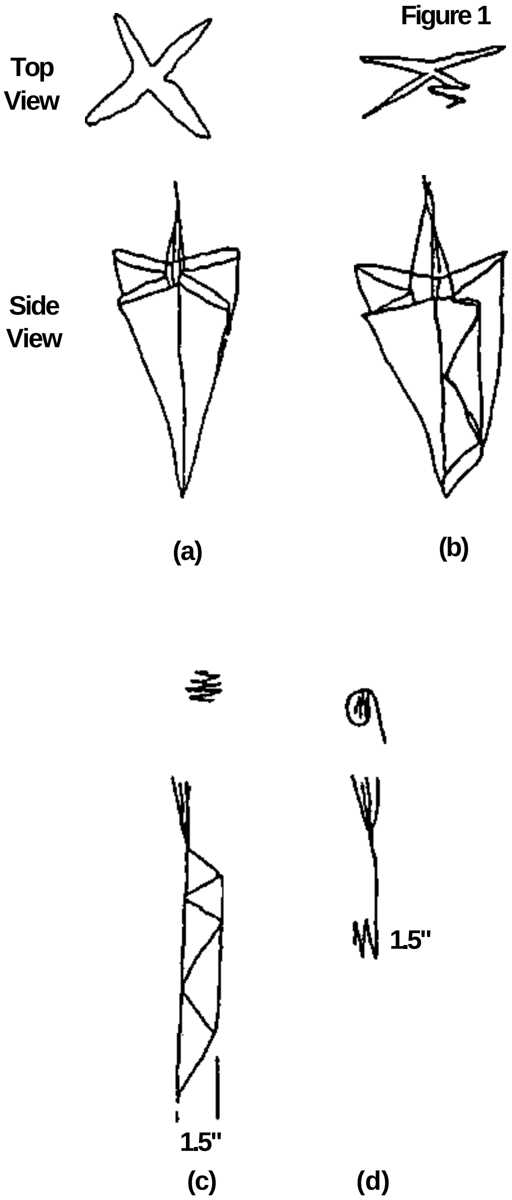
These fanfolds must be 1 1/4" to 1 1/2" wide - the larger the better. I tried folding them tighter to be able to make smaller overall headings in my rockets. I found that in 50% of the time when the chutes were hand thrown they did not open. This should be the first test to ensure that the chute works, and done before being incorporated into a rocket heading.

The final folds are now done by fanfolding the chute from bottom to top as shown in Fig. Id, which is a side view of Fig. lc, being folded from bottom to top. Once again the fold should be about 1 1/2-inches. I do not fold all the way to the top. This is the second point that will determine if the chute opens or not. I leave enough of the chute unfolded to circle around the folded part once (top view, Fig. Id). After circling around the folded part of the chute with itself, I continue circling around it with the chute strings, and finally with the leader string. The chute should now be in a cylindrical shape about 1 1/2" tall and about 1 1/4" in diameter, including the string wrapped around it.

My next step is to prepare the flare or illuminating star. I start by making a 1" dia. pumped star with 20 grams of star comp. Before removing the star from the pump I press 1 tsp. of clay on top of the star. I use illuminating star mixes instead of flare mixes because of their ability to produce a deeper color and still have a relatively high candle power.

After the star has dried I paste a piece of kraft paper 5" long around the star. It has to be as wide only as the length of the star (about 1 1/4"). Now I center a small piece of wire, about 3" long, on top of the clay, then glue a 1-3/16" chipboard disc on top of this, running a bead of glue around the outside of the star to the disc. This is to ensure that the star will not separate from the disc.

Figure 1



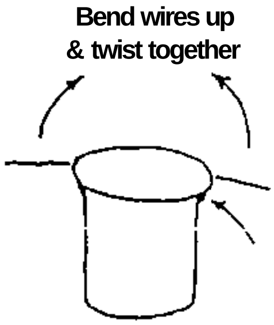


Figure 2
Star

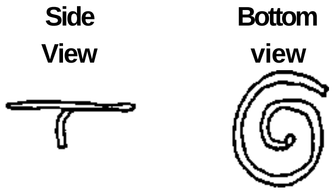


Figure 3
Thermolite Coil

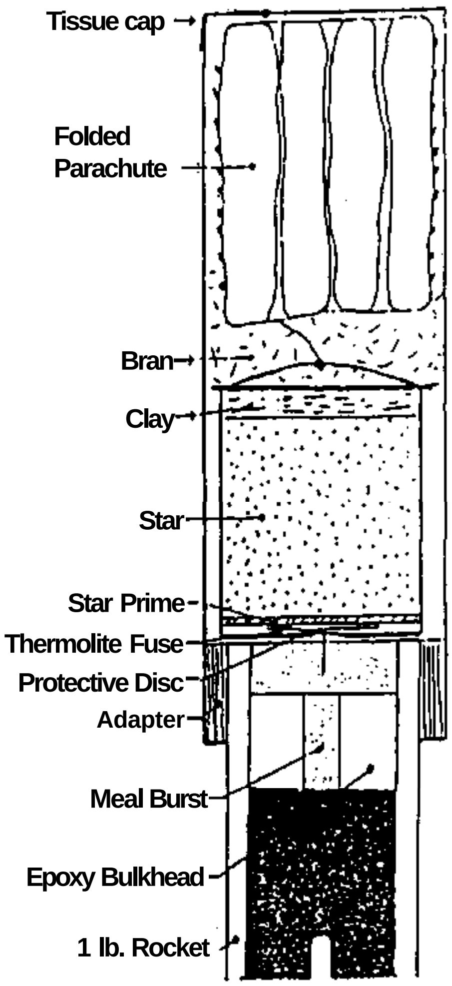


Figure 4
Payload Chamber

After the glue has dried, I bring the two ends of the wire together and twist them well (Fig. 2). Then I tie the leader string to the wire. The chute-to-star assembly is finished except for the priming and fusing of the star.

Each change of star comp. must be tested for ignition to see if a prime is needed. I simply tape a piece of thermolite to one end. If the thermolite lights the star, then no prime is needed. If not, a suitable prime must be applied to the star.

The next step is to make a small coil of thermolite with a leg coming out of the center at a 90° angle (Fig. 3). I tape the thermolite to the end of the star with a small piece of tape, making sure that the leg is centered on the star. Then I cut a 1-1/8" disc and punch a small hole in the center, and tape it over the fused end of the star with the thermolite leg sticking out of the hole in the disc. The disc will protect the star prime and fuse from the blast of the blowing charge. The tape holding the disc will burn away from the star's flame, allowing the disc to fall away while in flight. See Fig. 4 for the completed star assembly.

With the chute/star assembly ready I can now construct the rocket payload chamber. The finished size of this chamber is 1 1/4" i.d. by 3 3/4" long. This is made from three turns of very heavy kraft, or six turns of paper bag kraft. For strength, I glue all but the first wrap of paper. While this is drying I cut a piece of kraft to a proper length so that when it is wrapped around the rocket o.d., it will make a width of 1 1/4" for the payload chamber to fit over. This adapter strip should be 1/2" wide. I glue the adapter strip in place around the rocket tube, even with the end of the rocket. I use a 1-lb. rocket for this size star and parachute. The payload chamber can now be glued and slipped down over the adapter. When the payload assembly is dry, the star and parachute can be loaded.

I begin the final assembly by inserting 1 tsp. of hot homemade meal in the bulkhead passfire and rocket head, as shown in Fig. 4. This may not sound like much of a blowing charge but it works well. Now I slide the star in place until it rests firmly on the top of the rocket body tube. Over the star I place about 1 1/2 tsp. of bran, fine rice hulls or fine sawdust as a fire barrier for the chute, then insert the folded chute on top of this barrier, and cover the top of the payload chamber with a piece of tissue. See Fig. 4 for finished payload details.

The rocket bulkhead should be made of an epoxy-type material. Because of the light blowing charge, a clay bulkhead will blow out, instead of the chute and star being ejected as planned.

References:

Shimizu, "FIREWORKS, The Art, Science & Technique", pg 287-8, 323-4.

Weingart, "PYROTECHNICS", pg 98-100.

Steyding, *Rocket Nose Cone Construction,* AMERICAN FIREWORKS NEWS, Aug. '88, pg 4.

Kentish, "THE COMPLETE ART OF FIREWORK MAKING", pg 135-7.

Lancaster, "FIREWORKS PRINCIPLES & PRACTICE", pg 155-7.

Lienhard, *The Straight Chute,* Best of the PGII, Vol. 1, pg 42.

HINTS & TIPS

I found a good use for styrofoam packing peanuts. They dissolve quickly in toluene, forming a good adhesive that dries to a rockhard glaze. It takes a good number of peanuts, and not much toluene, to make a thick soup. Toluene, xylene, acetone and all the other solvents useful in fireworks production are available in gallon size at local Sherwin-Williams stores. If they are not on the shelf, the proprietor can order them.

A 2 or 3 gallon garden chemical sprayer makes a handy fire extinguisher. The spray stream flow is about equal to a soda/acid unit, they are portable, inexpensive, and actually have use in the garden as well.

THE SPOOLETTE ROCKET

Most of us are familiar with that small thick walled convolute tube used as the timing element in traditional canister shells. Well, I had a lot of fun with those little tubes this holiday season and I'll tell why. During the two fireworks seasons my daughters, nephew and a couple of their friends run one of my fireworks stands in Dad's front yard. As in all years past, I have been subjected to all manner of con games to shoot up my product. No matter how hard I try to prevent it, there always seems to be a large pile of "dead soldiers" in the yard. The cons run from "Dad, this new product we really need to try out so we can tell the customers what it does." Then the famous, "Uncle Bubba, we need to see if this product is as good as it was last season."

This year while loading product to take to the stand I was struck with an idea. If I teach them to make a rocket maybe I can occupy their time and keep them out of my profit margin. One-pounders were out of the question so what could I do? I saw a bag of spoolette tubes in the corner and the light bulb went off. I grabbed the hand rammer I used for making spoolettes and rammed in a little clay. Then I rammed in some meal, took a drill bit and hand drilled a nozzle, threw in a little flash on top for a report, stuck it on a stick, shoved in a piece of medium thermolite and lit it up. Damn, it flew! It didn't fly great, but it flew. So I grabbed all the stuff I needed, put it in a box and took it with me to the stand.

Across the street from Dad's house was a nice stand of bamboo (rocket sticks). With various revisions in nozzle size, it didn't take long to get them flying real good. I called the kids around and told them Rocket 101 was in session. I showed them how to do it and turned them loose. It was a fantastically slow process. In turn they each built their rocket and fired it. This is great. I thought it could keep them occupied for hours, maybe days. Then the worst happened.

A friend who builds girandolas showed up. He showed them how to modify nozzle size to get more height, then to add titanium to get a silver tail, and worse yet, how to speed up production. So while I saved some of my product, created some junior rocketmen (women), I'm now about out of spoolette tubes and thermolite. Oh well, it was a blast to watch them. Now here's how we did it:

Materials needed:

1. Dead blow hammer or leather mallet
2. A non-sparking rammer to fit spoolette tubes
3. Masking tape
4. Spoolette tubes
5. Measuring device (kitchen spoon set)
6. Light stick material (we used split bamboo)
7. Drill bit set
8. Funnel (we made outs from cut up soda cans)
9. Scissors
10. Black powder (we used homemade willow meal 75/15/10)
11. Flash (for heading)
12. Fuse (thermolite or something that will fit in the nozzle)
13. Clay (we used bentonite)
14. Ramming table (a concrete block with a 2x4 on top)

Procedure:

1. Ram in one increment of clay. All increments for this rocket were 1/2 tsp.

2. Alternate ramming increments of black powder. We rammed four increments.

3. Hand drill nozzle hole through clay to black powder. We used from 3/32 to 1/8. This will need some experimentation.

4. Place a wrap of tape around tube at nozzle end.

5. Insert fuse into nozzle and with a twisting motion, seal tape around fuse.

6. Attach suitable stick and tape with masking tape. Put flash in top of tube and seal with tape.

7. Go shoot it!

I made my group wear safety glasses while ramming, and kept reminding them not to put your head over the rammer.

LGN

SKY ROCKET PERFORMANCE CHARACTERISTICS

by K.L. & B.J. Kosanke

Over the years, we have occasionally had the opportunity to conduct brief studies of fireworks rockets, both sky rockets and bottle rockets. Most recently, an investigation was performed using some Horse Brand sky rockets (Glitterous Lights, Clustering Bees, and Flying Butterflies). This short article is written in the belief that a summary of those results may be of general interest. In our experience, much of what is reported for the Horse Brand sky rockets, applies to other brands of non-whistling sky rockets, and in a general way to smaller (bottle) rockets. However, since not all brands and types of rockets were investigated, there can be no guarantee that the results reported here are universally applicable; there is no guarantee that these exact results even apply to different production lots of Horse Brand rockets.

The approximate characteristics of these rockets are as follows:

Initial Mass, 18 g (0.65 ounce)
Overall Length, 40 cm (16 inches)
Motor Outside Diameter, 1.5 cm (0.62 inch)
Motor Length, 7 cm (2.8 inches)
Propellant Mass, 4 g (0.15 ounce)
Motor Burn Time, 3 seconds approximately
Heading Mass, 3 g (0.11 ounce)

In one series of measurements, thrust profiles were determined for these rocket motors. Figure 1 is a typical graph of propulsive force as a function of time (i.e., a thrust profile). These data were produced using a piezoelectric force transducer to sense the thrust of the rocket motors, and a digital oscilloscope to record the data.

It should be noted that the duration of significant thrust is much less than the total burn time of the motors. Thus, after the initial high thrust phase of the burning (approximately 0.2 second), the rocket is in a coasting mode. Just how little thrust is produced during this coasting phase, can be seen in Figure 1, where the typical range of times until motor burnout is indicated. A relatively short, high thrust phase such as this is common for the non-whistling rockets that we have investigated to date.

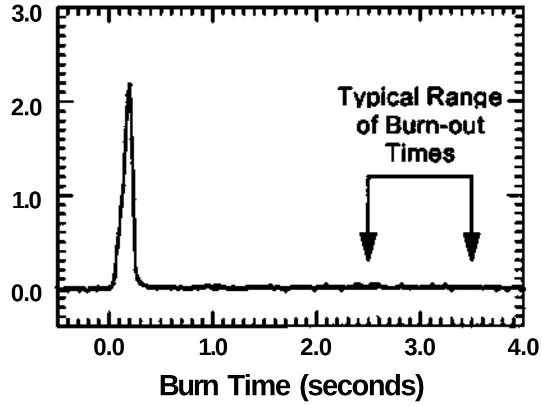


Figure 1. Typical thrust profile of a Horse Brand sky rocket.

Figure 2 is a typical graph of the speed of the sky rockets as a function of distance traveled. This data was collected by monitoring the flight of rockets flown horizontally on a distance calibrated flight range. To accomplish this, two video cameras were used. The first camera viewed the flight of the rockets from their approximate point of origin, to confirm that their flight path did not deviate significantly from their initial alignment down the flight range. The second camera viewed the rocket from a point 200 feet from, and perpendicular to, the flight range. This camera recorded the progress of the rocket along the flight range each 1/60th second, and allowed the calculation the rocket's speed along its path.

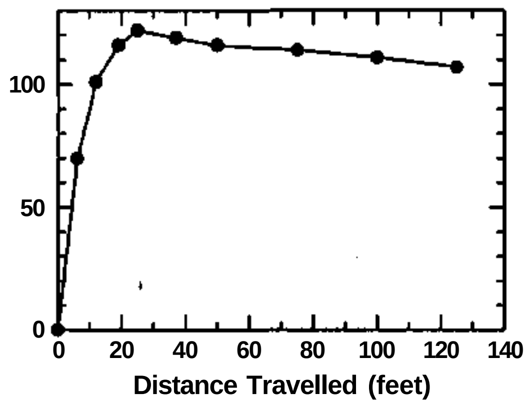


Figure 2. Typical graph of the speed of a Horse Brand sky rocket as a function of distance traveled.

In Figure 2, note the obvious ramification of the short thrust phase, specifically that the rocket's maximum speed is reached very early in its flight. In the data shown, the rocket's speed has peaked after only traveling approximately 25 feet down range. Thereafter, the rocket is mostly coasting, and its speed decreases.

As a result of data such as that illustrated in Figures 1 and 2, some safety related conclusions can be drawn as a result of data such as that illustrated in Figures 1 and 2. In this discussion, unless otherwise stated, it will be assumed that the subject sky rocket is reasonably well designed, is fired according to instructions, and does not suffer a significant malfunction.

That high velocities are reached very early in its flight has positive ramifications regarding stable and safely-oriented flight. This is because it is during the initial, low speed portion of a rocket's flight that it is least stable and most susceptible to becoming reoriented from its intended direction. For that reason, external guidance such as a "wooden trough or iron pipe at a 75° angle" is required. Thus, if the rocket quickly reaches at least a modest speed, the distance through which such guidance is necessary is reduced, and safety is enhanced.

That essentially all of the rocket's propulsive energy is expended during the first 0.2 second has another positive safety ramification. For example, were the rocket to become seriously reoriented any time after the first 0.2 seconds (~30 feet) of its flight, there is insufficient means for the rocket to propel itself away from its current path. That is to say, the rocket will tend to continue with the velocity (speed and direction) it assumes during the reorienting event. Specifically, the rocket will not be capable of dangerously accelerating in an unsafe direction. One type of event with the potential for reorientation could be a collision with a massive object. For example, consider a hypothetical case of a rocket colliding with a wall or tree trunk, causing it to be completely stopped but now aimed in the direction of the person that fired it. If this collision occurs after the rocket has traveled approximately 30 feet, the rocket must fall essentially vertically to the ground because no propulsive energy remains. It definitely does not have the ability to return and injure the person that ignited it.

On the other hand, that the rocket quickly reaches a particularly high speed, and thereafter merely coasts to reach its peak altitude, can have negative safety ramifications as well. One such example would be in the case of misuse, where a rocket is launched in the direction of people. In that case, were it to impact a person, the rocket could potentially be traveling with dangerously high energy. In Figure 2, the speed peaked at over 120 miles per hour. (In another test, a speed in excess of 150 miles per hour was recorded) Given the likely mass of the rocket at that point in its flight (15 g), this amount of energy upon impact is roughly equivalent to that of a two pound weight falling from a distance of 11 feet. This is approximately the energy of a hammer falling off the top of a tall step ladder onto one's toe. [Most unfortunately, there was a recent fatality of a child resulting from such a rocket impact to the temple of her head.] If the rocket motors were redesigned slightly, such that the initial velocity was a little less, but the duration of thrust was longer, it could make such accidents less severe.

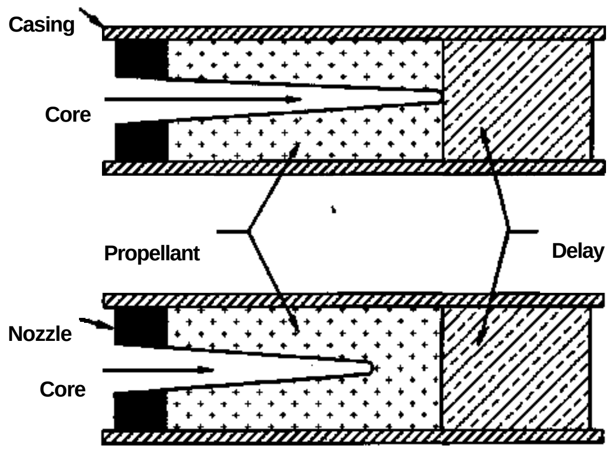


Figure 3. Rocket motors with varying core length.

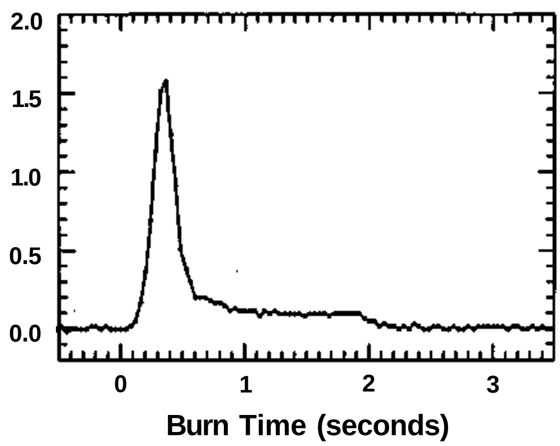


Figure 4. Typical thrust profile of a Sky Bloom rocket.

One way in which peak rocket speed could be reduced , without significantly altering the height it reaches, is shown in Figure 3. This can be accomplished by simply using a motor core that is less deep. Figure 3 illustrates this, and is apparently the method used in the older "Sky Bloom" rockets from West Lake Brand. Figure 4 is the thrust profile of a typical Sky Bloom rocket.

Obviously this brief article has not exhausted the subject of sky rocket performance and safety. However, hopefully, it has presented useful information. KL&BJK

ROCKET NOZZLES

This is the first time I have heard of *kyanite* (excuse my ignorance). I am sure if I asked my wife she would give me a small dissertation and perhaps a pound or two from her ceramics studio or at least an address where I could buy it. I assume it is a type of clay which someone has had great success with in making rocket nozzles, along with kitty litter, fireclay, bentonite, Durhams Rockhard Putty, and for the space age guys, graphite. Needless to say, this is a vast topic and although discussed before by many knowledgeable people, is always interesting.

As always I believe one should try and control variables when making pyro devices with any intent of repeatability and reliability. Even in the best hands, rockets will go boom before getting into the air. The variables are many but we are talking about nozzles.

What are the characteristics of a good nozzle? It needs to stay in the rocket tube rather than separate from the walls of the tube and blow out. The hole must be of the right size (typically 1/3 the i.d. of the tube) and resist erosion to becoming bigger as the hot gasses from the fuel pass through it. They are designed so as to funnel the gasses through the hole in an efficient manner and allow them to escape efficiently as well. And there you have it, the "perfect" rocket nozzle. Does it really take a rocket scientist? If you stick with a Black Powder type of fuel, paper tube bodies 3/4" i.d. (1 lb.) and clay for a *nozzle*, you have three variables potentially under control and are bound for success.

I use fireclay with approximately 10-15% grog added (I have never measured) for my nozzles in all my rockets up to 6 lbs. They are all hand rammed, a variable which I need to get under control. The best ones are still Black Powder types with a little variation from a 6:3:1 ratio. The tubes are strong, convoluted rolled, thick-walled paper. I have access to many different types of clay as I hinted above but why bother changing something that works?. By the way, to add to the confusion, grog comes in different mesh sizes, as does clay. And yes, it does scour the brass spindle. I use medium grit and just barely mist the clay-grog mix with water before hammering. It takes about three increments at once to compress down to a good nozzle with hammering such that the tube just bulges, which helps to hold that nozzle in place. JJV

GROUND TESTING OF ROCKET MOTORS

Using a 2" x 2" wood apparatus (shown in diagram) to test rocket motors without flight provides a lot of useful information.

Taping the motor snugly against the stop block with the nozzle down, ignition is via any convenient method.

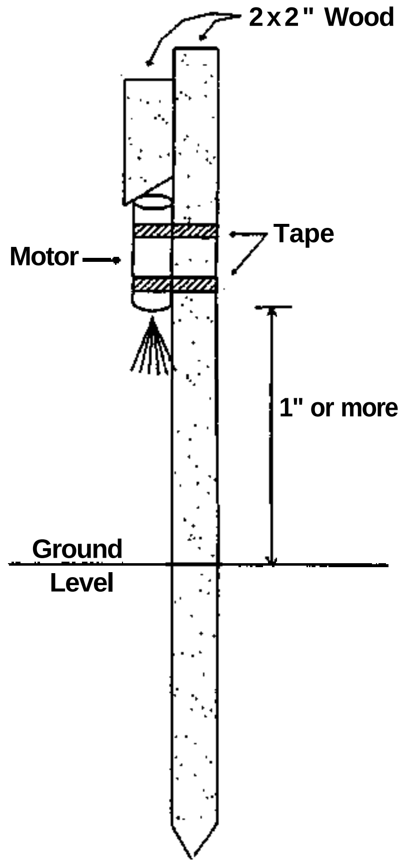
Electrical ignition allows the entire setup to be covered by a 50 gallon plastic drum to contain explosion "products" and/or reduce noise.

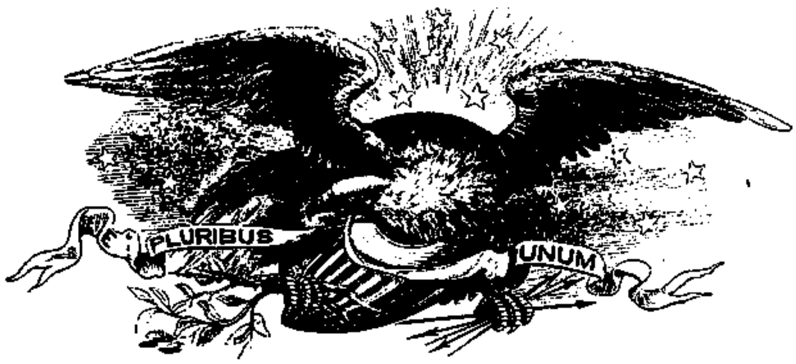
After testing, motors can be checked for nozzle erosion and case condition.

If no drum is covering the motor, the thrust and delay times can be accurately measured.

New Batches of black powder rocket fuel can be quickly charcoal adjusted for maximum power without explosion. This can be done even in windy weather, and rocket sticks aren't blown into toothpicks as often.

Whistle rockets can be ground tested, but won't make the ripping sound unless the motor is permitted to move away from the listener. This demonstrates the doppler effect. If the rocket were fired at the listener, the pitch of the whistle should increase, probably above the range of human hearing. Once the rocket passed the listener, the normal "ripping" should start. FJ





BOTTLE ROCKET LAUNCHER

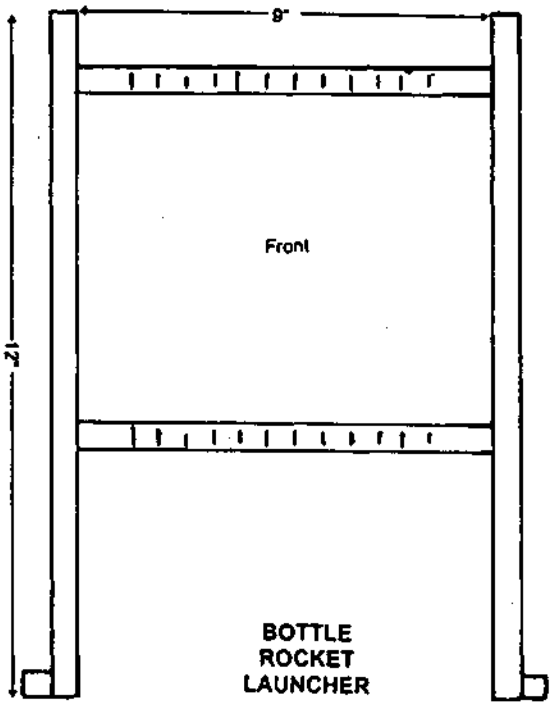
This launcher will send four dozen rockets off at the same time. It's well worth the effort.

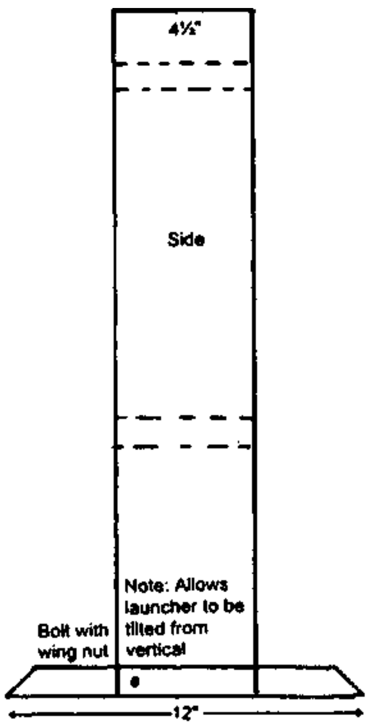
Other than building the launcher you need a launch pad. I take a lightweight cardboard or still paper, cut to the size of the launcher. Holes are punched to correspond to the holes in the launcher. The holes can be slightly larger than the holes in the launcher.

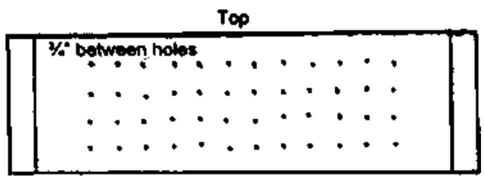
Then I mix up some homemade primer, adding water until it becomes the consistency of paste. I paint it on the launch pad and add a fuse to one corner.

The bottle rockets are loaded through the launch pad and the two holes in the launcher, making sure that the fuses are touching the impregnated launch pad.

This method will work with the old paper fuses as well as the newer hard fuse. JRE







Hole diameter 1/4"

POLY-LUBE COATING

During my seminar on 5" crossette shell construction at the Summer Fireworks Festival, I discussed a treatment for aluminum tooling which greatly extends the service life of the tooling and improves their ease of use.

This treatment is essentially an anodizing process which incorporates as the final step the infusion and sealing of Teflon into the porous anodized surface of the aluminum. This creates a surface which combines a surface hardness of Rockwell "C" 62, and the low-friction characteristics of Teflon. As a point of reference, twist drills, milling cutters, and reamers possess a surface hardness in the range of Rockwell "C" 63 to 65.

The process is ideal for tooling such as comet pumps (barrel, plunger, and crossette shot-hole tips), rocket and gerb spindles, etc. However, the coating will not prevent scoring or lock-up of the tooling if titanium-containing compositions are used. I have also found that it will not tolerate impact very well. For instance: the end of a rammer will eventually mushroom and cause the coating to fracture. The surface treatment will add .001" to .002" to each surface of the tooling, therefore be sure there is enough clearance built into your tooling before you send it for coating. Example: a total of .008" additional clearance between the barrel and plunger of crossette tooling would be required.

Costs: Small parts can be done on a batch basis for about $65 - no matter whether you have one part or a dozen (maybe more), coated. Large parts - a four-inch comet pump for instance - will probably cost about $18 for each piece. If you are in a pyro club, you may want to combine orders to economize. Masking of any area on the part to prevent coating should be avoided as this will add cost.

For more information and ordering of the "Poly-Lube" process for aluminum contact:

Poly-Metal Finishing, Inc.
1 Allen St., Bldg.218
Springfield, MA 01108
Ph. 1-800-628-8356 or (413) 781-4535
Fax (413) 781-7160

PM

PRODUCT WARNING - NITROCELLULOSE PRODUCTS

The manufacturer of the Pyropak™ line, tells us about a drying technique for one of their items that has a hazard potential. They say:

"There was a recent personal injury accident involving Sparkle String. The technician was attempting to dry the material, which had been shipped wet, by using a hair dryer. This is not a good idea.

"An even worse idea is to use the hair dryer up close to the material. Flash and Sparkle string are made by partially nitrating cotton string, and should be shipped and stored wet with 20% or more of water by weight. This presents the problem of having to dry the string prior to use, which should be done using flowing, *NOT MORE THAN WARM,* air.

"In a secure spark- and other ignition source-free area, flowing air will dry the material safely. Increasing the air flow is more important than, and safer than, raising the temperature of the air.

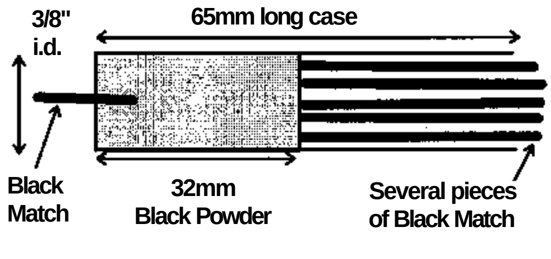
"The material is extremely flammable, and is sensitive to heat and sunlight, both of which will cause it to deteriorate badly. Any location too warm for continuous comfortable body presence is TOO HOT for Flash String or Sparkle String.

"These precautions apply to Flash Paper, Flash String, Sparkle String and any other nitrocellulose form."

EASY MADE SHELL TIME FUSE

Here in the Channel Islands, regulations state that any importation of ignitor cord, NoMatch, electric matches or any fireworks is illegal unless you have the appropriate license, as they are all classified as explosive. What can we do? Unable to obtain of any time fusing, we have had to build our own. Although simple, they are very reliable and strong.

The fuse is made by rolling card stock bonded with wheat paste around a 3/8" former so that there are four complete wraps. Once dried overnight, they can be filled up with a prepared mixture of Black Powder (we use the CIA method) + 5% dextrin, and dampened with water and alcohol (50/50). The powder will need to be tapped down firmly using a mallet and 3/8" rod. Once the powder measures 32mm, we continue with the next stage of inserting a short piece of black match into the front end of tube. This is done by simply drilling a hole 5mm deep into the powder and inserting it. We let the powder dry for about five days, then to finish it off, we insert several pieces of blackmatch into the open end of tube, leaving some protruding. This will produce a very hot flame front for the bursting charge.

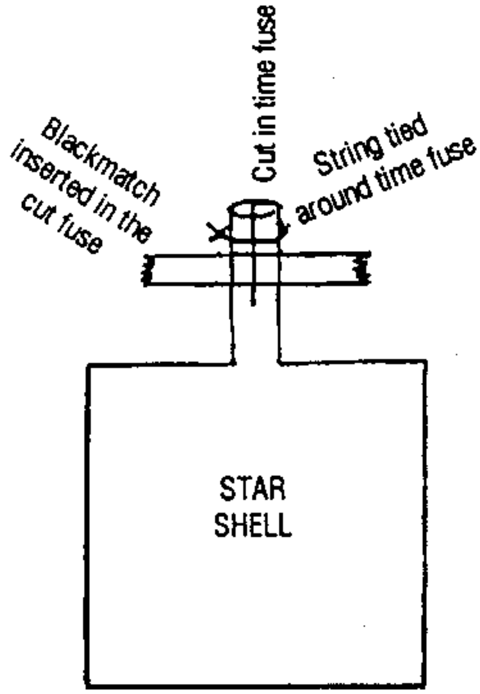


This delay will take 3 to 3 1/2 seconds from ignition of lifting charge to ignition of bursting charge. This fuse has never burned through sideways or been damaged by the pressures of the lifting charge.

Other items we produce are 3" magnesium/chlorate aerial maroons, superb mines, 4 lb. rocket motors, plus all the usual. PT

CROSSMATCHING SHELLS THE EASY WAY

Over the past several years I found that it was a lot easier to crossmatch shells by splitting the 1/4" time fuse down the middle and then insert the crossmatch in the middle of the time fuse. Then I would tie the top of the time fuse to secure the cross match in place.



I found that using this method had several advantages, including more accurate timing as to the burn time from the ignition of the shell to the time it would break in the air. This is also a lot easier to do than punching a hole in the time fuse and then trying to insert the blackmatch.

After showing several of my fellow shellmakers this method and the tool I made to cut straight down the center of the time fuse, they prodded me to make this item for sale, and you can find the ad in the trading post.

JFM

MAKE YOUR OWN MORTARS

Here's something I learned at the Western Winter Blast. The first key is to use "gas distribution pipe". This is used to distribute natural gas. The samples I saw were bright yellow and very thick walled. They told me it came in a number of different diameters and wall thicknesses. The sample they gave me has walls that are nearly 3/8" thick (on a 3" mortar) and was considered to be the "medium" thickness grade. The pipe is made of one of the polyolefins (I got conflicting reports if it was polyethylene or polypropylene), and behaves much like HDPE pipe under stress. One nice thing - they bought it from a local source for about a buck a foot.

The stuff is very strong, and resists fracturing under stress. They gave me the remains of a tube that had been subjected to a test salute, and while it was clearly bulged out (the diameter of the bulge must have been 6"), it was still intact. There were weak spots showing where the pipe would undergo the sort of longitudinal ripping characteristic of HDPE mortars - but it was still intact! I tested the intact gun against a 3" five-break shell, and it survived the hefty lift charge I used with no problem. (I can't say that about one of the commercial mortars I used in late January to lift a somewhat heavy 3" three-break.) Strong stuff!

The second (and most attractive) key is in how one plugs the bottom. Many of the readers will know the frustration of trying to fit wooden plugs to HDPE mortars. Sometimes the plug is just a hair too big, sometimes it is *too small, sometimes the pipe is oval, etc.* And then there is the question of nails/screws/bolts. But that's not a problem with this technique - one simply uses a hot air gun and heat seals it!

First it is necessary to build a jig. This simply consists of 4 uprights made of wood, with a 3+" hole in each one. The holes are big enough to allow the pipe to pass through without binding. These four pieces of wood are affixed to a base, such that the holes line up (sort of like the holes in the axeheads in the Oddessy). The spacing isn't critical, but my sample was about 24" long. This means that there is a space of about 8" between each vertical support.

Next, one has to cut a length of pipe that's about 2 times the length of a single mortar. This piece of pipe is passed through the holes in the standards, and the center of the pipe is placed between the middle two standards. This is the place where the heat sealing will be done.

Once this is all ready, the center of the pipe is heated with a heat gun. One needs to use the type sold for paint stripping, etc. I'm pretty sure a hair dryer won't work, and I suspect a torch will tend to burn the plastic. They did say that if the plastic is overheated, it "oxidizes" and won't seal to itself. The heat gun is allowed to stand on its own, and the two halves of the pipe are turned so that their rotational speeds correspond to each other. After a while the pipe begins to soften, and it develops a bulge or a belly. This simultaneous rotation is continued until the plastic becomes quite fluid. This is the only tricky part, since the plastic has to be at the right temperature. If it is too cold, it won't seal to itself, and if it is too hot, it oxidizes and won't stick to itself. The gas companies weld this material at 500°F. Anyway, practice will make perfect. They got good tubes without a lot of waste, so the temperature control can't be that persnickety.

Once the pipe achieves the right temperature, the pipes are separated and sealed. This *is done by simply twisting the two halves in* opposite directions. This causes the belly to become an hourglass, and then to twist itself shut. I was told it behaves just like taffy at that point. It is turned a few more times, and then the two halves are separated. The bottom is shaped by placing the pipe vertically on the floor with the molten twisted end downwards, and dropping a square ended object into the pipe. This pushes the molten plastic flat against the floor, and helps square off the end. A few taps, and the internal former is removed and the plastic is cooled. *Voilá*! A mortar. TIP

SMALL AERIAL INSERTS

Here are two techniques that can result in very effective aerial inserts for shells, which can be made quickly and economically, without resorting to more exacting traditional techniques. The first method was used by the late Barry Rothman in his NOVA PYROTECHNICS INC. shells, and the second was borrowed from a Brazlian *Thunderstorm.*

1. *NOVA* TYPE SHELL

A lightweight paper casing about 1/2" o.d. by 2" long is rolled in about six layers of heavy-duty aluminum foil, leaving about 1 1/2" of the foil projecting at each end. One end is twisted closed, then stars and a bursting charge, or flash comp is introduced. A piece of black match is put in with the contents and then the foil is twisted tightly around the black match, with a small piece left exposed.

A clove-hitch on the foil, closest to the casing will further ensure restriction of the burning gases. The ignition end is not tied off.

This tightly-wrapped match produces a delay because the foil constricts the advance of the burning gases, unlike piped match, wherein ignition is almost instantaneous. For estimating timing, one can figure about 1 1/2 seconds per inch, but the delay will vary with the quality and burning speed of the match itself and, of course, really close accurate timing is not possible with this technique.

2. BRAZILIAN-TYPE THUNDERSTRINGS

The Brazilians make an interesting report shell which produces a rolling series of reports and is most appropriately named *thunderstorm.* The actual components for insertion in the shell will be referred to here as *thunderstrings.*

The construction of these devices is more easily illustrated than described, but the technique should be clear from my drawings and text. Here's how I would make one:

I begin by dry rolling heavy Kraft paper into a tube about 3/4" diameter and 8 to 12-inches long. Six or eight turns of wrapping should be enough, depending on the paper strength. One end is tied off and a quantity of flash comp is put in, along with a short length of black match. The other end of this section is then tied around the piece of match, which leaves part of it in the filled section and part extending onto the next section to be filled.

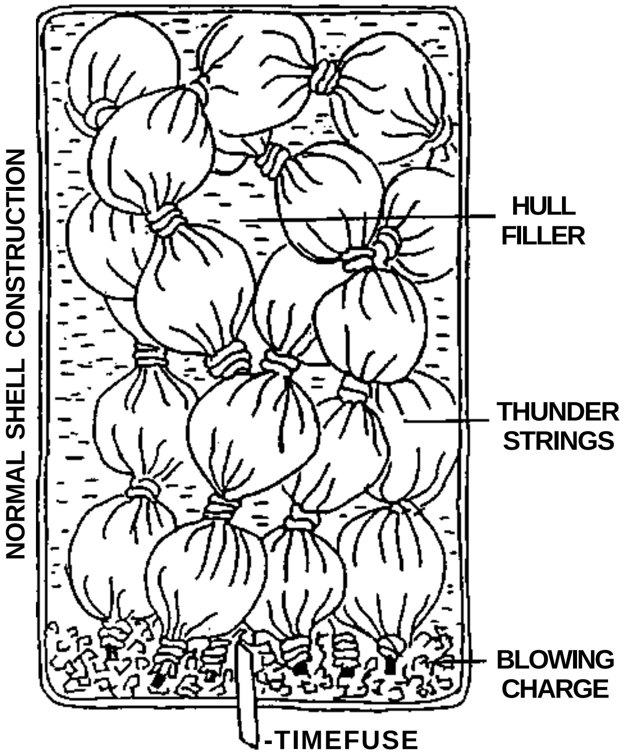
Four to eight sections are created in like manner, each filled with an appropriate charge and each lined to the adjacent sections by lengths of match for communicating the fire from one to the next.

The longer the wrapped junctures between each two sections, the longer will be the delay between reports.

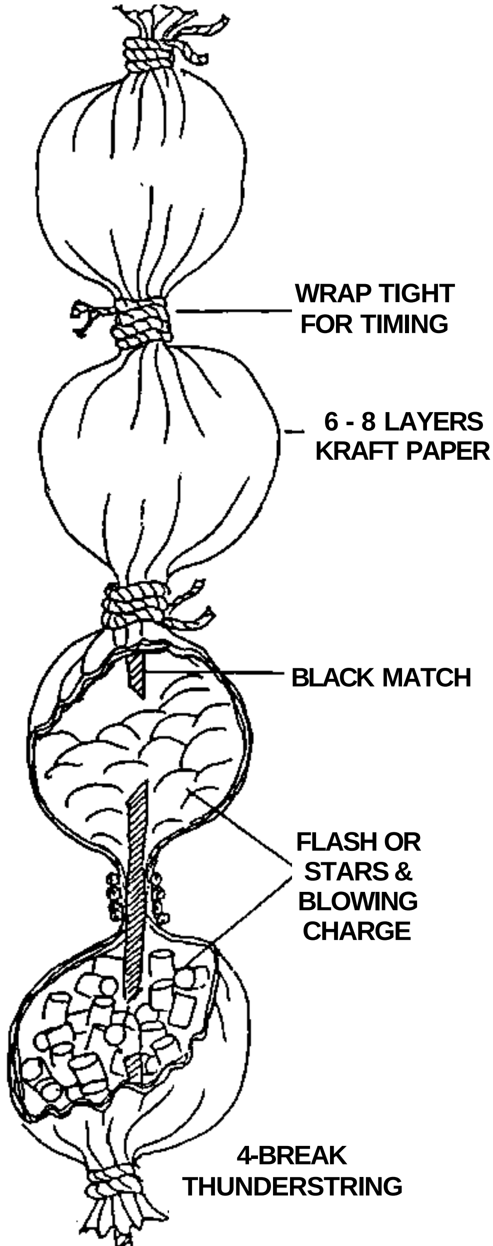
When enough of these strings have been made, I loaded them into the main shell, for which normal lightweight construction, without stringing, is adequate. It's important that the ignition end of the strings (with the protruding black match) is at the fuse end of the large shell, as shown. The empty spaces around the strings is filled almost to the top with sawdust or bran hulls, while the shell is shaken to consolidate the filler. It is then topped off with an adequate blowing charge, making sure the charge is in contact with the ignition end of all strings. The shell is completed in the normal manner.

The technique is also very effective using small stars and a Black Powder blowing charge for a *shell of shells* effect.

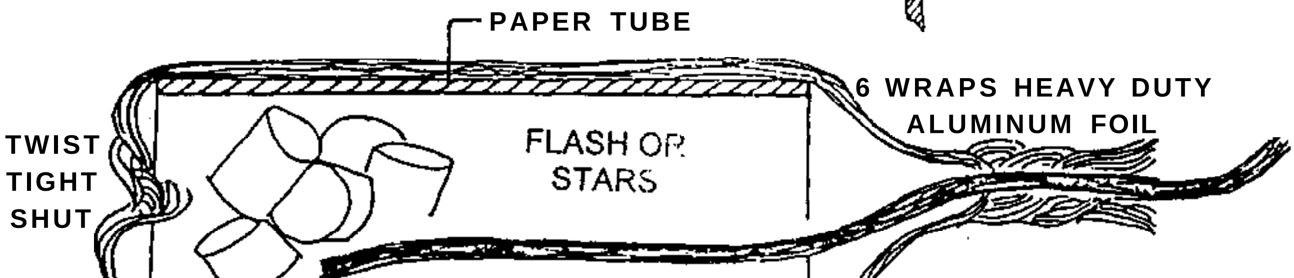
[1998 addendum]
The building of this device can be more efficiently accomplished, and they can be made significantly longer if the pyrotechnician inserts a single long piece of black match the full length of the paper tube. Then previously prepared packets (sachets) of plastic film-wrapped flash or garniture are dropped in and then the device is tied off between sachets as explained above, starting at the middle and working toward both ends. Timing between shots can be controlled by the number of hitches. Note that overloaded flash shots have a tendency to detonate simultaneously. Ignition can be at one end or both ends. GBG



'NOTE TEMPESTUOSO' SHELL



4-BREAK THUNDERSTRING



"NOVA" TYPE SHELL INSERT

THE HOW-DO-YOU-DO-THAT MULTI-BREAK SHELL

Some months ago we tried a few experiments with some commercial shells and came up with the following novel idea of easily producing a multi-break shell with high quality breaks which are symmetrical. We have tested them in many pyro shows with very good results and quite a few "how did you do that?" remarks.

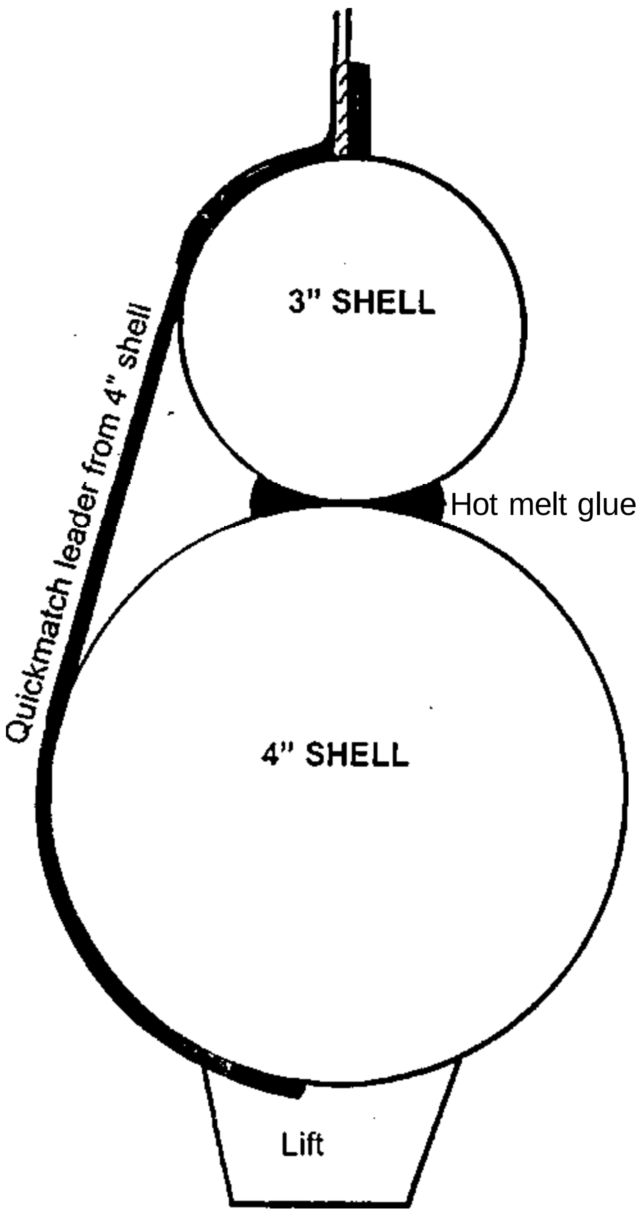
We call this design a piggy-back because the main shell will piggy-back the other shell into the sky with itself. The best effects we have had is by pairing together a 3" and a 2", and a 4" and 3", and also a 5" and a 4".

The work required is minimal but first the sizes must be decided. Here is a 4-3" example. First the loop at the top of the 4" shells is cut, then the top is gently roughed up with sandpaper so as to aid the adhesion of the glue that will bond both shells together.

The same procedure is done with the 3" shell, then the quickmatch and lift charge are removed. (The top half of the 3" shell which was roughened up will become the bottom of the shell, leaving the 3" shell time fuse at the top of the shell.)

Using great care, a liberal amount of hot melt glue is applied to the top of the 4" shell. Other glues may be used but they take more time to dry. Now the 3" shell (roughened side) is placed on top of the 4" and held in place for a minute or two until the hot melt starts to set.

Some people have said that at this stage the piggy-back shell is complete and ready to use, but I don't like the open time fuse on the 3" shell. It could get damp or worse, being a risk of accidental ignition. So all we do is to bring up the quickmatch from the 4" shell, cut a notch in the appropriate place and tape it to the time fuse. The benefits are that you have a much safer piggy-back shell to handle, and ignition is assured because the cross-matched time fuse is in contact with the quickmatch. PT



ANOTHER METHOD OF MAKING ROUND SHELL PAPER CASINGS

Recently I discovered a method of making paper casings for round shells. The method is similar to the article in AFN #153 (June '94, page 4), but in the reverse fashion. No hard feelings with the author; I have used that method and it works quite well, but I think my discovery saves time and paper. Also, I get blisters easily, and maybe you do too, because of the massive amount of rubbing out air bubbles and wrinkles.

First, it is necessary to cast a mold. I use cement. I found that using *Quickrete* in the yellow & black bag works fine. The stuff is inexpensive ($3 - $5/80 lb. bag) and goes a long way. It also has stones in the mix for extra reinforcement.

When making up the mix, care must be taken to not make it too stiff, yet also not add too much water. I begin by taking a round plastic container (a good example is the plastic tubs that holds 5 lbs. of potassium nitrate and has a mouth opening of about 5.75"). Then I pour the cement into the container until it's about 3/4 full. Needed next are two hemispheres, and perfect for this is a plastic ball set, which can be easily obtained from most of the supplies vendors. For this article, I will make 3 3/4" casings (same as the plastic sets), used for a 4" mortar.

The procedure I use: I take the plastic sphere (fuse side) and dip it into the cement until the cement reaches the top of the sphere. Of course, I have taped over the fuse opening on the outside before dipping. The sphere will float to the top of the cement, so some way to hold it down is required. One way would be to place some pieces of flat wood on top, held down by some kind of weight, per Fig. 1a.

The cement is left alone to cure into concrete, leaving a round block of concrete with a concavity in the center. Next I'll make the plug, or male half of the assembly. I use the other piece of the plastic shell set, fill it with cement until flush with the lip, then let it dry. When removed, it will be the upper plug to match the lower mold. See Fig. 1b.

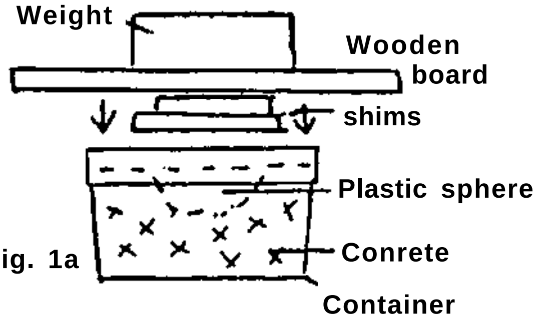


Fig. 1a

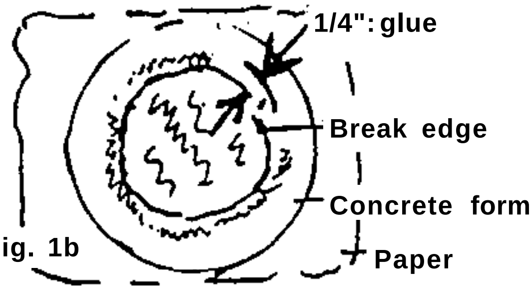


Fig. 1b

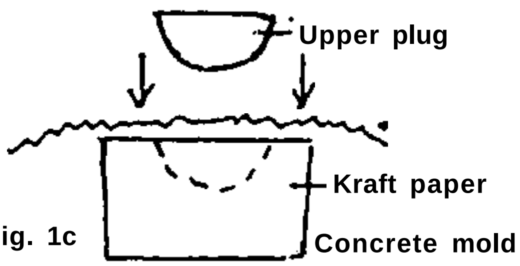


Fig. 1c

Hint: Applying wax to the sphere halves before placing them in the cement will make them easier to remove from the cured concrete. Automobile wax works fine.

Six pieces of 8 x 8" (for a 4" shell) Kraft paper will work fine with little waste. These will give a ball half that is about .060 - .080" in thickness and which is very strong when dry.

One piece of pre-cut Kraft is placed over the bottom mold. Next the top plug is carefully pressed down over the Kraft until it is fully seated. Then it is removed and the bubble and wrinkles are rubbed out, using the cue ball. Care must be taken not to chip the edge of the mold.

The next five steps are simple but critical. Using white glue (which I water down slightly to make it more brushable), I smear the Kraft that's in the mold, including at least 1/4" past the edge. See Fig. lc.

The next piece of paper is added, using the same procedure. The wrinkles and bubbles must be ironed out with the cue ball for each piece of paper that is added. I use six sheets, five increments of glue per half sphere.

After all six sheets have been placed in the mold, one of the original plastic halves is placed inside the paper casing (that's still in the mold), carefully leveled, then a line is traced with a fine marker or pen so that about .125" is left past the break edge. The "mushroomed" edge may look strange at first, but this will serve as the edge to be sealed after the stars and burst have been introduced. Then scissors are used to cut around the line and remove the shell half. The halves are glued together with white or wood glue.

JCB

EASILY MADE 3" PAPER BALL SHELL MOLDS

The book *Round Stars & Shells* suggests using metal or plastic forms for 4" ball molds, or a set of commercial 4" strawboard hemispheres to make shell molds. I have tried this for the 4" and 5" shells, using 3-3/8" and 4-3/8" casings. These really do work but in cutting, the edges get frayed and you cut the edges of the mold. I'm not complaining, but I found something that may work a little better on the 3" shells.

I have used 2 1/2" wooden balls that I purchased at a local craft store. When using these it's not really easy to find the center so what I do is find where the lathe cut-off holes are, then wrap a strip of thin cardboard around the ball, lining up the lathe holes and overlapping the ends of the cardboard. This should give a straight center line. Then I draw the cutting line and make cross marks to use to align the two halves for later assembly. I use a band saw for cutting the ball in half. A hacksaw may be more available and a lot safer.

I lay one half piece of the ball on paper and draw around it, then cut out a paper pattern, fold it in half and measure 3/16" from the edge on each side to mark for alignment pins. I use 1/8" wood screws, pre-drill on the marked holes at the alignment mark as a reference point, usually about 1/4" deep. I run the screws into one half of the ball, leaving 1/8" to 3/16" of the screw exposed, then cut off the top and smooth the edge.

On the other half of the ball, I drill holes in the same location as on the other half, slightly elongated to allow for a little wobble. This will help in finding the center line after paper is glued on.

Finally I hollow out the middle of each half about 1-7/8" across and deep enough to hold excess plastic covering*. Then I build shells as per the *Round Stars & Shells* book.

A real benefit in using wood is that when smoothing the pasted paper layers, the operator can press really hard without fear of crushing the molds. Pressing too hard will cause the paper to slide around on the ball.

We're trying 2" shell molds now, using 1 1/2" wood balls, but the saw kerf really makes a difference in the smaller size balls. It makes the molds out-of-round, so I compensate by using a round brass shim about the same thickness as the saw kerf.

Here are a few notes I made that might help when using the method in the book. The way I figured, the paper size on his 3-incher should be 1 1/2x6". The outer wrap was 1x3 1/2".

A good burst for this size is a decent willow polverone 5:1 on rice hulls and 7 grams of potassium benzoate whistle comp. These burst very well. I would suggest keeping them in a magazine, not in the bedroom closet on your wife's side of the bed.

I always wrap the fuse with two strands of cotton string before the final paper wrap.

*If your clothes come back from the dry cleaner in those thin plastic bags, the bags are excellent as free mold wraps. BH

MORE ON MAKING ROUND PAPER SHELL CASINGS

Referring to my method of making round shell casings from paper that was in *Best of AFN III*, I don't use that method now. I have changed to another method, as described in European Pyrotechnics Association Newsletter #2. It uses a lightweight polystyrene ball as a mold, a thin plastic bag for protection, and pasted paper.

The mold was pasted with sufficient layers, and thoroughly dried. Then a straight line was drawn over an imaginary equator, and then a random mark was made on this equator as a realignment mark, to help to get the two halves back together at the same place after the paper layers are cut through using a very sharp knife. I think this aspect of better alignment makes this method more attractive than the earlier one, plus you make use of all the paper.

The materials are cheap and the methods are simple, but sometimes the work does outweigh the advantages. Of course, there are some other options, like using plastic hemispheres, but they have disadvantages too. Advanced workers have designed and tested caseless shells, but they have drawbacks too. I would like to see real biodegradable hemis for sale soon!

Squeezing out air bubbles from pasted paper doesn't give me blisters like cutting many cardboard discs. It's a seasonal sickness!

RW

HINT OF THE MONTH

Try a little aerosol spray Dow Bathroom Cleaner to clean up aluminum powder. A quick shot of spray on the workbench or equipment will lift the aluminum so you can wipe it away. DP

UNCLE TOM'S FLUFFY RICE HULLS

Here is a little tip about meal coated rice hulls. Recently at a club shoot I saw one of those human life dramas that sound like television soap commercials - "Gee, your rice hulls are so light and fluffy. Mine always come out lumpy." . Here is the secret to "Uncle Tom's Fluffy Rice hulls".

The clumping in meal-coated rice hulls is caused by the sticky surface of one rice hull touching and becoming attached to the sticky surface of the next hull. Thus, there are two solutions to this problem: 1) make sure they never touch, or 2) have an outer layer which is non-sticky. The first seems to be difficult, but the latter solution is easy to achieve.

Let us look at the "Uncle Tom's" way of making rice hulls coated with 5:1 meal D. First, the one weight of dry rice hulls is soaked in warm water for 5 to 10 minutes, and then allowed to drain. It is important not to soak them too long, and to allow them to drain well. Then they are placed in a cardboard box, and one weight of meal D with 5% additional dextrin is added. This is shaken around until the meal D coats the hulls. There are probably clumps - in fact, it may look like a hopeless mess. Another weight of meal D with dextrin is added, and the box is shaken again. This is repeated twice more, yielding sticky rice hulls with four weights of meal D. Now comes the trick, and such a simple trick it is: a final weight of meal D WITHOUT dextrin is added. This is shaken around until all the clumps are broken up and the meal D has coated the sticky rice hulls. The outer layer isn't sticky! So simple!

The same procedure can be used if the rice hulls are being coated with pulverone, KP, or H3. Other ratios can be used, such as 4:1. All that is required is that one simply makes sure that the last coating is without dextrin. (Of course, one should never mix H3 with pulverone or Black Powder.)

That's it - that's the secret to Uncle Tom's light and fluffy rice hulls. Try some at your next dinner party! TIP

A COUPLE OF FORMULAS FOR MEAL COATED RICE HULLS

For the common 5:1 meal:hull burst charge I have found the following formulas useful:

FORMULA #1

$$\frac{\text{Meal}}{\text{final} \quad x \quad .83}$$

- Meal - the amount of meal plus 5% dextrin required
- Final - the final amount of meal coated hulls
- .83 - the percent of meal in a 5:1 ratio

To use the formula you need to know two of the three variables. Then if you have the bottom two you multiply them; if you know only one of the bottom two you divide the top by the bottom. Rounding off to the nearest gram is OK.

Examples:

Q. I have a pound of meal powder. How many coated hulls will this make?

A. 1 lb. of meal will make 574.3 grams (about 1% lbs. of hulls).

The math:

1 lb. = 454 grams
Add 5% dextrin so 454 x 1.05 - 476.7
Meal = 476.7

I now have two of the three variables, so I just plug in the numbers:

$$\frac{476.7}{\text{final} \quad x \quad .83}$$

Final=476.7 / .83 = 574.3 grams.

Q. I want to make a kilogram (1,000 g) of rice hulls. How much meal do I need?

A. You will need 788.5 of meal and 41.5 of dextrin.

The math:

Since I already have two of the three variables, I just plug in the numbers:

$$\frac{\text{Meal}}{1000 \quad x \quad .83}$$

Meal = 1,000 x .83 = 830 grams

Remember, this is meal plus 5% dextrin, so take 830 x .95 to find how much actual meal is needed.

Meal = 830 x .95 - 788.5g
Dextrin = 830-788.5 = 41.5 g.

FORMULA #2

$$\frac{\text{Hulls}}{\text{final} \quad x \quad .17}$$

- Hulls - amount of rice hulls needed
- Final - final amount of meal coated hulls
- .17 - percent of hulls in a 5:1 ratio.

To use this formula you need to know only two of the three variables. Then if you have the bottom two you multiply them. If you know only one of the bottom two you divide the top by the bottom. Rounding off to the nearest gram is OK.

Examples:

Q. I have a pound of rice hulls. How many coated hulls will this make?

A. A bunch! 1 lb. of rice hulls will make 2,670.6 grams (about 5 3/4" lbs.) of meal coated hulls.

The math:

1 lb. = 454 grams
Hulls = 454

Since I have two of the three variables I just plug in the numbers:

$$\frac{454}{\text{final} \quad x \quad .17}$$

Final = 454 / .17 - 2,670.6 g.

Q. I want to make a kilogram (l,000g) of coated rice hulls. How many hulls do I need?

A. You will need 170 grams of hulls to make a kilogram of coated hulls.

The math:

Since I already have two of the three variables, I just plug in the numbers:

$$\frac{\text{hulls}}{\text{final} \quad x \quad .17}$$

Hulls = 1,000 x .17 - 170 grams.

BS

[Editorial note: The importance of this article is that rice hull powder is very important in shell construction, and mastering the technique is vital for the serious worker. These simple formulas answer one of the most frequently asked questions about rice hulls powder. Keep this article handy.]

PYROTECHNICS BY MICROSCOPE

As comp is air dried in sunlight, the temperature can reach about 140°C. The percentage of moisture may be small but the amount of oxidizer it holds in solution can be twice or more the weight of the water. How that changes the particle size and distribution of the particles can only be understood and measured with a microscope, which is the only way to see what you have to the distribution of, and size of, microscopic particles. The use of pressed powder in tubes or cylinders to assess burn rate is not as good because the pressing alters what you are measuring before you measure it, so the numbers derived are really rather a silly rough guide at best.

A 10-power hand lens is very handy and beats nothing by a mile, but you will need a very good one or it will be useless. A 40-power machinist's microscope that looks like a simple tube is useful but difficult to get illumination for, and it is not easy to use. At 100 magnifications you begin to assess the condition and size distribution of the materials. Five hundred to 600 is quite useful, especially at first when you are training yourself to see, observe and understand what you are dealing with. A really good microscope can run into the price of a very fine car, but only research and a few other things require that.

Only governments can afford really fantastic microscopes and all the equipment needed to go with them. Scientists need equipment like that, but it would be silly for a hobbyist.

A microscope, if you use it for some pyrotechnic experiment once a day for a year, will make a big difference in your fireworks.

All chemists are optimistic, always looking for new solutions. Buy a microscope. LSO

ROLLING BOWLS

Finding enough appropriate containers for pyrotechnic work seems to be an ongoing problem. If you roll your own round stars, you know how expensive those stainless steel salad bowls can be. Additionally, they have that sharp transition from round to flat at the bottom, which interferes with rolling delicate mixes.

Recently, K-Mart stores in our area began selling Spring picnic supplies — I think other stores will follow suit as soon as all the snow begins to melt. Among K-Mart's offerings is a nice, 10.5 quart plastic salad bowl which fits star-rollers' needs to a tee.

The bowls are made of high-density polyethylene, which means that they're resistant to most solvents. That also makes them slippery - not much will adhere strongly to them. They also have a nice shape for rolling stars.

Each bowl has almost vertical upper sides, which keeps stars in the bowl, even when rolling vigorously. The bottom is almost flat. And the transition from side to bottom is a gently-radiused curve with no sharp changes. There aren't any sharp edges anywhere to break fragile stars. Not all plastics are suitable for rolling.

Plastic can be hard to wet. If solvent tends to bead on the surface, it interferes with the rolling, tending to wet some stars excessively, while starving others. I've found that 50/50 denatured alcohol/water thoroughly and evenly wets these bowls; so does acetone. The bowls are also brightly colored, so you can keep an array of them color-coded to certain tasks. An array of them? That might be expensive. But there's one other attractive thing about these bowls - they're only two dollars apiece! I've rolled a number of batches of stars with them, and recommend them highly. LES

CONVERTED CEMENT MIXERS

No machine is ever perfect for pyrotechnics or explosives. There are always compromises, even with machinery built for explosives. The compromises that I speak of here are those that alter the equipment to make it reliably safe. The alterations go hand in hand with specific operating procedures, i.e. barricading, static guarding, conductive parts in lieu of non-conductive parts, bonding, grounding, eliminating pinch points and friction, operators wearing conductive shoes and cotton clothing, batch limits, etc. The compromises are arrived at by first conducting a haz-ops analysis of the equipment design and intended use, and documenting the identified risks and action items to alter the equipment. This is usually a team effort. The basic idea is to eliminate (if possible) sources of ignition or initiation energy, and limit exposure to the operator, then limit the process to preclude such things as propagation, damage to surrounding property, etc.

I know it is possible in some circumstances to alter existing commercial equipment to meet the haz-ops requirements. It is done frequently in military and civilian explosives manufacturing. It can and is being done with commercial cement mixers, and gum ball rolling machines converted for making fireworks stars. I know of one manufacturer who has been in business making only round stars for the past 20 years. He has 10 such cement mixers running day in and day out, side by side. He has never had an accident. I made stars that way for the last eight years I was in the business and estimate I processed 60,000 pounds in that period.

Ideally it may be true that all equipment for pyrotechnic use should be specifically designed and built for that purpose, but it is not practical for the commercial fireworks industry where most operate on limited budgets, virtually no capital, and serve a mature flat market. Competition is fierce. The cost for designing and fabricating from scratch is very high compared with the cement mixer conversion. If done right, and the procedures for operating are strictly followed, a particular model cement mixer is a reliably safe piece of equipment. When our mixer was bought 15 years ago, it cost $600. The cost of the new motor was about $300. The weld sealing and grounding added very little more. To build an alternative machine to do the same from the ground up would have involved engineering costs, machine shop time and work, and fabrication of many parts; the cost would be many thousands.

We always sealed the opening of the drum with a sheet of conductive rubber stretched tight across the opening, and held in place with a flat rubber strap, stretched and wrapped twice around the drum, before starting. This was done for tumble blending compositions, or ball milling single, unmixed chemicals. When used for stars, the stars were grown from a core, and always dampened with water, or water/alcohol mixtures. Dampening kills the dust. The process was always done outdoors in good weather. I never had a problem with dust. The dry charges were removed with the machine stopped, and machine was completely washed down, inside and out, with a hose, after being emptied, motor, drum, and ring gear. Damp stars were removed with the drum rotating and tilted so the stars would fall out the opening into a rubber pail, then spread on drying screens. The mixer was then cleaned with warm water and detergent, then completely hosed down.

As for dust or material getting into the bearings or friction points, that is a problem only with sloppy operations where no cleaning is being strictly adhered to after each use. And then only if powder gets into these greased locations, and the grease has dried out or is not there. The bearings on our mixer were bronze journal bushings with grease fittings. We greased these bushings before each use, mainly because of the hosing down we gave the machine regularly. If dust were a problem, we wouldn't use the machine at all. Responsible operation is required for any machine in any process, but especially so in explosive material processes. If dust is leaking out of a machine, the machine is stopped with the problem remedied. If the mixer is seam-sealed with tig welding when it is new and before it is used, then filled with water for a leak check in all rotation positions of the drum, there will be no powder leaking later, except if the drum cover is improperly fitted. This is determined in the first few minutes of operation of any new charge.

TENV motors are acceptable by the NEC article 500 for Class II, group E, F, & G, division 2 hazardous locations (explosive dust and metal powder). I consider the cement mixer (as I have described, modified, and used for many years) to be a division 2 location. By definition, a division 2 location is one that does not have hazardous concentrations of dust present during normal operations, but may occasionally experience dust during abnormal conditions, cleaning, or maintenance. My successful, accident-free use of this motor and sealed drum, and the same successful operation by many others in commercial fireworks, bears this out to be true.

I strive very hard every day in my job at a large explosives company to rationally identify situations that can cause safety problems and be prevented by human intervention. Accidents that result in death are the result of sloppy operations, poor housekeeping, indifferent apathetic attitudes, and the frequent violation of many safety rules, usually to take short cuts. It can happen with machinery, but in commercial fireworks, there is very little machinery in use. Most machinery is in the form of small air operated tools, or presses. The exception may be commercial fireworks companies that do star rolling with modified cement mixers. I know of five such companies that actually use cement mixers, and there are probably several more.

I have heard of no serious accidents from the use of cement mixers to make damp stars, or ball mill hard lumpy oxidizers that are unmixed with any other chemicals.

Cement mixers are most likely out of the cost range of amateur hobbyist fireworks experimenters. However, we frequently hear of mishaps when inexperienced amateurs do things such as: vacuum oven (bake) mixed powders, ball mill with glass marbles, ball mill flash, boil Black Powder over the kitchen stove in a sauce pan, dry stars on trays in their living room, grind mixtures in blenders, mix sulfur with chlorates, etc. When the local press gets wind of these accidents, that's what gives fireworks a black eye. When inexperienced display shooters set up a display that ends with finale shells firing into the spectators, that's what grabs the media and gives fireworks a bad name. When spectators bring their own bootlegged supply of rockets and other C items to the display, fire them in the crowd causing injuries, the commercial companies get the blame and their insurance takes a hit. When 12 year olds are buying and shooting bootleg M-80's on the streets, that is what gives the public the black image and results in stricter legislation.

Cement mixers have not been the problem, and it is unfair to characterize those who modify them properly and operate them responsibly, with such black hat suggestions that they will have an accident and bring the public or legislators down on fireworks.

WO

HINTS & TIPS

Potassium biphthalate does not decompose, but its lab use demands that it be very pure. To guarantee purity, a chemist will often times opt to open a new bottle rather than trust one that is half-empty. The halves are discarded. This chemical is used as a whistle comp. (*Chemistry of Pyrotechnics*, pg 178.)

So, on your next visit to the neighborhood chemical research lab, stop by and get some free chemicals (bring donuts). I've always wondered how my friend the chemist keeps finding the diverse assortment of chemicals used in his formulas.

I have been told that methylene chloride is used as a stripper for furniture refinishing.

Decent bases for #0 and smaller mortars can be quickly made by filling French-fry trays with about 1" of plaster. The tubes might need to be waterproofed before pushing them into the wet plaster.

CHEMICAL RISKS

When handling chemicals (or anything at all), one must always be aware of the potential risks and then take actions designed to reduce the risk to an acceptable level. This is a personal choice, based on one's own risk-tolerance and the perceived and actual costs of the risk management. To give an example, consider speeding tickets - some people feel it is too costly (time, boredom factor) to drive slowly and are willing to accept a higher risk of getting a ticket, while other people are either willing to invest the extra time or to invest the money to purchase a radar detector. The purpose of this month's column is to help the reader understand a little more about the risk factors in handling certain pyro chemicals, and to help them find their own information. Then the reader can make their own decisions about their risk tolerance, and how much they are willing to invest to manage those risks.

First of all, there are several good sources of information about the risks associated with chemicals; the MSDS which should be included with every chemical you purchase, "The Merck Index", Sax' reference entitled "Dangerous Properties of Industrial Materials", and the Internet. The MSDS sheets are generally good sources of information, but they must be read with the understanding that behind every MSDS there is a lawyer playing "CYA". How else can one explain that the MSDS for Lactose (also known as milk sugar) states that ingestion requires immediate medical attention and that skin contact should be followed by 15 minutes of washing with soap and water? However, the lawyers haven't completely ruined the MSDS sheets. The MSDS rates each chemical for various hazards on a scale of 0 (no hazard) to 4 (severe hazard), and then gives some specific details about the types of hazards. Thus we can find that lactose is not carcinogenic, is not listed by OSHA, has no known effects for overexposure, has no target organs, etc. This seems like a pretty benign chemical!

Compare that with ammonium or potassium dichromate: It is listed as a carcinogen with very low permissible exposure limits (0.5 mg/cubic-meter in air). The MSDS goes on to state that skin contact may cause ulcers, discoloration and eczema, and prolonged exposure to dust may cause perforated septum and ulcerate the mucous membranes. Ingestion may cause nausea, vomiting, headaches and dizziness along with gastrointestinal irritation. It concludes that skin absorption may be harmful or fatal. Pretty awful stuff, eh?

Well, seeing this got me worried - as a kid I used to play with a lot of ammonium dichromate, making volcanoes and growing crystals. Many times I went to bed with orange or brown fingers. I was worried if this meant that I was going to get cancer. So, I did a bit of research. First place I looked was in "The Merck Index". This is an EXCELLENT reference book and is a steal at only $45. The entries of the Merck Index did mention the acute effects, but failed to mention the carcinogenicity. Moreover, it listed a host of common uses for each chemical ranging from tanning leather to printing to bleaching palm oil. My first thought on reading that was, it might not be so horrendously dangerous - after all, with such widespread usage it can't cause cancer "first time every time" or they would have stopped using it.

So my next place to look was in Sax' reference work "The Dangerous Properties of Industrial Materials". Once again I received conflicting signals. The individual entries for ammonium and potassium bichromate (an older term for dichromate) stressed the acute toxicity, but didn't mention anything about cancer. The general entry for "chromium compounds" stated that they are "recognized carcinogens of the lungs, nasal cavity and paranasal sinus". This entry was much less strenuous than those for compounds that I have worked with in the lab which are considered "dangerous but useable without heroic protective measures".

Thus, I turned to the Internet to see if I could find more details. I performed several searches using search engines such as www.excite.com and www.altavista.digital.com, using combinations of keywords including "chromium", "dichromate", "cancer", "carcinoma", "epidemeology", etc.

When one uses the web one has to learn how to be a good critic since anyone can "publish" anything on the web. I found literally hundreds of documents ranging from the scientifically rigorous to the eccentrically amusing (cancer therapy by the use of chromium plated electrodes to directly introduce 'electro-orgone energy' into the body to reharmonize the natural blah-blah-blah). The documents which survived a culling based on rigor/fluff were not all in total agreement, but I began to see a pattern when all of them were looked at as a whole.

The most dramatic document was one from the Health Resource Group (associated with Ralph Nadar). They are filing a suit in court demanding that we put increased restriction on chromium. This brief estimates that the current Permissible Exposure Level will lead to 22% of the people so exposed dying of lung cancer! YOICKS, 22%! However, all subsequent reports seemed to be much less dramatic. OSHA estimates that an exposure to a chromium level which is 6 times higher will lead to about 8 deaths per 1000 people.

Early epidemiological studies on people who worked in chromium smelting plants in the 40's and 50's found that such people were 13 to 31 times more likely to get lung cancer than the general population. Of course there was a large synergism with smoking. Many cancers seem to operate by the so-called "two assault" mechanism, where one assault creates the opportunity for tumor growth, and the second different assault then initiates the tumor.

In 1975 NIOSH found a correlation between solubility and cancer. The soluble salts are apparently less carcinogenic than the insoluble ones. Thus, dichromate might not be so bad, but the dust from the coating of Mg might be worse. This is supported by a study that found that chromate pigment plant workers with an exposure to 218 - 413 (µg/m^3 had an "elevated risk". A study on 1,879 workers found that people who had worked in the plants for more than 10 years had three times greater incidence of lung cancer than the general population. However, the same study found that people in more modern plants with levels from 12 to 120 (µg/m^3 showed no statistically significant increase.

A study on 1,193 workers in a chromium plating plant who worked for more than 16 years found a 1.18 times increase in lung cancer and a 2.34 times increase in liver cancer. A study of 5,000 people who worked in chromium and chromate plants from 1937 to 1971 found a 1.51 times increase in lung cancer overall, and a 1.94 times increase in those people who had worked in those plants for more than 20 years. They did find a much higher incidence (5.18 times increase) in nasal cancer.

Several studies found a fairly linear effect of total chromium load and cancer for airborne levels from 10 to 500 (µg/M^3. Thus, it may be assumed that a higher level in the air may very well be proportional. Little or no acute toxicity was found for short term exposures to very high levels of chromium, chromate, or soluble chromium salt dusts. However, it probably has some increased cancer risk.

Of course, nothing is ever simple. A study of 62,641 women found that post menopausal women had a slight increase in breast cancer with increased levels of chromium exposure, but that premenopausal women had a DECREASE. They concluded there was no significant risk at the levels examined.

The final conclusion that I reached was that long term exposure to chromium dusts and chromium salts would increase my cancer-risk, but that the risk was acceptably low. Thus, while I will continue to use a respirator and gloves when handling chromium compounds, I am not worried that an accidental short exposure is a serious risk. However, that is a personal choice based on my risk tolerance, and as the ads say "your mileage may vary".

The important thing about this article is not just an assessment of the risks of chromium in the pyrolab. The real point is that it is important that every pyro know how to discover the pertinent information themselves so that they may make their own informed decisions. The Merck Index should be on every pyro's shelf, and everyone should start learning how to use the Internet. While there is a lot of poor information out there, it is possible to winnow through the chaff to discover the hard facts. TIP

PYRO ROULETTE - SAFETY ISSUES

If you've been doing your reading, you will already be learning some of the do's and don'ts of manufacturing, shooting, and storing fireworks. I encourage you to read those sections on safety until they are second nature. In fact, you should DRILL yourself on them. The military uses drill so that soldiers will do the right thing when they are surrounded by smoke, fire, and mind numbing explosions. (Josh, that sounds like fun!) You want to use the same technique to make sure that you automatically flinch when somebody suggests grinding flash powder, drying chlorate stars in the sun, or looking into a hang-fire mortar to see what's wrong.

However, there is one safety issue that I haven't seen clearly enunciated in these books: "Pyro Roulette". This is a term I've coined from numerous postings on the Internet that are replies to safety suggestions. Often times, the more experienced people say "It is dangerous to do XYZ" and some person responds "Well I've done XYZ and it didn't blow up on me, so it can't be as dangerous as you claim". Well, Russian Roulette is much like that... heck, the chances are 5 to 1 in your favor. So, if you gave revolvers to 6 people, the odds are that 5 of them would come back and tell you that it wasn't that bad. Notice the second aspect of this scenario - not only do most people survive, but the dead ones don't come back and tell you about it. Thus, having a group of people who can testify that they have done something and not had an accident is not adequate evidence that a procedure is safe - you have to understand some of the cause and effect, or do a statistically meaningful survey.

To some extent the statistics have been done for us. For example, in the mid-19th century the English Parliament enacted a law prohibiting some practices that were notorious for causing accidents. They then met a decade later to revise those laws based on the types and causes of accidents that had occurred in the intervening time. Thus, the British standards for manufacture are a good place to start, and are discussed in some small detail in Lancaster's book. Also, the American fireworks industry has evolved standards that are incorporated in the National Fire Protection Codes for manufacture and use (NFPA 1124 and 1123). Your local library should either have or be able to borrow copies of these documents for you.

One question that arises is "why are hazardous pyrotechnic practices like Russian Roulette, why aren't they either safe or unsafe?", i.e., why does the same mixture behave differently at different times? For example, when testing the sensitivity of a composition by dropping a heavy weight onto it, the sample might only explode three times out of four for a given height, and some batches will be much more sensitive than other batches. Well, the answer is complex, but I can try to scratch the surface here.

First of all, different batches of the same mixture are seldom "the same". There is the famous example where a certain pharmaceutical firm couldn't get a reaction to work in the morning. They finally determined that the catalyst was being poisoned by the traces of the ammonia glass cleaner used to clean the glass enclosure on the balance before each day's work! Even if two workers use the same chemicals obtained from the same source, there is a chance that slight variations in humidity and temperature and other environmental factors may affect the sensitivity. Then there is also the problem that mixtures of solids are never perfectly uniform. Worker A might screen a mixture more times through a slightly finer screen, and allow it to fall a slightly greater distance, while worker B might use poorer technique. Since the ignitability (accidental or purposeful) of a mixture is a function of the fineness of the components and the degree of mixing, then we would expect worker A's mixture to be more ignitable. And since humidity affects clumping, it makes sense that the efficiency of mixing might vary depending on the weather.

Secondly, amateur fireworkers tend to use technical grade chemicals from suppliers who probably obtained them from the surplus market. These chemicals will have varying amounts and types of contaminants. The effect of a few percents of a contamination can be surprisingly large. MacLain reports that potassium chlorate which has been co-crystallized with less than 2% of copper chlorate undergoes a spontaneous explosion within 30 minutes of mixture with sulfur, while uncontaminated chlorate may be stable for extended periods of time. There are also certain contaminants which can "phlegmatize" a chemical, making it less reactive. This is one reason that a beginner should stay with "tried and true" formulations - it is possible that the exciting new formula that you heard about will only be stable with an unsuspectedly phlegmatized oxidizer, and it might spontaneously explode if a pure or sensitized oxidizer is used. In general the "tried and true" formulations have been time-tested under a wide range of "standard operating practice", and so their hazards are better understood. Of course that doesn't mean they are "safe" - but it does mean that as long as a person follows normal safety guidelines the risks will be "low".

In addition, there are differences in handling. Two people handling the same mixture will treat it differently. Even if these two workers perform the same operation they will work at different speeds, apply different amounts of force, etc. Learning through books loses many details -without force scales it is hard to say how vigorously components can be rubbed, pressed or handled. Heck, this is difficult even when the mentor is right there - Louis Semenza talks about how his father would often shout at him and his brother for pounding on the chlorate stars while loading shells. One man's gentle tamping may be another man's hardpounding.

Finally, there is random chance at the microscopic level. When compositions are tested for friction and shock sensitivity, there are slightly different results for each experiment. One sample might explode when the drop-hammer is released from 35 cm, while the next sample might require a drop of 42 cm. This is partially due to the fact that the samples are composed of lots of little grains, and those grains will lineup differently every time. One can imagine that if two particles just happen to be perfectly aligned that the force will cause a smashing event, while two particles that are not aligned may be able to slide away from each other. Thus, one can imagine a person using a spoon to grind flash powder might get away with it for a while, but eventually a rough spot on the paper will catch a few crystals in just the right alignment, and a rough spot on the spoon will deliver just enough crushing energy, and

FOP!

These are the factors that go into "Pyro Roulette". People using different chemicals, under different conditions, with different methods of handling, can get different results - at least for a while. But examples of successful handling of a composition don't contradict statements about the risks or hazards that might be associated with that composition, and you shouldn't allow such stories to cause you to relax your safety precautions. Even if YOU have handled a composition successfully, it doesn't mean that what you are doing is "safe" - it might mean that you have just not had those couple of crystals line up yet, or gotten that slightly contaminated chemical yet, etc. In other words, you might have been playing pyro roulette, and the bullet hasn't fallen under the hammer - YET.

In general, it is not a bad idea to handle every composition in accordance with the WORST reports rather than with the best. Safety should be your key concern. We are all excited by the bangs, the fires, and the wonderful sights and sounds. But the only way to make sure that we will all be able to enjoy it for many years is to make safety our highest priority. Don't play pyro roulette. TIP

CAUTION ABOUT USING NON-PROVEN OXIDIZERS

The oxidizers commonly used in fireworks have been studied in great detail. Additional years of experience in their use has resulted in acquiring a large body of information in the "do's" and "don'ts" of their use in combination with other components in fireworks mixes. The list of those found to be usable in fireworks, because of their stable and predictable performance, is rather small. This note is a suggestion that you stick with those proven oxidizers to achieve new effects that you might wish to develop. I will describe some undesirable effects that have been observed with some off-beat oxidizers.

This note was written because of the appearance of ammonium nitrate in a recently published star formula. Ammonium nitrate has not seen the exhaustive studies of chemical compatibility with other chemicals and solvents that the accepted list of oxidizers has seen. Although most might feel that it is a rather poor oxidizer, under certain circumstances it can exhibit properties that are very hazardous. For example, I have personally witnessed a demonstration in which some ammonium nitrate was mixed dry with a fine metallic fuel that is commonly used in fireworks. It was put into a paper cup and water was poured on the mix. After perhaps one minute, a puff of steam was seen to arise from the cup, followed shortly by a violent explosion which left a crater in the earth.

Another demonstration that I have witnessed involved the oxidizer magnesium perchlorate. Magnesium perchlorate is commonly used as a drying agent (desiccant). If a suitable liquid fuel is poured over some magnesium perchlorate (and some of these are used as solvents in fireworks compositions), the mixture will first grow very hot, then spontaneously explode with great violence.

Finally, I have seen proposed the use of sodium chlorate as an oxidizer. The WiZ pointed out years ago that many explosions have resulted from the use of sodium chlorate. Because of its high solubility in water, it can leach out of compositions and drastically change the stability. This has resulted in the loss of many lives in the past. FR

FREE MAGNESIUM

Magnesium is almost a fireworks by itself. Small thin strips burn as bright as an arc welder. This without the addition of any oxidizer! Not much is used in today's fireworks as it tends to overpower the colors of stars. If you need a lot of light fast, magnesium is a good bet. The military uses a lot of devices made with magnesium. The flares shot out of planes to distract heat guided missiles is one use. A flare shot into the air and suspended from a small parachute to light up a battle field is another. Sparklers used to be made with magnesium but it appears that most state laws prohibit it now for a reason unknown to me.

Although magnesium is quite easy to get these days, the types and sizes are limited. Powder and spherical shapes are common but sometimes big flakes and chunks are desirable. I found a free source of magnesium in the form of a rod. It's the anode used in all water heaters. It's attached to a hole plug between the hot and cold water pipes. It sacrifices itself to keep the metal tank from corroding so it may be completely gone; but in my experience there's usually a lot left by the time the water heater hits the curb for disposal.

The rod is removed and cleaned with a wire brush. A lath is used to make strips, curls and chips. Mill machines, grinders and exceptionally coarse sharp files can also be used. I stop often and move away accumulating chips as they are quite flammable and burn extremely hot. This is probably why magnesium is seldom used in manufacturing.

One annoyance is the steel rod in the center. Apparently the magnesium is plated onto this about a half inch thick. I work around that if I must be sure there is no steel contamination.

Don't be too surprised if you see me wrestling with your water heater on the curb if you do not save the anode for yourself. CD

MAKE YOUR OWN POTASSIUM NITRATE

One of the most commonly asked questions I see on the Internet is "how can I get potassium nitrate? The obvious answer is "buy it from a pyrotechnic chemical supply company". However, a lot of people don't seem to want to go that route... perhaps they are afraid of paper trails, perhaps they are underage, perhaps perhaps perhaps... Whatever the reason, they want to get it in a different way. Some people are lucky - they can find it at an agricultural supply house. K-power is a brand of potassium nitrate that often sells for between $15 to $20 per 50 pound bag. One has to mill it, but it's cheap! However, not all stores sell fertilizer stock potassium nitrate, and many won't order it. Thus, these people are often compelled to buy it from pharmacies at exorbitant prices, or try to extract it from stump remover or even from fecal matter. It was obvious that a better source was needed.

The answer can be found in two other common agricultural chemicals - potash and ammonium nitrate. I called three garden places and all of them had these two chemicals. The prices are cheap - at the time of this writing I can get potash for $5.10/50 pound bag, and ammonium nitrate for $8.99/50 pound bag. One should be able to make around 55 to 60 pounds of potassium nitrate for around $14, plus labor, plus heating costs.

The process relies on a bit of elegant chemistry. Potash is potassium carbonate. When potassium carbonate is dissolved in water, it largely disassociates to potassium ions and carbonate ions. The same is true of ammonium nitrate. Thus, a solution of potash and ammonium nitrate will consist of four different types of ions - potassium, ammonium, nitrate and carbonate. One can get the same mixture by dissolving potassium nitrate and ammonium carbonate. Thus, the solution can be viewed as some sort of mixture of all four chemicals - potassium carbonate (K2CO3), potassium nitrate (KNO3), ammonium carbonate ((NH4)2CO3) and ammonium nitrate (NH4NO3). It can be said that all four compounds are in equilibrium, thus:

$$K2CO3 + 2 * NH4NO3 \longleftrightarrow 2 * KNO3 + (NH4)2CO3$$

Long ago a chemist name Le Chatelier observed that when an equilibrium is disturbed, the system adjusts to re-establish the equilibrium. Thus, if one removes one of the components in the equation, a reaction occurs and more is created. For example, if one had an equilibrium solution of the four compounds shown above, and removed the ammonium carbonate, then more ammonium carbonate would be generated by the reaction of potassium carbonate and ammonium nitrate. This would generate more ammonium carbonate, but it would also generate more potassium nitrate. If one could remove all of the ammonium carbonate, then the final solution would contain only potassium nitrate!

Fortunately, it is actually easy to do just that! Ammonium carbonate decomposes to ammonia, carbon dioxide, and water at temperatures above 60° Centigrade (140° F). Thus, dissolving potash and ammonium nitrate in water, and then bringing it up to the boiling point will cause ammonia and carbon dioxide to boil off, leaving behind water and potassium nitrate.

The amount of potash and ammonium nitrate should be *stoichiometric,* i.e., there should be two molecules of ammonium nitrate for every molecule of potash. That can be accomplished by using the molecular weights to calculate the weights of chemicals that will contain the appropriate ratios of molecules. However, there is one tricky part - both ammonium nitrate and potash absorb variable amounts of water. Thus, the starting materials must be assayed for their water content. This can be done by weighing out 100 grams of each compound and placing it in an oven at about 150°C (300°F). The samples are weighed every hour until the weight stops changing. This allows one to calculate the percentage of water, and to adjust the amounts of the starting materials as needed. This can be done as such - let us say that it was found that the potash contained 16% water (a typical number). To determine the adjustment factor, one takes 100/(100-water percentage) = 100/84 = 1.19. Thus, to obtain 250 grams of anhydrous potash, one would take 250 * 1.19 = 298 grams of *wet* potash (one won't see or feel the water).

The appropriate ratios for the weights of anhydrous ammonium nitrate and potash are 160 grams and 138 grams respectively (these must be adjusted for water content). The room temperature solubilities of ammonium nitrate and potash are about 130 grams/100 milliliters and 115 grams/100 milliliters respectively.

This idea was tested in two experiments. In the first laboratory scale experiment, 169 grams of ammonium nitrate (which had been found to contain 5% water) were dissolved in about 150 ml of water, and 164 grams of potash were dissolved in 150 ml of water. (Remember, the solubilities given above are for anhydrous compounds, and so the water is not factored into the equation to determine the minimal amount of water needed.) When ammonium nitrate dissolves in water it takes up heat, so the solution gets very cold (this is the basis for some instant ice-packs). The solutions were both warmed to about 50°C, and then mixed in a large beaker. The odor of ammonia was immediately evident. The beaker was placed in a fume hood. The solution was then heated and stirred by hand. At about 60°C a few small bubbles appeared, and at 80°C the bubbles were forming rapidly. The solution appeared to be boiling, even though the temperature was far below the boiling point of water. Heating was continued, and over the next half hour, the temperature stayed around 80°C. After that time, the rate of gas bubble formation slowed down and the temperature of the solution rose to 100°C, at which point a more normal looking boiling commenced. The volume of the solution decreased steadily over 30 minutes, during which time the temperature of the solution raised to 113°C. At this point, the volume was around 100 ml, and a large rime of crystals was beginning to form around the surface of the boiling solution. The beaker was removed from the heat, and allowed to stand for a minute, after which 100 ml of denatured alcohol was added to cause rapid crystallization of the potassium nitrate. The solution was allowed to cool to room temperature, and the crystals were collected via vacuum filtration, and dried in an oven at 150°C. The final yield was 194 grams of very finely divided pure-white microcrystaline potassium nitrate (96% of the theoretical amount of 202 grams). The crystals were tested for ammonium ions by the KOH/litmus/evolved-gas method, and for carbonate by attempted precipitation of barium carbonate via barium chloride. Both tests showed < 1% contamination.

The success of this laboratory experiment led to a "production scale" test. In this experiment 7.4 pounds (3.36 Kg) of ammonium nitrate were dissolved in 1 gallon of water in a 20 quart stainless steel pot, and the pot was placed on a grill over an outdoor wood fire and warmed to 50°C. An electric heater could probably be used as well. While that solution was warming, 7.2 pounds (3.28 kg) of potash were placed in a 1-gallon plastic milk jug, and 2/3 gallon of hot tap water was added. The jug was shaken, and the undissolved potash was allowed to settle. The potash was poured into the hot ammonium nitrate solution, and the choking odor of ammonia gas caused the experimenter to retreat upwind at a rapid pace. The rest of the potash was dissolved in a similar fashion, and was added to the stainless steel pot at arms length while standing upwind. The fire was stoked and the pot was allowed to heat up and begin the evolution of ammonia and carbon dioxide. Once the rapid evolution of ammonia commenced, the experimenter amused himself by seeing how far downwind he could detect ammonia with his nose. The odor was unbearable at a distance of fifty feet downwind, and could easily be detected up to 500 feet away. Obviously this procedure on this scale is NOT suitable for normal urban settings.

After about three hours the odor of ammonia diminished to a barely noticeable level, and the temperature of the solution was found to be about 104°C. The solution was allowed to boil until it appeared to be a little more than 2 quarts. At this point, the temperature was 110°C. The solution was allowed to cool and sit overnight. The next morning the mess in the bottom of the pot was broken up using a heavy oak 2x2, and poured into a pillow case. The crystals were wrung dry, and allowed to dry in a shallow pan in the sun. After two days, they were weighed. The final yield was 8.1 pounds (about 90% of total possible yield) of a mixture of large and small potassium nitrate crystals. The material would obviously have to be milled before use. The material was tested for ammonium and carbonate ions, and was found to contain a slight contamination with carbonate ions (perhaps 1%).

The process is not terribly difficult, and could even be interrupted part way through to make CIA black powder or non-milled Chrysanthemum type mixes. For example, once the solution has been boiled to eliminate the ammonium and carbonate ions and concentrated to a minimal volume, it should contain only potassium nitrate. Rather than isolate the potassium nitrate, one could add charcoal and sulfur, followed by a period of boiling and then addition of alcohol (see articles in *Best of AFN II*).

Safety Notes: The process releases choking and poisonous gases. Do not breath the gas. This process HAS to be done outside or in a laboratory fumehood. Normal kitchen vent hoods would be inadequate to remove the ammonia gas. Note that this also makes the process a little hard to do on the sly in large quantities. The potash solution is caustic, and hot concentrated potash solutions might cause chemical burns. As always, rinse all chemical spills with copious quantities of running water, and if burning or irritation persists, see a physician. Ammonia readily attacks copper, so one cannot use brass or copper kettles. Potash solutions attack aluminum. Finally, the Merck index remarks that while ammonia is generally regarded as non-flammable, that mixtures of air and ammonia will explode if ignited under favorable conditions. However, since the ammonia explosions only occur when the concentration is between 13% to 79% in normal air, it is very unlikely that such huge concentrations will be formed, especially as the ammonia will always be accompanied by equal amounts of non-flammable carbon dioxide. Be aware. TIP

MORE ON POTASSIUM NITRATE/FERTILIZER

Last year I finally located an agricultural dealer who had fertilizer grade potassium nitrate in stock, so I bought a 50 lb. bag of prilled *K power.* They also had the greenhouse grade, *G.G. Flowable* which is 100 mesh. I bought the prilled because that's all I had ever heard of. The cost was $15.50 for a 50 lb. bag, and it takes about 30 minutes to ball mill a pound, which isn't too bad.

I have nothing but praise for the *K power* that is made by Vicksburg Chemical Co. 111 match my black powder with anyone's. What I have found is that you better have the best charcoal for the best finished product, being polverone or pressed and grained. To get the best charcoal, I found you have to make it.

Over the years I've tried a lot of charcoals and they all made inferior black powder compared to my own made charcoal. I use willow - old, dead willow. I use the sound wood, not rotten, and I also separate the heart, which is sort of red, from the more white outer wood. The white wood will make a slightly faster powder. The white cooks up quicker and makes a lighter charcoal.

The sulfur I use is "burning sulfur", that I get from the Amish in Pennsylvania Dutch country. It's $16. for a 50 lb. bag. The Amish use it to clean the soot out of their chimneys. It's about 325 mesh and is 99.5% pure.

Here are some specs, that Vicksburg quotes for *K power.* They are for the prilled product.

Typical analysis:
KNO - 98.8%
K_2O - 46.0%
N - 13.8%
Cl - Max. 0.005%
Na - 0.3%
H_2O - <0.1%

Screen analysis:
99% on +20 mesh screen
96% on +14 mesh screen
75% on +10 mesh screen
20% on +8 mesh screen

Solubility in water:
At 32°, 1.08 lbs. per gallon
at 194°, 16.83 lbs. per gallon

Vicksburg Chemical Co. advises that Agway carries their materials, and suggests that if your local Agway doesn't have *K power,* they can get it for you from another Agway. Other outlets are Land-o-Lakes Cooperative and Southern States. AP

POTASSIUM NITRATE/ FERTILIZER UPDATE

[A recent issue of AFN carried an article which discussed producing potassium nitrate from fertilizer-grade materials. Now we have received the following letter from a long-time AFN subscriber who is an industrial hygienist. He has uncovered a series of articles written by a staff reporter for a major daily newspaper that reported the fact that incredible amounts of toxic wastes are legally being recycled as agricultural fertilizer. Cadmium, lead and arsenic are just a few of the substances in these wastes. He writes:

I am concerned about the article on making your own potassium nitrate from fertilizer. The author apparently was not aware that fertilizers escape many of the labeling laws which apply to other products.

The root of the problem is that it is still legal in most states to sell toxic industrial waste as fertilizer as long as the major amount of other toxic ingredients are plant nutrients. This means that significant amounts of other toxic ingredients may be present including lead, cadmium, arsenic, dioxins, chrome, nickel, and radionuclides. These substances will not be disclosed on the label and the sellers usually do not know they are there.

I wrote two articles recently on this labeling problem to warn potters who were using fertilizers as glaze ingredients. However the same information applies to using fertilizer for making pyrotechnic ingredients.

There are now several bills in the works to try to change fertilizer regulations at the federal level, but until they are passed I would not recommend using fertilizer for anything other than fertilizer. In fact, I'm not sure I would use certain fertilizer as fertilizer at present.

The author of the AFN article replies: I wasn't aware of this appalling possibility. This amplifies a warning that I often give to beginners - wear disposalable gloves and don't breath the dusts! Many of the chemicals we use are technical grade chemicals, and we have little knowledge or control over the possible contaminants. Trying to minimize exposure to ANY chemical is a good idea. Disposable examination gloves and respirators are cheap, and afford some level of protection. Working in well ventilated areas is always a good idea, and cleanliness is a matter of habit, not cost. Don't allow familiarity to breed contempt - treat every chemical as a hazardous material. TIP

MAKING BETTER CHARCOAL

Another tip that was passed around at the Western Winter Blast was how to make intermediate sizes of charcoal from large chunks of homemade charcoal. Seems like people who use a *Sponenmill* complain that while they can make airfloat, they were having some problems making coarser material, such as 80-100 mesh. These charcoals are desirable to give long lasting tails to rockets and stars, as well as to make more esoteric stars such as zinc spreader stars. The problem is that these mills are TOO efficient. Coffee grinders suffer from a similar problem. In addition, the capacity of such coffee mills is limited. Some other method is needed to make these intermediate grades.

Fortunately, there is a surprisingly easy way to make small mesh charcoal. It just involves gallon-size zip lock baggies and a length of plastic pipe (1" & 1/2" PVC works well). Most people are surprised at how much punishment a ziplock baggie can withstand if there isn't air to provide a "popping action".

It is simple to place a small amount of charcoal into the bag and press out as much of the air as possible. I would then seal the bag, and start abusing the charcoal through the bag. One can actually whack it gently with the pipe to break it up into smallish chunks, and then roll the pipe back and forth over the charcoal. The operator should be careful not to press the charcoal against the zipper and pop it open, but with a very little practice it is easy to get the hang of it.

Once the charcoal seems to have been reduced to a fine powder, it can then be sieved using a series of graduated screens. Many of the pyro supply companies sell sets of screens such as 20, 40, 60, 80 and 100 mesh. They might also be found in some hardware stores. The charcoal is passed through the larger screens on the way to the finer screens, and anything that stays is graded as being *- the screen above and + the screen it stayed on.* Thus, if it passes through a 40 mesh screen and stays on a 60 mesh screen it will be either described as *40 to 60 mesh,* or *-40 +60 charcoal.* Anything which stays on the coarser screen can simply be returned to the baggie for further processing. TIP

THE EFFECTS OF WATER ON COMPOSITIONS

Some time ago someone wrote that he did not understand why a batch of comp had a faster burn time while still damp and actually lost burning speed as it finished drying. If you measure burning speed in open burning, you are usually measuring flame spread speed, not burning rate, and anything that increases the rate of ignition particles lighting material at a distance from the combustion will make the burning appear to be faster because the particles spread ignition faster. Try burning a little comp on newsprint paper. You can measure how far and how large the condensed particulates were from the comp.

In my book on Glitter there are comments about the formation of the spritzels; water and even humidity in the air have a very noticeable effect on particulate agglomeration in the solids and liquids and their vapors in the combustion products. What causes larger particles will cause faster flame spread as they are more easily accelerated by pressure differentials and have greater inertia so they move faster and farther.

As it happens, some chemicals, like Epsom salts and alum, form crystals that contain quite considerable amounts of water. The sulfates are easily reduced by the metal fuels, i.e., aluminum, magnesium and the alloy called magnalium. These reactions are exothermic, but not greatly so, and are often quite slow by pyrotechnic standards. Epsom salts is the old name for magnesium sulfate hydrate. It can be easily dehydrated with heat. If that is done slowly in an oven, the crystal form is retained but becomes an easily crumbled material that makes an excellent drying agent for solvents like acetone and MEK, and since it is essentially insoluble in these, it is far better than calcium chloride for drying solvents for pyrotechnic use.

One of the most useful testing devices for mixtures is that old standby, the 5/8" dia. x 1 1/2" long paper tube. My procedure would be to grind up both the dry Epsom salts and the hydrate, then mix two parts by weight with one part of each of the metal fuels in their various forms, and compare the results of each fuel with both. It should be noticed that the hydrate is a better oxidizer and it may be a little noisy with some of the fuels. Water is a better oxidizer in the form of steam than is the sulfate ion. LSO

PURIFYING CHEMICALS BY RECRYSTALYZATION

From time to time we may want to purify our chemicals. There are many reasons to do this - we might have obtained some slightly impure chemicals at a bargain rate, we may wish to remove some suspected impurities, or we might wish to improve the reproducibility of our results. Professional chemists go to great lengths to purify their starting materials, and utilize many complicated methods and pieces of equipment. However, there is one method which is easy to perform, gives good results, and isn't expensive. This is called "recrystallization". It doesn't work for all chemicals, but when it does work it is often the method of choice. Let's discuss how it can be used on pyro chemicals.

First of all, let's discuss the theoretical basis behind crystallization. A crystal is a regular ordered arrangement of atoms, ions, or molecules (to save time, I will just use the term "ion" from now on since we will be focusing on ionic crystals). The crystal is held together by several types of crystal packing forces. These forces vary from molecule to molecule. Thus, it shouldn't be surprising to learn that different molecules have different preferred crystal packings and crystal shapes. Sodium chloride forms cubes while potassium perchlorate forms rhombehedrons.

These forces play an important role during the process of crystal formation. Imagine the surface of a crystal which is exchanging ions with a solution. For each ion on the surface of the crystal there are two opposing forces: crystal packing forces which hold the crystal together, and the opposite forces of solvation energy and entropic freedom. If the crystal packing forces are slightly greater than the solvation and entropic forces, then the crystal grows. Conversely the crystal will dissolve if the packing forces are less than the dissolving forces. While packing forces are roughly temperature independent, the solvation forces are favored by increases in temperature. This is why things dissolve in hot solvents and crystallize from cooling solvents.

During this cooling there is a purification when ions try to fit onto the growing face of the crystal. There is a better fit between similar ions, and so a growing crystal of potassium perchlorate will not include many ions of either sodium or chloride. This preference is more pronounced when crystal growth is very slow. Thus one can take a mixture of 10% sodium chloride and 90% potassium perchlorate, and recrystallize it to obtain crystals of potassium perchlorate which will be at least 99.9% pure. Now, to a few practical details.

First of all, as can be realized from the previous discussion, the purification will be improved if the rate of crystallization is slow. Thus, the hot solution should be allowed to cool as slowly as is reasonable. Secondly, it must be accepted that the process of recrystallization loses material. We'll discuss this below. Third, one has to do some calculations based on the relative hot and cold solubilities to determine how to perform the procedure. All of the desired material must go into solution at the upper temperature, and none of the impurity should come out of solution at the colder temperature.

Consider 100 grams of a mixture of 10% sodium chloride in potassium perchlorate. First, we have to look up the solubilities at 0°C and 100°C. Then these values are used to make sure sufficient water will be present to dissolve all of the material at the hot temperature, and to determine how much material we expect to obtain. Purification only happens when the crystals grow from solution. Thus, sufficient water must be present to dissolve all of the desired material. Since 100 mls of boiling water will dissolve 21.8 gms of potassium perchlorate, 412 mls of boiling water will be required to dissolve 90 gms. The impurity doesn't have to be dissolved, and can be filtered off (more below). When cooled to 0°C, since 0.75 gms dissolves in every 100 mls of water, only 0.75 * 4.12 = 3.09 grams of the potassium perchlorate will remain in solution. Nearly 87 gms will be found as large crystals at the bottom of the vessel. However, we also have to check to make sure the impurity isn't near it's saturation point (where it begins to crystallize).

Since 412 mls of cold water will dissolve almost 150 gms, the 10 grams of impurity in the original sample will still be safely dissolved. In general, one doesn't want to approach the saturation point more closely than a factor of two.

Thus, the purification can be performed as follows. About 5% more than 412 mls (440 mls) of water is used for every 100 grams of impure perchlorate (the excess helps make up for evaporation during heating, lower boiling points due to reduced atmospheric pressures, etc.). The purest water available should be used. The water is heated in a vessel which won't react with the hot chemical solution (a Pyrex beaker is best, but one can use stainless steel or enamelware). The material is added with constant stirring once the water is boiling. The solution must be filtered if there is undissolved material or cloudiness. This is a difficult process since the solution will tend to cool and deposit crystals in the filter, thus clogging it up. It is often a good idea to add excess water to the bulk solution to allow some degree of cooling before crystallization occurs and to boil the excess water off after filtration. The filter should be heated by placing it over a receiver containing boiling water and pouring some boiling water through the filter apparatus. Coffee filters are convenient for volumes up to a liter or two, but the plastic filter holder isn't designed to allow for easy heating. An old-fashioned metal or glass filter should be used because the steam from the boiling water in the receiver can heat the outside of the filter.

Once the solution has been filtered (if needed) and any water added to assist in the filtration has been boiled off, the solution can be allowed to cool. Remember, the slower to cooling the purer the final material. Thus, the container is covered to exclude dust, and the container can be placed in a Styrofoam cooler or wrapped in insulating cloths. Once the solution has cooled to room temperature, it can be further cooled to as close to 0°C as is convenient. The crystals can be collected after a half day at 0°C. This can be done by carefully pouring off the solution, or by using the same filter apparatus described above. The crystals are still damp with traces of the solution containing the impurities, and so a small portion (about l/10th as much as the original solution) of pure ice-cold water is used to wash the crystals. The crystals are then dried, ground, and used. Drying is generally accomplished by air drying for a day or more, followed by several hours in a small oven at around 150°C (250°F). Don't use the kitchen oven - a cheap toaster oven at Goodwill will suffice.

This is a very efficient example of this procedure. We recover 87 gms of potassium perchlorate for every 90 gms we start with. However, this is not always the case. Consider barium nitrate; the solubilities are 8.7 gm/100 ml at 20°C, and 34.2 gm/100 ml at 100°C. Thus, 300 mls of boiling water will dissolve 100 grams of barium nitrate, but only 74 gms will crystallize out at 20°C. Even cooling it to ice temperatures will only recover a few grams more. This loss of material is typical of purification procedures, and is one of the reasons that most high-purity chemicals are so expensive. However, this loss can be reduced by performing another recrystallization cycle. For example, consider the experiment just mentioned. If the crystals were collected and then two-thirds of the water was removed by boiling, another 17 gms of the barium nitrate would be collected upon cooling. However, there is a risk that these later crops may be contaminated because the ratio of the concentrations of the impurities to the desired material is rising and the driving forces to include impurities in the crystal are becoming proportionately greater. Thus, the pyrotechnist who is performing such purifications must walk a fine line between quantity and purity. TIP

MINING THE PYRO TAILINGS HEAP

Most pyros have what we call a "tailings heap" - a box gathering dust in the corner filled with all of those cake items that stopped firing part way through. You really intend to work on refusing them someday, but somehow that day never comes. This article describes a way to "mine" this heap, creating new and entertaining pyro effects from the remains of the old.

The first step in this process is to mine the useful nuggets of pyro gold from the tailings heap. Each cake consists of a number of tubes. The unfired tubes are separated and carefully dismantled. Most of these tubes are dry rolled and will unroll easily after slitting the outside layer or two with a utility knife. When fully unrolled, exposed is a small quantity of loose black powder, a clay plug, and the payload - one or more stars or small cardboard tubes containing some sort of effect. The black powder gets carefully separated and poured into a plastic container. The effects get saved to another container, sorted and labeled if you're that kind of person, or all together if randomness is more your style. The clay plug and the remains of the tube go into the trash.

The second step is to create a launcher that can be used to forge these nuggets back into objects of pyro delight - in this case, mines! The launcher consists of a small mortar (mine is a 2" Mighty-Mite HDPE mortar) mounted on a stable base. The mortar can be either plastic (HDPE is recommended) or thick-walled cardboard - the tubes supplied with festival ball kits are not strong enough. A base needs to be made for the mortar. We cut a 10" piece of 2x10" lumber and drilled a 1" dowel slightly shorter than the mortar into the hole.

The mortar was prepared by drilling a fuse hole through the side just above the bottom. This hole should be sized to be a snug fit for the intended fuse - we use bare blackmatch but visco is also excellent for the purpose. Now the tube gets fastened to the dowel using cable ties, duct tape, or monofilament strapping tape.

Now we're ready for the fun step - loading and firing the mine. We begin the loading process by cutting a piece of fuse (about 5" for blackmatch, or 2 - 3" for visco) and sliding one end into the mortar through the fuse hole. We then pour some of the salvaged black powder into the mortar. The amount of black powder depends on the size of the mortar, the quality of the powder and other factors - I'd start experimenting at about 2 tablespoons for a 2" mortar. We then dump a small handful of the salvaged effects into the mortar on top of the powder. We carry it into an open area with a minimum of flammable material, set it securely on the ground, light the fuse, remove ourselves to a safe distance, and enjoy!

The effect will be similar to the cakes from which the effects were salvaged, but more intense and short lived. One Class C item deserving special mention is the Saturn Missile Battery. These popular items come in several sizes, and frequently stop firing before they are completed. The unfired missiles are easily removed by pulling straight up on them. We take enough of these to create a bundle just large enough to slide easily into the mortar, and tie the bundle securely together with a wrap or two of thread. When fired as a mine shot, it is quite good fun!

TD-MM

COAX CABLE FOR LANCEWORK

When making lance work, I use coaxial cable to form any curved parts of the framework. The stuff is stiff yet flexible, and bends into nice, even curves. I use cut-offs from work. I suspect that many users throw a lot of the material out. Lance can be attached with screws and it works just great! PG

SPHERICAL TITANIUM OFFERS REDUCED SENSITIVITY

I'd like to give people a "heads up" about spherical. This product not only is 20 to 40% cheaper than granular or flake titanium, it also has certain advantages in some formulations. I recently obtained some and tested it in various fountain and star formulations. For example, I substituted the spherical titanium for the spherical aluminum in Davis' *Snowball Sparkler* formulation. The resulting stars burned with a nice white flame and had a 6-foot long trail of brilliant white sparks. Not quite a titanium glitter, but pretty damn close! I showed off a few of these at Kellner's annual gathers of the clans, and they were widely admired.

I also have put these in fountain formulations. They add a nice white spark to the fountain. However, the biggest advantage lies in the decreased risk of ramming fountains with spherical titanium, compared to sponge titanium. For several years I have taught a beginner fountain class at the PGI and other conventions. During this class we hand-ram a 68 potassium nitrate; 22 airfloat charcoal; 10 sulfur composition, which has been enhanced with from 5 to 10% additional metal particles. While we have never had an accident, I have been worried about the safety of hand ramming a BP-like composition with hard titanium granules. I suspected that the spherical titanium would reduce the risk.

To this end I made up three samples of fountain composition. The first contained the 68:22:10 composition mentioned above with 5% additional 40-80 mesh sponge. The second contained 5% additional 18-120 mesh titanium flake. The third contained 5% additional 40-200 mesh spherical titanium. The three samples were analyzed for impact sensitivity, using a 5 Kg drop hammer, using the "up & down" method. The order of sensitivity was sponge > flake > spherical, with the sponge being the most sensitive and the spherical being the least. The difference was dramatic. The spherical titanium required a 25% higher drop for ignition than either of other two forms. The reader is cautioned against reading too much into this test. It may be found that different loadings may show different relative sensitivities. A more complete study needs to be performed. However, it is possible to conclude that for this particular ratio and this particular composition, the mixture containing the spherical titanium was clearly less sensitive. This is important when hand ramming fountains. Thus, I *will* be using spherical titanium for all my fountain classes in the future.

Of course, it is also possible that there are some applications for which the flake or sponge titanium may well be better, just as there are certain applications where spherical aluminum doesn't work as well as flake or sponge aluminum. As always, this is part of the fun of pyrotechnics! There is plenty of room for new experimentation and for the discovery of new effects! TIP

INEXPENSIVE MILLS

Long-term, no self-respecting pyro should be without a good ball mill. But if you don't have one yet, or if you just want to grind small amounts of stuff, get thee down to thy local WalMart for a great, cheap pyro chemical mill. (In London, you can get a nifty one for about £62 down at Harrods.) Look in the cooking wares section for a coffee and spice mill. I bought three of them for around $12 bucks each. I have dedicated one for oxidizers, one for fuels, and one for everything else. If you shake 'em while you hold the button down, you can grind up just about anything in 30 seconds or less to a nice, fine powder consistency.

The only way to clean 'em that I have found is with a dry brush.

At the risk of belaboring the obvious, you should only mill individual chemicals this way. DO NOT MILL MIXED COMPOSITIONS USING THIS DEVICE UNLESS YOU WANT IT TO BE YOUR LAST TIME. HG

SIMPLE RAM MODIFICATION ENSURES IMPROVED COMET IGNITION

We have recently found that we can improve the reliability of igniting our flitter comets and other comets that use difficult-to-ignite formulas (i.e., high in aluminum content) by altering the shape of the comet ram.

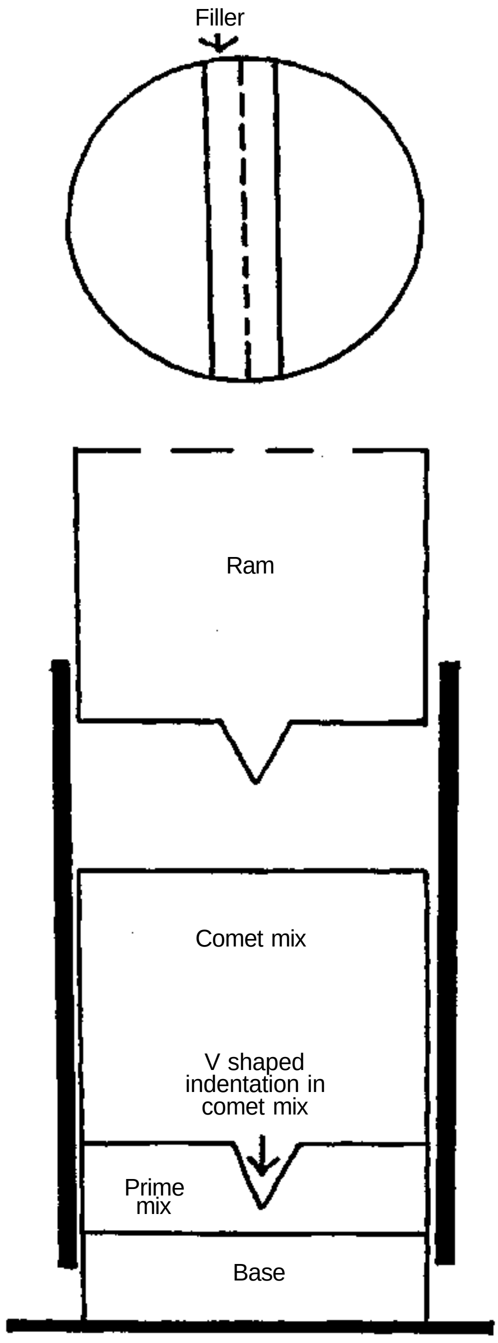
The conventional way of making difficult-to-ignite comets is to place the prime in the ramming case and, if required, a second stage prime, then the comet mix. The problem with this method is that the prime has to heat up a large flat surface area for successful ignition.

Our experience shows that the best place to ignite this type of comet is on a well defined edge where the heat buildup will be at its greatest. We set out to try an idea that involved the use of the prime molded around an internal edge of the comet mix.

Using one of our comet rams, we carefully built up a V shape wedge by using car body filler. That done, we tried making our first comet with the new tool.

The required amount of prime was placed in the rammer case, the new ram was inserted and pressed down firmly with hand pressure, then removed. Then the normal comet pumping procedure followed.

Any comets we make which require a prime are now made with this method. Since changing over to the new ram, we have had a 100% success rate. PT



A PRESSING CONCERN

One tool that ought to be in any pyrotechnist's workshop or lab is a press. Most people may not have the resources to afford, or store, a ten-ton arbor or hydraulic press but there is more affordable alternative. This is the common bottle capper. These are available at any store that sells beer and wine making supplies. They can also be found at flea markets or yard sales for a very reasonable price.

Two different styles are produced. One style works with a cam that supplies the pressure; these have limited use in pyrotechnics because the stroke is small. The other style works with a rack and pinion gear and has a stroke up to six inches. These two styles are further divided into types where the head of the press is stationary or adjustable. The later type is more desirable in that it gives the operator more flexibility in production.

A common concern is that these presses don't have the force to consolidate the composition as well as a mallet. A good capper has enough power to split a three-quarter inch casing without too much strain from the operator. Rockets, gerbs, and whistles with inside diameters up to one inch have been made with excellent quality control. Other items that can be produced efficiently are pumped stars and comets, hummers, tourbillions, color and strobe rockets, and garnitures with split second changing effects. With simple tooling, end caps and cups sets are easily and quickly produced. With simple setups, end caps can be inserted to precise depths very rapidly.

One advantage of a press that quickly becomes apparent is that the press keeps the dust from flying all over the place. It also eliminates the obnoxious pounding noise the rammer makes. Life around the place can be much nicer once the press is mastered.

For best results the press should be securely anchored to the work bench. This can be done with permanent bolts or clamps which allows the press to be stored somewhere else when not in use. When doing repetitive work, spacer blocks can be used under the spindle to avoid resetting the press head. The blocks can be made from scraps of wood. Birch plywood in various thicknesses is very convenient. This technique also works on presses with a fixed head. Some drifts may have to be cut down to get the most out of the throat depth (the distance between the ram and the base).

The safety of ramming color compositions, or those that contain potassium or ammonium perchlorates, with a mallet, is not good. They have been known to blow with varying amounts of damage. These accidents probably could have been avoided by using a press. Any formula that has the slightest hint that it could be shock sensitive should be pressed, never rammed.

While pressing greatly increases the safety factor, it does not take all the risk out of working with pyrotechnic compositions. It's a good idea NOT to hold the casing being pressed by hand. It's also a good idea to not allow compositions and finished pieces to accumulate in the work area, and, of course protective clothing is worn, never shorts and T-shirts. Pyros should always listen to that little voice in their head that tells them when what they are doing is stupid. It's a good idea to listen. It's probably right! CV

AN INEXPENSIVE PRESS FOR PYRO USE

Quickly after I became hooked on sky rockets it became apparent that I was going to need a press as I wanted to try many different types of rockets such as titanium tailed black powders, whistles, strobes, red tailed, etc. and one doesn't dare hand ram such sensitive compositions.

After doing some research on presses I decided on a simple "H" frame press that utilizes an inexpensive bottle jack to apply the hydraulic force as they are relatively inexpensive and are easily modified for use with different jacks (or hydraulic cylinders if you decide to go that route in the future).

I do have a well equipped shop, and building a press is not a complicated affair. However it does take time to accurately cut all the pieces, drill the holes, etc. and I simply did not have the time so I decided to purchase a press.

I purchased my press from Harbor Freight Tools. One should be aware that, as with most things in life, you get what you pay for and presses are no exception! The press I ordered cost me $120 delivered to my door. For this kind of money I did not expect a professional quality product and, as I expected, when the press arrived I found that it was not of the highest quality. However, for small scale pyro use it was serviceable - in fact I pressed a rocket up with it about a half hour after I assembled it!

Although it is serviceable in stock form, with just a few simple modifications it can be made much easier to use.

First and foremost, I would not trust the capacity rating. Although it's rated at 12 tons I would not venture beyond about 4 tons with it. Since I am mainly interested in pressing one poured and smaller rockets I chose to also order a two ton jack and install it in place of the 12 ton unit that came with the press.

The next modification concerns the press bar. The sleeves that guide the bar had a large gap between them and the upright posts. This large gap made using the press quite a challenge - as I actuated the jack lever the press bar moved around a lot making it difficult to line up with the rocket rammer. To solve this problem I simply drilled some holes through the guide sleeves and welded some nuts onto the sleeves, then installed bolts and jam nuts. To adjust the gap you just screw the bolts in and out. Once the proper gap is found you just lock down the jam nuts. I've included a drawing of where I welded the nuts.

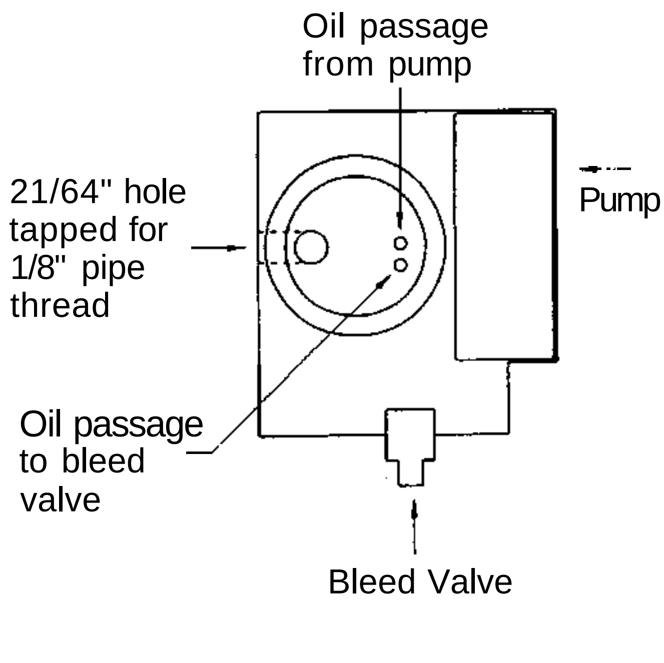
The last modification is one that may or may not be necessary. The press bed was warped and would rock. I found that one corner was 1/8" too high so I just welded a small 1/8" plate to that corner.

That's it! Although not of the "beefy" construction I would have used, the press works just fine for pressing rockets and I have a minimal investment in time and money.

Reference:

Central Hydraulics 12 Ton Shop Press. Item# 33497-4CBA $119.99 (includes shipping)

BS



INSTALLING A PRESSURE GAUGE IN A HYDRAULIC BOTTLE JACK

Once I began using a hydraulic press to ram rockets I decided it would be nice to know how much force I was applying while ramming.

I decided to install a pressure gauge in the hydraulic bottle jack used in my press. The process was simple to perform and was as follows:

* I removed the rubber stopper on the side of the jack and drained the hydraulic fluid.

* The ram of my jack had an adjustable extension on it. This had to come off or the jack body would not slide off. The extension was threaded into an insert that was pressed into the jack ram. To remove it I just wrapped the ram with a rag and grabbed it with a pair of vice-grip pliers, then I grabbed the extension with another pair of vice-grips and twisted; the extension threaded out without effort.

* There was a cap nut on top of the jack body, I loosened it and carefully removed it (there was a seal in it I didn't want to damage so I was especially careful).

* Now there was just a short piece of pipe with the ram in it threaded into the base of the jack. I carefully loosened it with a pipe wrench and removed it.

* Below where the ram sits is where the hydraulic force is applied to move the ram and that's where I wanted to install the gauge.

* Using a 21/64" drill bit I drilled down through the base for about half the thickness of the base. While drilling I hit an oil passage....uh, oh! Upon examination it was found that the oil passage was the oil passage from the jack pump and they had simply drilled it deeper than the hole they intersected it with so it was of no concern.

* Using the same 21/64" drill bit I drilled a hole in from the side of the jack that intersects with the first hole I drilled. It's a challenge to hold the jack base square while drilling it; to help with this I used a magnetic welding 90.

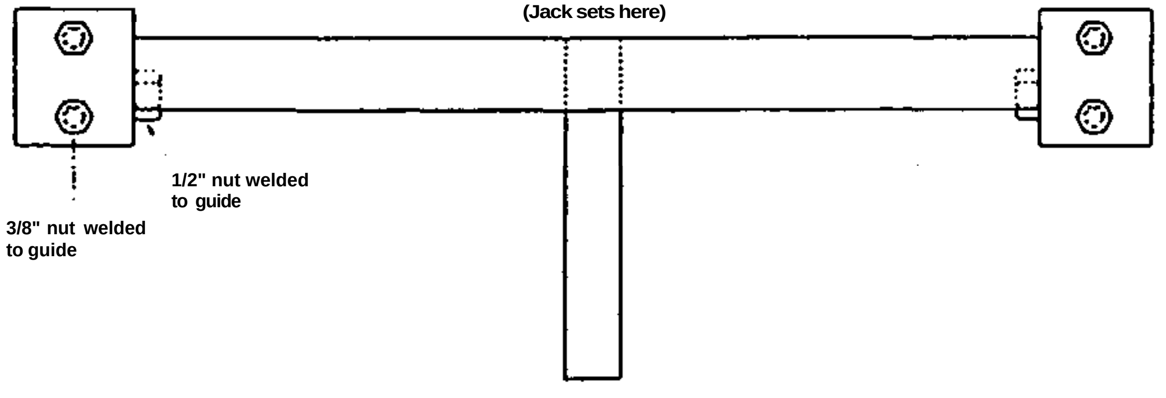
* Using an 1/8" pipe tap I cut threads in the hole.

* I carefully cleaned the jack up, reassembled it, and filled it with new hydraulic fluid.

* Using standard 1/8" plumbing materials I installed a nipple and an elbow, filled the line with hydraulic fluid, and then threaded on the gauge.

Additional notes:

The Gauge: The gauge I installed was bought from Surplus Center and it displays pressures up to 5,000 psi. This jack will actually develop about 6,800 psi when at it's maximum 2-ton ram force, however, I am mainly concerned with ramming 1 lb. and smaller rockets and it only takes about 2,500 psi or so to ram these rockets. I preferred the 5,000 psi gauge with it's finer graduations and easier reading dial than the next higher pressure gauge they had (15,000 psi). The gauge is simple to replace so I'll keep an eye out for a reasonably priced 10,000 psi gauge.



A DISCUSSION OF PRESSING FORCES

I've had several inquiries concerning the use of the gauge and a better explanation of force as opposed to psi. I must admit that this whole concept had me too fairly confused for a while. In my search for enlightenment I asked for an explanation on the Internet's *Pyrotechnic Mailing List* and several members were kind (and patient) enough to explain this to me. In what follows I will try to pass that information along.

First a couple definitions:

Force: Force has several definitions, but I think the clearest for this discussion is "Power made operative against resistance." Force can be measured in several units, but in this discussion I will use pounds.

Psi: In looking for a definition for psi I found a couple of different definitions; for the purpose of this discussion it will stand for "pounds per square inch."

Now, imagine an object weighing 1 pound - the exact shape or dimensions do not matter, the thing to remember is that it weighs 1 pound. If we place the object on top of a block that has a footprint of 1 square inch, the 1 pound of force will act on the block evenly and the 1 pound of force will be distributed over the 1 square inch. We quantify this as 1 psi.

If we place this object on top of a block that has a footprint of one half a square inch, the force will once again act evenly on the block and the 1 pound of force will be distributed over the half square inch. Since there is half as much area, the psi will increase to 2 psi. Conversely, if we placed this object on top of a block that has a foot print of 2 sq. inches, the force will be distributed over twice as much area and the psi will fall to .5 psi.

In mathematical terms:

force = area x psi
area = force / psi
psi = force / area

Let's apply this to our press.

Using these formulas, we can see that by knowing the area of the ram in the cylinder and the psi being applied to the ram, we can figure the amount of force being delivered. To find the area of the ram one must measure the ram diameter and use a little more math.

Example:

Ram diameter = 1"

Area = pi x (diameter squared) / 4

Area = (3.14 x 1) / 4 = .785 sq. in.

To find the psi acting on the ram you must install a pressure gauge in the hydraulic chamber below the ram or in the line running from the pump to the cylinder. In this example, we will use a gauge reading of 2,000 psi. Once you have the area and psi you just plug the numbers in:

Force = .785 x 2,000 =
1,570 pounds of force

It should now be apparent that when sharing information with others one should always refer to the force being delivered by the press and not to the gauge reading of the pressure applied to the ram in the hydraulic cylinder as the pressure reading for a particular force is unique to the diameter of the ram.

Now, for most pyro activities we stop right here - all we need to know is the force to apply. However, for the perfectionists out there:

Ramming a core burning rocket by using the same force on every increment does not result in the fuel grain being compacted the same amount. The reason comes back to area - due to the hole in the rammer (that accommodates the spindle) the first rammer typically has about 25% less area over which the force is distributed. This reduction in area increases the psi being applied to the composition and consequently the comp. is compacted more. (Those of you who have hand rammed rockets without a sleeve have probably noticed that it's easier to bulge the casing while ramming the nozzle or the first few fuel increments than it is while ramming the delay or upper bulkhead. This is why.)

Hopefully this helps clarify things a bit! BS

CLIP-MATCH

Picture this: You're in the middle of a show. You light a fuse connected to a flight of five shells, move away and crouch down with your back to the tubes, listening for the five thuds that tell you everything went. Woosh, woosh, woosh, then silence. You look back to see that one of the shells took out the quick-match connected to the last two shells. There is still a short piece of quickmatch connecting the two shells, but no fuse or blackmatch to light them. No time to splice in another fuse, so there are two perfectly good shells that you will probably have to shoot after the show or take back with you.

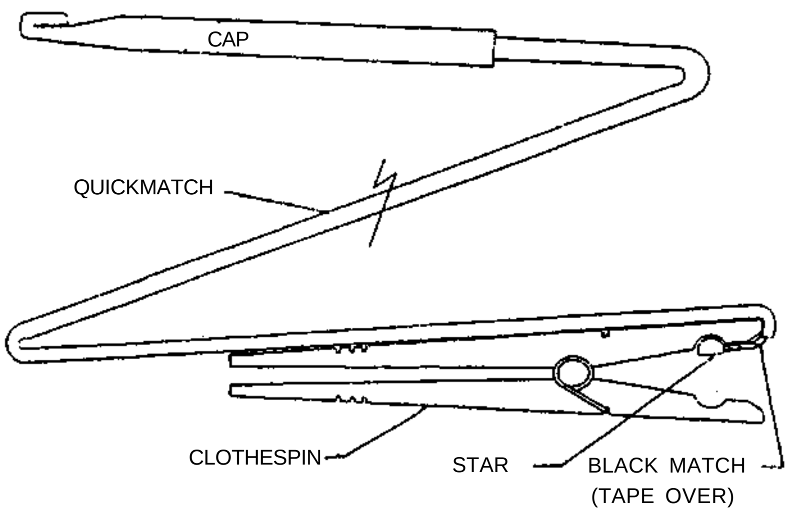
Faced with a dilemma like this a few times (and also short fuses), I've come up with a solution. It's a portable clip-on fuse that you can use to re-light anything from a flight to a finale. Here is how to make it and use.

I take a two-foot piece of quickmatch with a leader cap on one end, the ones you cut off of a shell when you fit it with an electric match). I strip back the paper to expose the blackmatch for about 1/2". Next I glue the blackmatch to the inside of a clothespin (the kind with the spring), making sure to start it right next to the inside notch, per diagram. Then the quickmatch is run down the outside of the clothespin and glued in place. A small star (the cylindrical type fits best) is glued into the notch where the blackmatch ends. There'll be more room inside the clothespin if some of the star is shaved off. Tape is placed over the exposed match and it's finished.

The device is used by simply clipping the clothespin anywhere on the piece of quick-match that you want to light.

It now becomes an instant fuse. The cap is pulled off and it is lit. After the normal 3 - 4 second delay, the quickmatch burns rapidly to the star and ignites it. The star then burns through the paper of the quickmatch that's captured in the clothespin, which ignites the shell.

Now, when I'm faced with the above scenario, I simply reach near the tube (never over it!) and clip the clothespin on the remaining quickmatch. Then I can come back with my fusee, remove the cap, light, and still have 3 - 4 seconds to retreat. It's a safe solution to a common problem. PG



CHEAP & EASY QUICKMATCH

If you're a new pyro like me, you find out very early on that good, dependable quickmatch is absolutely essential for the endless testing and firing of your favorite fireworks.

You also learn that quickmatch is just about impossible to purchase, and even harder to make! Over the past two years I've read countless articles about how to make it, what to do, etc. Despite my very best efforts, the quickmatch I've made is not very dependable. Some was good, some was OK, some was fair, and some wouldn't burn if you put it into a volcano. I soon learned that I would have to come up with a good substitute, or take up coin collecting.

In addition, the process of making good, dependable quickmatch was expensive, very time consuming, and worst of all, as messy as all heck. Homemade meal was not good enough, and using all commercial meal was too expensive.

After some experimentation I found what I think is the perfect answer.

Materials:

l)2Fg (e.g. GOEX) black powder
2) Commercial smokeless powder (800X)
3) 1 Straw
4) Scotch-type 2" wide tape (such as mailing tape)
5) Visco fuse

I mix the 2Fg black powder and the smokeless powder in a 1:1 ratio until well mixed. Then I simply lay out a length of 2" tape, sticky side up, and using the straw, I lay down a trail of my mix, 1/4" thick. I then attach a 3" (or longer) piece of visco at one end, then fold the tape over itself longways. That's it! I now have a one-foot long piece of tape with a powder trail in the middle and a visco "leader" at one end! The other end is inserted in the item to be ignited. The tape can be trimmed as needed.

So far IVe used this tape to ignite literally hundreds of pieces, from 2" to 6" shells, gerbs, set pieces., etc., with *never* a misfire! That's more than I can say for my homemade quickmatch.

Another method IVe tried is to use 2" self-sticking packing tape. The process is exactly the same except the tape is rolled on a 45° angle.

It can be flattened as it is rolled up. It works just great for me.

IVe experimented with different powder ratios, i.e., 1:1, 2:1, 3:1 and 4:1 (smokeless to black powder). They all seem to work just fine. It's worth experimenting.

Homemade black powder will also work if commercial is unavailable, but it is necessary to make the powder into grains approximately the same size as FFg or FFFg.

Homemade blackmatch/quick-match, when made correctly, is stiff and brittle and cracks very easily. These cracks can lead to problems. My process above will never have that problem.

Smokeless powder is cheap, and mixing it in a 3:1 or 4:1 ratio with the FFg results in a considerable cost saving.

Despite my reading everything I can find on ignition techniques, I have never seen this method described. Maybe it's well known, but it's new to me! So I claim:

- Inexpensive
- Clean and neat
- Takes a fraction of the time needed to make good black/quickmatch
- Effective - it works!

IVe shown the technique to several old time pyros and their response has been: "Big deal - IVe been doing that for years."

My only response is, shame on you for not sharing it with us new guys. BB

EASILY MADE HIGH PERFORMANCE BLACK MATCH

Having tried many different formulas to produce high quality black match for use in quickmatch, we came up with this new method that gives a performance far superior to any other method we have so far tried. This new method will give a performance equal to that of the commercial type, and is as neat in appearance as well.

High quality black match, when inserted into a paper tube (quick-match) will burn through instantly, even if both ends of the paper tube are left open. It will also produce a noticeable WHOOSH sound, and if left unsecured when lit, will disappear as it shoots across the ground.

This new method has been tested directly against commercial types and has exactly the same performance.

To make the Black Powder, we use the standard 75/15/10 (by weight) formula of 75% potassium nitrate, 15% charcoal, 10% sulfur. The basic grinding tools we use are a liquidiser and a coffee grinder.

For a half-kilo run we grind 375 grams of potassium nitrate, although we will dissolve the nitrate in water later to speed up the operation. Using the coffee grinder next, we grind to a fine powder 75 grams of charcoal, followed by grinding 50 grams of sulfur. Once complete, we pour both the charcoal and the sulfur into the liquidiser, thoroughly seal, then switch on for approximately 5 minutes.

In a reasonably sized metal pot we mix the nitrate with warm water and bring to a boil over a single ring electric cooking element that we bought especially for pyrotechnics. The ratio of water/nitrate is 0.8ml water to 1 gram nitrate. Thus, in this batch we use 300ml of water.

Once the nitrate has dissolved and is bubbling away, we add 25 grams of dextrin (the amount of dextrin to the total amount of composition is 5%), then add the charcoal/sulfur mix and stir in. This part of the job takes about five minutes. It is tedious and cannot be rushed. Once it starts to mix, it doesn't take long. When the task is completed, we boil for a further 2 minutes.

Taking a ball of string, we cut 30 to 40 pieces into five-foot lengths, and make a loop in the end of each string so it may be hung to dry. To help coat the string evenly, we use a 2" length of brass tube that has an internal diameter just wider than the string. The string is inserted and the tube is slid towards the loop end, leaving about 3" bare.

Each strand is immersed in the pot and stippled with a brush for 30 seconds, while the loop end is held. Then it is lifted out of the pot, and holding it over the pot, the brass tube is slid down the string. This action gives the Black match a very even and smooth finish. All that remains is to hang the string and let it dry. Normal drying would be 3 - 4 days.

A great idea to aid drying is to use a "crystal dehumidifier", the type with white crystals in a cone that attracts moisture and deposits it in a jar below. It's truly surprising how much moisture can be collected. We have found that leaving one inside our meal powder container certainly increases the power, having had most of the moisture removed.

PT

E-Z FORMABLE BLACK MATCH

Use pipe cleaners! Dip pipe cleaners in wet black meal powder slurry (4% dextrin added). Ater an hour or so, wipe off the extra buildup so a rough surface remains. It's easily cut, formed and wrapped-around. JB

ANOTHER MATCH MAKING MACHINE

I subscribe to the philosophy that simplicity is the key to success for just about everything! With this in mind, I approached the design of a black match machine. Admittedly, the design is somewhat obvious; after all, how many different ways are there to build one of these things? Anyway, I like the design because it is easy to build, easy to operate, and remarkably effective.

In the construction I used 3/4-inch plywood for the base, side panels and top. The base measures 8x14" and the side panels measure 6x8". The top piece is 9 1/2x3". Dimensions are not critical, however they must be practical. Holes were drilled in the side panels to accommodate a length of 1/2" wooden dowel. This serves as a spindle shaft for the spool of string. It is a good idea to finish the woodwork with a sealer to help prevent moisture damage.

I just happened to have an 8 1/2x4 1/2x2 1/2" loaf pan laying around the house. As it turned out, this proved to be ideal for the project. In the center of the pan at one end I drilled a 3/16" hole and soldered in the spout, a 3/4" length of 1/8" i.d. copper tubing. (The spout will remove excess compound from the string and give the match a professional finished appearance.) I smoothed the inside edge of the spout to prevent string snag. At the opposite end of the pan I carefully measured centers for the guide bar and drilled two 1/4" holes. Through the holes I passed a piece of 1/4" brass shaft stock cut to length. With proper fluxing, the bar can be soldered in place. The idea is to locate the guide bar close to the bottom of the pan, leaving enough room for the string to pass under it. Again, the dimensions are not critical. Secure the pan to the base at each end with a wood screw and rubber washer (made from an old inner tube) to prevent leakage.

The string guide assembly is made from a 12" piece of 1/4" polyethylene plastic tubing and is secured to the top of the frame assembly with two metal clamps. Polyethylene tubing is sold by the foot and is available at any builders' supply or hardware store. This type of tubing is typically used to supply water for ice making machines, etc. The role of the string guide is obvious.

Set-Up

It is best to perform match making outdoors. A sunny day with calm winds is ideal. The machine should be secured to a sturdy work surface. I used two C clamps to fasten the base to a Black & Decker Work Mate™. My work area was out in the back yard next to a fence. For the drying rack, I mounted three 9" angle brackets on the fence, 12-feet apart. (The match will be hung in 24-ft. lengths between the protruding legs of the brackets, with the center bracket as a support.)

I used a spool of 4-ply cotton string that I purchased from a vendor at the PGI convention. The spool is mounted by passing the wooden dowel through the spindle and the support holes in the side panels; the string unwinds from the bottom. The string is threaded through the guide assembly, under the guide bar and through the spout.

My favorite match composition is meal powder made from fertilizer grade potassium nitrate, with 5% added dextrin. To this I add water until the consistency of the mix is like that of tomato juice. I have found it helpful to heat the mixture before using, which seems to help reduce the grainy texture, making it easier to work with. I have always prepared my mix intuitively so I cannot specify a temperature. As you read on, you will see that the hot mix comes into contact with the operator's fingers, so it shouldn't be *too hot to handle!* The mix is prepared in a 1-lb. coffee can over a hot plate - outside!! When it appears that the mix is at the proper temperature and consistency, it is poured into the loaf pan until the pan is about 1/3 full.

Operation

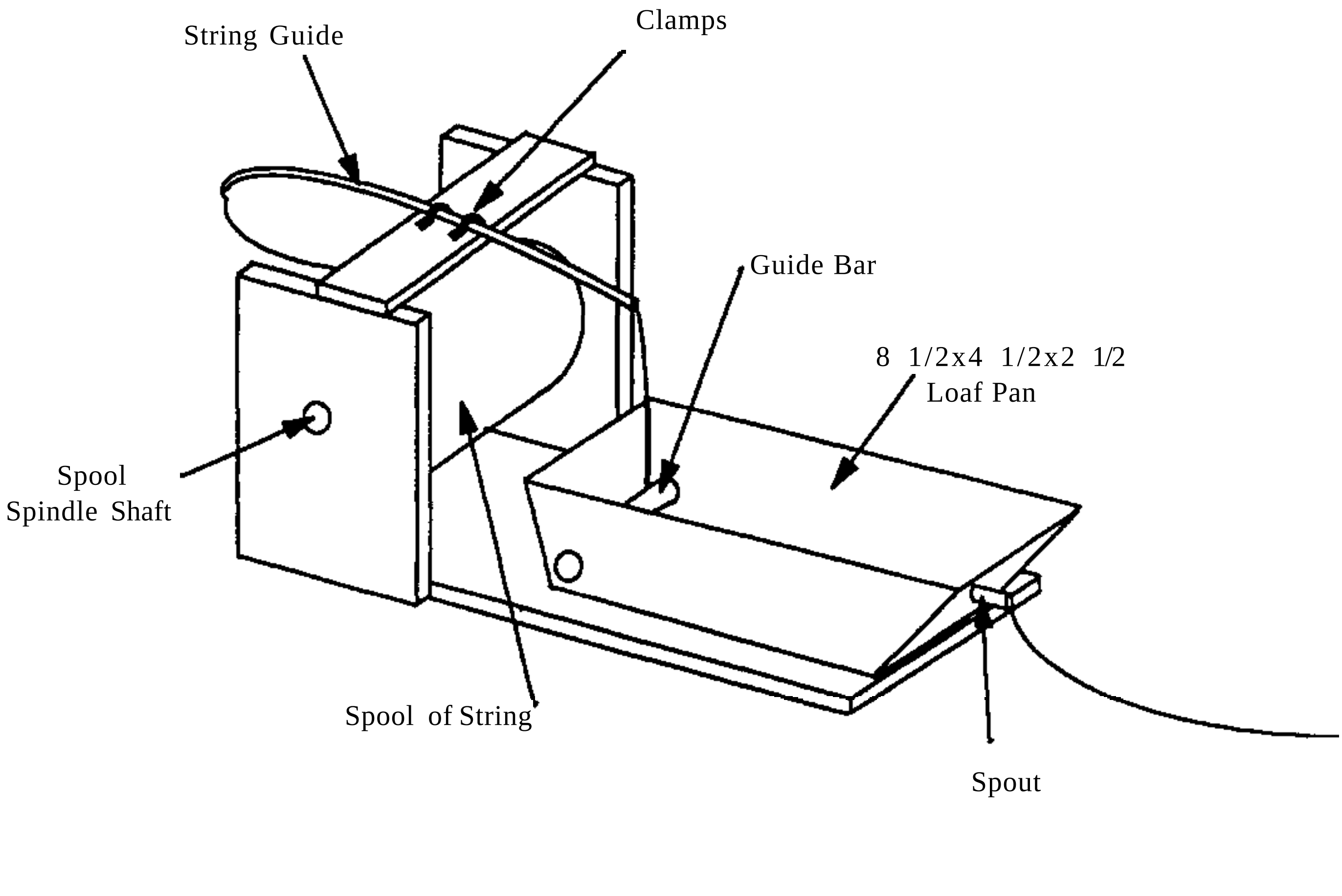
Operation requires the aid of an assistant to pull the string slowly through the machine. As the string passes through the pan, the operator, wearing disposable rubber gloves, works the mix into the string with his fingers. I have found that this hands-on approach is a very effective means of ensuring string saturation. Working in harmony with the assistant, the operator will discover that he can make a lot of match in a relatively short period of time. The supply of mix in the pan is replenished as necessary. As mentioned earlier, 24-ft. lengths of match are made and hung to dry on the protruding legs of angle brackets that I mounted on the back yard fence. I try to start early in the day to allow as much drying time as possible. I never leave the match to dry overnight because of the potential for atmospheric condensation. At the end of the day I lay sheets of newspaper end to end on the ground beneath the drying rack. I very carefully remove the match from the rack onto the newspaper, which can be a very delicate procedure since the match is not completely dry. Bundling together and making sure that the ends are even, I cut the bundle into 24-inch lengths. Sears Craftsman Handi-Cut™ shears are perfect for this operation. Lastly, I gather the finished match to a single sheet of newspaper and set aside to finish the drying process. This should take another day or so, depending upon conditions. For storage, I use a suitable cardboard mailing tube with end caps.

Comments

The methods described work very well for me. Recently my wife and I made about 500-feet of match. I didn't time the operation, but it certainly took us less than two hours (drying time not included). The two hours included preparation and set-up time/The appearance and performance of the match is very satisfactory indeed!

With a little imagination, variations of the methods I have described can be achieved. There are many possibilities. As always, it is important to follow the rules of safety.

When finished making match, the machine may be cleaned with soap and water, and stored until the next time! GP



MATCH MAKING MACHINE

I just finished making a match machine similar to the one depicted on page 13 of the *Best of AFN II* except for a few differences. Instead of wood I made it out of 3/8" Plexiglas, mainly because I just happened to have some hanging around my shop with no useful purpose. Plexiglas also does not absorb moisture like wood and should be easy to clean for storage. The difference is that this machine works each strand over all of the rollers separately and then gathers them into one bundle at the very last stage. This means that each strand is well coated with powder and should give a match less likely to die at a choke or at bare points where it rested on a nail when drying.

The rollers are 1.5" nominal dia. regular white nylon 2-7/16" long, with twelve grooves machined into them for a maximum of 12-strand match, and 7/32" axle holes drilled through them. After the last roller is a plate of Plexiglas with twelve small holes drilled in it, with a funnel shape on the entrance end of the hole (made with a No.2 center drill), and at an angle correct for guiding the strand towards the single gathering hole. A "bell" center drill will give the best hole entrance shape although I didn't use one.

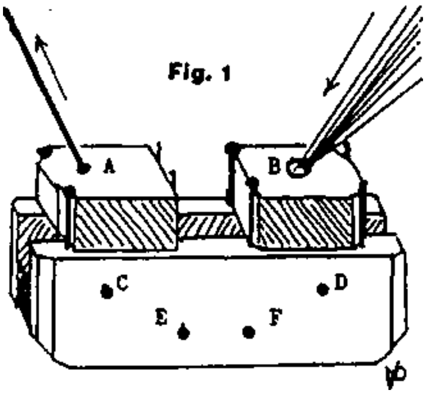
The top plate where the strands enter the machine according to the drawing in *Best of AFN II* uses twelve small holes instead of one as depicted in the *Best* article. All of this keeps the strands from jumping out of their roller grooves and helps work in the Black Powder composition better.

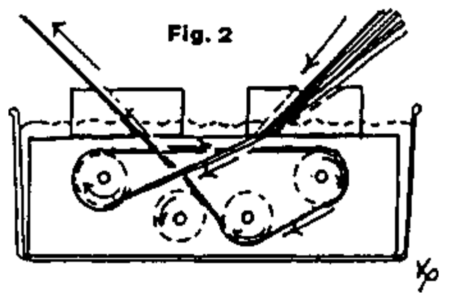
The roller pins are 3/16" dia. 7-4 PH stainless (just because we happen to use it in our plant and have it handy), not heat treated (age hardened). The rollers intentionally are a very loose fit on the pins to prevent them from binding up on the pins due to the Black Powder getting into the axle holes, and for easy cleaning. The rollers fit into a space of 2.5" between the Plexiglas plates giving 1/16" total clearance. The pins have a slight press into the Plexiglas and that's all that holds them in place for easy disassembly.

The Plexiglas is fastened together with four 8 x 32 THD stainless flat head machine screws, as is the guide plate just before the gathering hole with four of the same screws.

The whole thing fits into a 3.5" x 4.0" x 9.0" space envelope. A machine shop isn't needed to make this either. It could be built with only a saw and an electric drill. Needed are a 8x32 tap, and a countersink for the flathead screw. 3/16" brass rod will work instead of stainless. The precise pin press holes in the Plexiglas can be generated by drilling first with a No. 14 drill, then using a 3/16" drill to ream out the hole by hand.

The grooved rollers may not be necessary at all but can be made by ganging pulley rollers or mounting the drilled nylon rod onto a bolt, mounting that into a hand drill fastened into a vise (correctly so as not to damage the drill) and filing the grooves in or using a v shaped wood lathe turning tool. If a wood lathe tool is used, it is necessary to mount a tool rest next to the nylon roller in the drill in the vise; probably it will be possible to cut only the half of the grooves next to the drill chuck, then turn the roller round and remount to cut the other half of the grooves next to the other end of the roller. If a metal lathe or a wood lathe is used, there will be no problem machining nylon. As always, extreme caution and eye protection are needed when using power tools. Drilling and taping assembly holes in Plexiglas is very easy except it is necessary to tap dry, and need to remove the tap frequently to clean the shavings out of the hole (I use a small drill in a pin vise) or it will seize up when the operator attempts to back it out. PEJ





Original Max Vander Horck illustrations from *Best of AFN II.*

CAUTION: VERY FAST "BLACK MATCH"

by K. L. & B. J. Kosanke

There is a new style of black match used to make the quick match leader fuse on some Chinese products. The fuse has recently been found on some Flower Basket aerial shells and Lidu display fireworks boxes, and may also be used on other items as well. While this new black match seems to function well in quick match, it has one characteristic that is important to note for safety reasons. Where normal black match tends to burn rather slowly at about an inch per second, this new black match burns very much faster, perhaps as fast as quick match (roughly 10-20 feet per second). Because of this much faster burn rate, it is possible for someone to have a serious problem. For example, if the end of a shell leader fuse were damaged, someone might attempt a repair by cutting it off and exposing a few inches of this new black match. In this case, the person may have the expectation that lighting the tip of the fuse would provide a few seconds before the item would function. However, instead, the fireworks could begin to function essentially immediately upon ignition of the tip of the leader fuse.

Before further discussion of the burning of this new black match, it is appropriate to consider first the manner of its construction. (For a discussion of typical black and quick construction and their manner of burning, see reference 1.) Figure 1 is the end of a shell leader of this new type, with the safety cap removed. Figure 2 is the same piece of shell leader, which has been progressively dissected to reveal the manner of its construction.

The end of the shell leader is composed of three lengths of thin visco fuse (each a little larger than 1/16-inch in diameter and about four inches long). In Figure 2, the end of one of the pieces of visco fuse has been cut open for a short distance to expose the fuse powder contained in it. Further, these three fuses have been surface coated with a slurry of powder. These fuses are attached to the length of shell leader with a thin wrap of tissue paper (not shown) over a string tie. Upon initial inspection, the shell leader appears similar to conventional quick match, with an outer wrap of Kraft paper (match pipe) over an internal fuse which is black in appearance. However, most importantly, this is not conventional black match. It is made using a wrap of approximately two-and-a-half turns of a thin tissue paper around two cords of string heavily coated with a slurry of powder. Also in the tissue paper wrap is a substantial additional amount of a fine loose powder, some of which is tightly adhered to the tissue paper (suggesting that the tissue paper was probably wet when wrapped up). Figure 3 is an attempt at a cross-sectional illustration of the construction of this central fuse.

Because the tissue paper of the central fuse is only loosely wrapped, abundant fire paths remain within it. Accordingly, when it is burned, even when not enclosed within the Kraft paper match pipe, it burns very quickly, much like it does when made into quick match. Thus for this fuse, the purpose of the Kraft paper match pipe seems to be mostly for additional strength and protection of the central tissue wrapped fuse.

• There is nothing intrinsically wrong with having a central fuse that burns essentially as fast as completed quick match. In fact, although it has not been extensively tested by the authors, it seems to perform quite well. Further, the abundant amount and distribution of the fuse powder probably makes this fuse less likely to fail as either a hangfire or misfire. However, it can be important for users to know this new style fuse exists. For example, as suggested above, if a shell leader or the delay element is seriously damaged, or the delay elements are missing, one would normally make a repair in the field. This might be done by simply removing the damaged portion of the fuse and stripping back some of the Kraft paper match pipe to expose more of the central fuse. With a typical quick match shell leader this works well and is an appropriate repair. However, if this is done using this new style tissue fuse quick match, when it is ignited, instead of

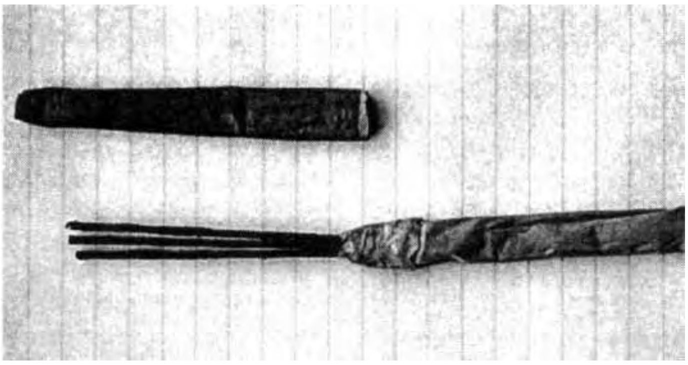


Figure 1. Shell leader containing the new fast burning black match. (Note that the three exposed fuses have been separated slightly for clarity.

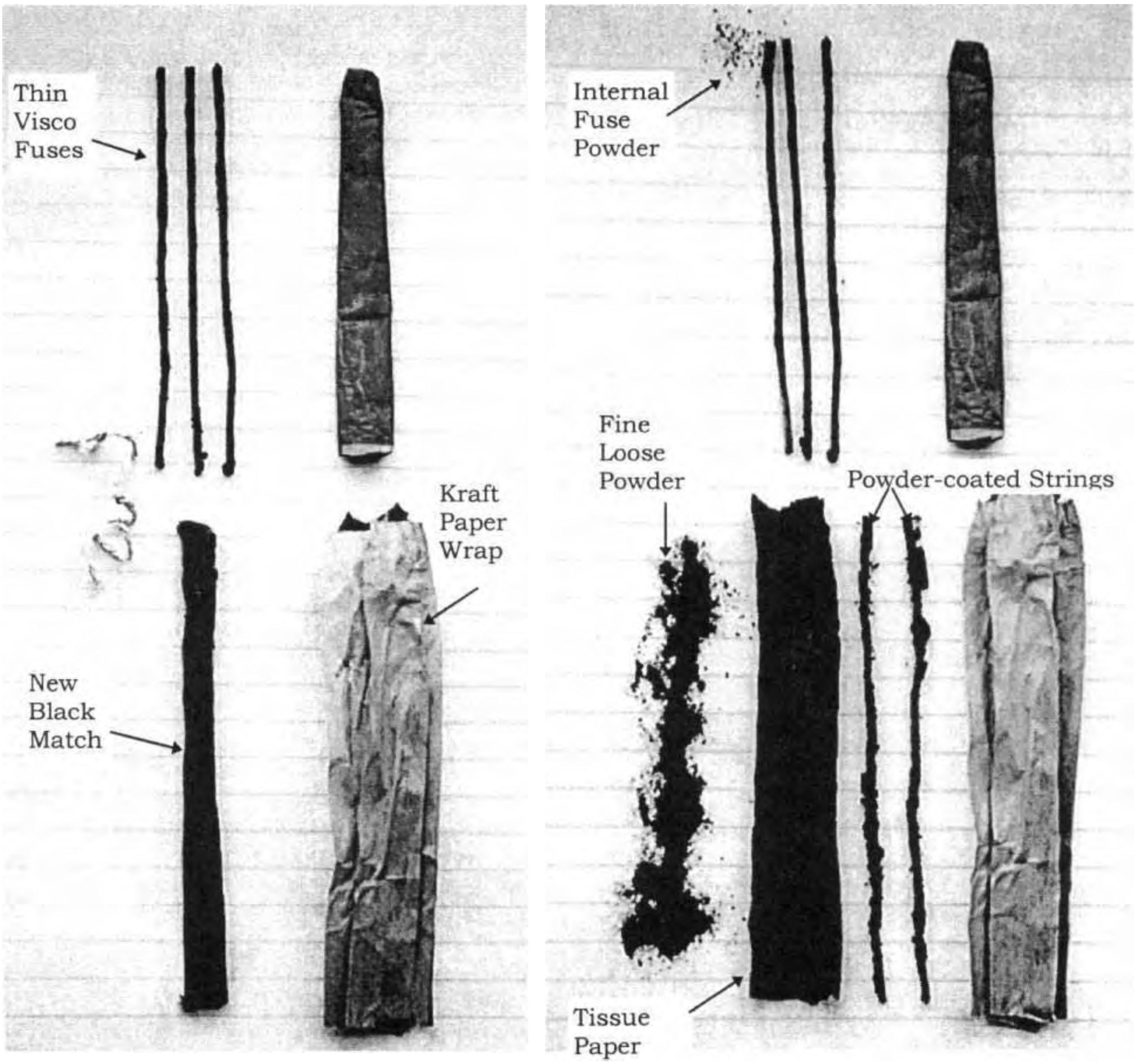


Figure 2. Photos of a dissected shell leader illustrating its construction.

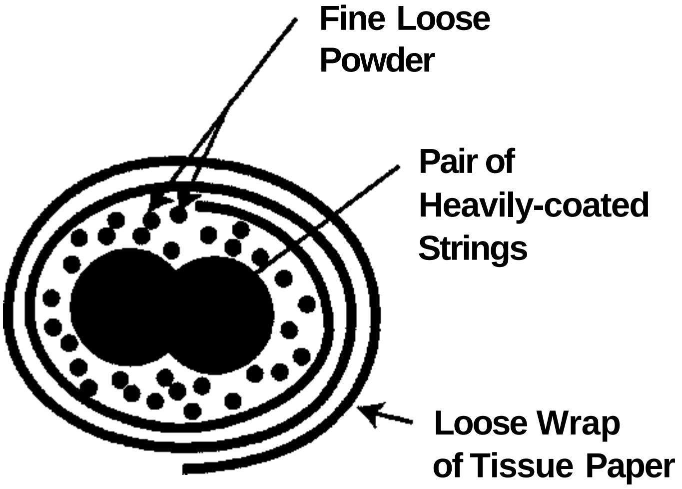


Figure 3. Cross sectional illustration of the new fast burning black match.

the expected few seconds delay, there would be essentially no delay at all. In most cases, that would merely startle the lighter. However, if the device being ignited seriously malfunctioned, or if the lighter was not properly positioned at the time, an injury could result.

It is not known how widely this new style of quick match is being used. The authors first saw it several years ago and have more recently seen it on Flower Basket aerial shells and on Lidu finale boxes. If you encounter it, there should be no problem, providing any delay elements are left in place or where no delay is intended when it is ignited. To reiterate, there seems to be nothing intrinsically wrong with this new style of tissue fuse core quick match. It is just important to be able to recognize it and to know what to expect when using it.

References:

K. L & B. J. Kosanke, "Quick Match: A Review and Study", *Proceedings of the 4th International Symposium on Fireworks* (1998).

KL&BJK

DISPLAY TIP OF THE MONTH

Here's a description of a display that was fired off a barge:

" ...the barge was anchored relatively close to shore. The aerial display lasted about 15 minutes with interludes of Silvery Swallows, 30" pinwheels and Roman candles. The finale...was followed by 40 thunderous 4" salutes. A very special ending was added. They suspended four 5" titanium salutes over the front of the barge, facing the audience.

Shortly after the finale went up and just as the audience was recovering from the 40 salutes, they blew the 5-inchers, which echoed off the front face of the barge and sent a shock wave into the shore that stunned everyone. The crowd was silent, then started cheering wildly. The ovation lasted for minutes.

Later, a spectator said that the flash and the titanium enveloped the barge and gave everyone the illusion that the barge had disappeared in the explosion. It was a great effect." PG

MY FIRST BOARD

When I first became interested in fireworks, I never dreamed of becoming a licensed shooter or eventually firing shows electronically. My inspiration was started by reading an article in AFN #137 (Feb. '93) titled *Winter Projects - A Tidy Little Electrical Firing Box. [Best of AFN III,* page 150.]

A few reasons why I decided to build this board are: I am the father of two special children, so my safety, as well as my crew's, is at the top; then the cost of buying a professionally made panel vs. actually building my own board is considerably different; and finally the result of an electronically fired display is visually more appealing and professional.

Because of my limited experience in electronics, my first project was to build the circuit and firing board illustrated in the AFN article. I tested it in the field and it worked well. My next goal was to add more circuits.

I looked at several other professional panels, which helped me design a board that would meet my needs. One unique feature of this system is the return ground being <u>inside</u> the cable which comes from the board and goes to the slat. Also, I use two distinct and separate keyed switches, which are NOT keyed alike. This avoids any confusion between the ARMED switch and the FIRE switch. And finally, I've designed the slats to be only three feet long; most systems are four to six feet long.

Then I called Bruce Blom (author of the AFN article); he referred me to Sam Bases. This conversation, and then gathering more information, resulted in seven months of assembling and testing. The board was completed. Now the try-out.

I had a scheduled display in December, 1994. That would be a good opportunity to try it.

During the setting up, about four hours before the display was to begin, a 5" shell suddenly lofted, without my permission! What happened? All of the slats had 20 cues. The first slat was set up without incident, but when I attempted to attach an electric match to the second slat, the 5-incher fired.

To avoid any more complications, and possibly putting my crew in danger, I packed up the system and manually fired the show.

The following day my father and I tore the system apart. After three days of looking we still had not found the problem, so we sought professional help. Bob, an electronics engineer, was the answer. Bob agreed to help when I said the magic word: FIREWORKS. With the three of us trying we soon found the problems.

After another month of reworking and testing the system, we felt ready again for another field test. As a thank you, and for moral support, I asked Bob and my father to come to the display. After setting up the board and doing a few tests, I was ready to go. Of course, there were four guys standing by with fusees, just in case.

IT WORKED! No problems. No injuries. Phew!

Since then, I have used this board for another 27 shows, all without complications. I owe a big THANK YOU to Bruce Blom and Sam Bases, and all the others who helped me accomplish my goals. I hope this information will be useful and inspiring to other pyros.

SAFETY is the key to any venture. DCB

SAFETY & RELIABILITY IN SHOOTING BOXES

I was prompted to write this article after reading DB's article *My First Board* in AFN.

I have built my share of shooting boxes and am aware of some of the problems which may occur. Avoiding these disappointments is a matter of planning and testing.

Each box should contain several levels of safety.

1. The display shooting box should not contain the battery. It may be more convenient to house the battery in the console but doing so does not allow you to isolate the system. When you have external terminals or a connector specifically for the power source you can immediately see if the console is "hot" or "cold". With the battery external to the box, it is obvious if there is connection or not.
2. Each ignition terminal on the firing box should provide a method of shunting or "shorting out" to eliminate extraneous currents from entering the system and accidentally setting off a display. A double throw switch will provide a method to choose "shorted" or "selected".
3. The switch just mentioned should be used to select the display only, and a separate "firing" switch should be used to initiate the fire. The firing switch should be separate from the selector switch and clearly labeled. The firing switch should be in series with the battery as further isolation from accidental initiation.

This gives three steps to accomplish before the display is fired. The display must be selected, the battery must be connected and the firing switch must be closed. This works only if you are willing to observe the proper sequence and think safety. Other circuits are often added to confirm connection to the electric match, show battery condition and provide other "bells and whistles". I prefer to rely on external testing and keep the device simple to avoid circuit failures at an inopportune moment.

Testing is the other factor involved in creating a successful display box. Testing should be done by someone who understands the principles and desired results of the device. Just a caution at this point, neat wiring will aid trouble shooting to a very great extent. The testing should be done using a load equivalent to the electrical characteristics of the firing device to be used. A lamp can be used which will operate at the desired voltage and current. Connect the lamp to the output terminals and operate the switches in the sequence to be used in practice. The results should be that the lamp will light when you operate the switches to initiate a display and only at that time. Any deviation from the expected results must be immediately and thoroughly investigated and the problem corrected. Wiring errors do occur, and as complicated as some electrical firing boxes are, it is to be expected.

Under no circumstances, should a display device, electric match, etc. be connected to test the firing box!

I use the lamp as a load and test all the circuits before connecting the box to any initiating device at every show.

Every time we screw up, we expose ourselves to the public as incompetent, and invite criticism and further legal restriction.

As mentioned on a popular TV show, "Let's be careful out there". DHK

QUICK & EASY E-MATCH FUSING OF VISCO-FUSED ITEMS

The following technique has proven to be both a quick and a reliable method for connecting electric match to visco-fused display items - candles, cakes and the like. I have found that the silicone rubber splices sold by B&C Products, Inc. for use with their "NoMatch" products provide an excellent means for coupling the visco to the electric match. The inside diameter of the sleeve retains 3/32" diameter visco very well and the silicone rubber sleeve is compliant enough to accept the e-match at the other end.

When the e-match fires, rising pressure within the sleeve causes it to expand and, because the visco is a smaller diameter than the e-match, the hot gases and the flame-front are directed over the visco, reliably igniting it. If a smaller diameter fuse is encountered, it can be adapted by folding it in half, making a small slit at the fold, and inserting in the sleeve. This technique has been developed using my TiTAN electric matches with excellent results. Limited testing using other brands of e-match have shown similar results. An added benefit is that the fuse-end and e-match are somewhat protected from the weather.

What can go wrong:

1. Do not tape the visco in-place around the sleeve! The e-match will be blown-out the opposite end with no ignition of the visco fuse. If a smaller size fuse is encountered, use the folded-over method described above, or place a piece of tape alongside of the sleeve and fuse to hold them together. If the latter is done, it would also be advisable to secure the e-match leads to the sleeve with tape or a clove hitch of small twine.

2. Reusing the sleeves is not advisable as the hygroscopic by-products of the previous firing(s) may cause the visco to misfire. PM

FIREWORKS AND ELECTRONIC COMPONENTS

Many electronic components are designed to operate at quite high temperatures. The heat dissipated is often removed with fans that circulate air. It is the component manufacturer's quality which makes these parts survive extreme temperatures. Often parts are made of ceramic materials. They are machine made in huge quantities, which makes them quite cheap!

What's that to a Pyro? Some components, especially resistors, make excellent ignitors. The value of a resistor (described in the units known as Ohms) is chosen to cause the resistor to burn up rapidly at any voltage desired. Other good things are: they are so common and necessary for modern life that they are easily obtained (in bulk for less than a cent each) and no governmental agency dares restrict their use.

One must overload a resistor to be useful for this application. I use 3.9 ohm resistors for work with a 12 volt source. Values from 1 to 10 ohms seems to work well also. For 110 volts 111 use a value of 100 to 5,000 ohms. Often, pyro mixtures are ignited when the resistor has intimate contact. If it doesn't then I dip it in a water/dextrin/Black Powder dough or dip it in syrup of smokeless reloading propellant dissolved in acetone.

If you like using nichrome wire ignitors, resistors can help. They make rugged and cheap holders for that thin wire. One can solder whatever length of lead wire that is wanted to the resistor right up to the body. Then the excess bare wire is cut off so it can't short out. The nichrome wire is wrapped around one leg then looped across to the other leg and soldered in place. This is dipped in a favored starter mix. CD

[Note: A reader points out that the power ratings of the chosen resistors is important but was not shown above. He suggests that 1.8 ohm resistors can be had ranging from 1/8 Watt to 2 Watts, and he says he suspects that the "little ones are intended".]

THOUGHTS ON ELECTRIC MATCH

It should be well known that non-covered (sleeved) electric match (e-match) heads are impact and friction sensitive. Anyone with some electric matches hanging around should go outside with a hammer and smack one on a rock to see for themselves (if they haven't already done so). They are also somewhat static sensitive as well - not so much the bridge circuit, but the pyro comp on the head. At Dyno Nobel where I work, we had several incidents of bulk packed match-heads (no lead wires assembled yet) static-igniting when removed from a "sandwich" of Styrofoam packaging. These matchheads were packed this way by the manufacturer in Europe, where they had been purchased. Consider also the hazards of stray induced current, and the incident at the Montreal Benson & Hedges International when a passing afternoon thunderstorm apparently set off a loaded display segment, coincidental with a nearby (but not direct hit) lightning strike. At over a million volts and over 100,000 amps, lightning strikes produce huge electro-magnetic impulses (EMI). When the magnetic flux of EMI crosses cable and wire, huge surges of current can be induced.

Electric matches do have their hazards. Care should be taken to shunt all wire leads (twist the bare ends together), and care must be taken to pack shells going out to a show so that they don't bang up the matchheads in transit and handling. When I packed out electrical shows, the shells were "squibbed" a day or two before the show, then boxed and kept in a separate magazine trailer from the rest of our inventory. I always felt uneasy with "squibbed" shells hanging around the plant.

Here's a good question for all of the experienced pyros. Which is better: installing the electric match directly into the lift powder of a shell, or cutting off the quickmatch six inches from the lift and installing and taping the e-match there? Both of these methods are the most common practices of "most" fireworks companies. Most shells are imported with the quickmatch already assembled into the lift.

Answer: Neither is the best method because shells will be handled and lowered into the mortar with the shell suspended on the wire leads of the electric match. This runs the risk of the e-match slipping or pulling out of the lift or quickmatch, and presents a serious friction ignition risk. The method I prefer is to leave the full length of quickmatch attached in place, then slit the match piping about 6" above the lift pocket, insert the electric match, and tape over with masking tape. Prior to installing the e-match, a single loop knot is tied in the wire leads about a foot above the matchhead. The wire leads of the e-match are then run parallel to the quickmatch shell leader and *taped tight* against the quickmatch with masking tape in at least two places, one just above the knot in the wire. This way the tape prevents the knot from slipping past and stress-relieves the shell weight off of the electric match. The quickmatch, taking the weight of the shell, is used to lower the shells into the mortars, and is left in place to burn away when the shell fires. Some Oriental ball shells have a loop of twine on top where the wire leads could also be tied, but many shells do not have this loop of twine. Many have the quickmatch taped against the top of the shell with a strip of pasted paper, and some have nothing at all. On the very large and heavy shells (8" and up), a thin rope is usually provided which is convenient for supporting the e-match lead wires. WO

CHARGING HEAVY ROCKETS

TESTING ELECTRIC MATCHES

AND TESTING THE TESTERS

Electric firing of pyrotechnic displays has become widespread and the predominant method of ignition, and for good reasons; there are more and larger fireworks displays than in the past, more displays are choreographed to music and require precise timing, there is more consideration to operator safety, and the realization that an electrically-fired display is better appreciated by the audience.

Consequently, electric matches ("e-matches", or incorrectly "squibs") are being used by the hundreds of thousands, and perhaps millions each year. Correct and safe handling and application is extremely important, but will not be discussed here at this time. However, pyrotechnicians need to know some basics of ratings, measurements and test instruments used with e-matches.

Each e-match type from every manufacturer may have differing characteristics, but several basic electrical specifications should be understood in order to get a practical "feel" for the product.

1) ***All-fire current.*** This is the current in Amperes (or milliamperes) that will always result in the ignition of the match. Be aware that this specification may be different for series or parallel wired circuits. Typical values range between 0.5 and 1.0 Amperes (500 and 1000 milliamperes). Associated with this current is the time duration that the current must persist for ignition to occur, and may be from 5 to 20 milliseconds (.005 to .020 seconds), and depends on the magnitude of current flowing in the match. Another related specification which is especially important to designers of C-D, or capacitive-discharge firing systems, is the energy required to ensure firing; this is on the order of 10 millijoules (.01 Joules) per e-match. Note that I have not mentioned "voltage", as it is the current in the e-match that causes it to fire.

2) ***No-fire current.*** This is the current for which the e-match will never fire, regardless of how long the current flows. It varies with type and manufacturer, but is typically about 150 milliamperes (abbreviated 150 mA.)

3) **Test** ***current.*** The test current is the maximum safe current that the manufacturer specifies for electrical testing. Typically, it is a maximum of 50 mA and includes a safety factor when considering the no-fire current. This value should never be exceeded by any test device, in any test condition, for any period of time.

4) ***Unspecified current range.*** This is, as the name implies, a range of current for which the e-match may or may not fire, and may also be time dependent. Never allow any operation in this range. For the examples above, the range would be between 50 and 150 mA.

TEST DEVICES

Naturally, a measurement instrument for e-matches is electrical in operation. What you are going to measure is the e-match electrical resistance (typically 1.8 to 2.6 ohms), before attaching it to the pyrotechnics, and later for continuity or circuit completeness when attached and wired into the circuit. A meaningful firing site measurement actually indicates the electrical resistance of the circuit, including the wiring, and its numerical value is expressed in ohms. The test not only verifies the integrity of the match, but provides information for calculating the maximum number of matches you can fire at one time.

Circuit Continuity Testers

The simplest tester is nothing more than a battery and a light bulb of some sort. It cannot accurately measure circuit resistance, only whether or not the circuit is incomplete (open) or complete (closed), with continuity between its wiring and e-matches. It is almost useless for a professional technician, and in fact is likely to be dangerous in use, for reasons to be explained later.

Analog Meters

An analog meter is a test instrument having a pointer-type indicator with a calibrated scale. It usually has several resistance testing ranges which are selected by a switch, and is powered by an internal battery. Common analog test instruments are usually multimeters, which also measure AC and DC volts and current. Avoid any type of analog test meter unless it has been verified to be safe on all selectable ranges, especially the lowest resistance range. Blasting galvanometers originally were of the analog type, and are, of course, suitable for pyrotechnic use because of their design.

Digital Meters

Digital meters are recognized by the type of readout that you will see, which is a LCD display. Most digital meters are also multimeters, able to test AC and DC voltages, resistances, often AC and DC current, and are powered by an internal battery. These might be safe for pyrotechnic use. Radio Shack carries inexpensive pocket-type digital multimeters which are convenient to use in the field.

Built-in Equipment Testers

Firing systems and controllers often have built-in test circuits, and must be checked to verify that the test current is less than the maximum safe value under all conditions.

THE HAZARDS

In order for a test instrument to measure your e-match or circuit it must cause a current to flow in the circuit. Ordinary meters were not designed for use with pyrotechnics and may be dangerous if the test current exceeds the manufacturer's maximum test current rating. For example, I have inexpensive analog meters which produce a test current of 160 mA, which is more than three times the safe test current. A light bulb type circuit tester is especially dangerous since the initial "cold filament" or inrush current may be as much as 10 times the normal, lighted value, and it persists for a period of time long enough to fire the e-match. Firing panels that use light bulbs instead of LEDs for continuity testing are to be avoided. LED testers, if properly designed, may be suitable and safe although they cannot indicate actual circuit resistance nor distinguish between a good circuit and a direct short.

How Can You Tell What Is "Safe"?

First, keep in mind that except for certified blasting galvanometers, all test instruments may be hazardous. Under no circumstance should personnel be near live pyrotechnic material during testing, including testing with blasting "galvos", and therefore assume NOTHING is really safe.

You can perform a very simple measurement of your tester to actually find out what the test current is. You need a DC current meter that accurately reads 0 to 50 milliamperes; this can even be the same "unsafe" inexpensive analog meter that must not be used to directly test an e-match. Connect the DC milliammeter leads directly to your e-match tester or firing panel, and then read the actual test current. Use the lowest resistance measuring range on your e-match tester, as the lowest range produces the highest test current. It's that simple. Most digital meters test at currents of 4 milliamperes or less, while analog meters are much higher.

Design Hazards

A very good guideline to follow when designing test instrumentation is for the test current to remain below 50 mA even if any one component fails in the worst possible manner. This means that if you have only one current limiting component and it fails so as to produce excessive current, a potentially unsafe condition exists. Use multiple components to ensure that any one failure will not result in excessive current. Also consider what would happen if someone replaces a battery with an incorrect, higher voltage type - the design must be unable to accept an incorrect battery.

GOOD DESIGN

Summing up all of the above, remember that except for blasting galvos, no commercial test meters are designed with pyrotechnic safety in mind. New designs must limit the test current under all conditions to less than 50 mA, and in practice, 10 mA is a good design value. Test any meter you intend to use by "testing the tester" with a milliammeter. Built-in testers, as in firing systems, must also be tested, and any design using capacitors might retain a charge that could cause an unexpected discharge. In C-D designs you must provide fail-safe switching and fast discharge of capacitors so that no firing energy is available, except when the product is armed. Consider the worst case failure of components and improper use, polarity and connections. SMB

NOVEL USES FOR STICKY MATCH

Last August I attended the PGI convention. While there, I noticed that many of the exhibitors were using Sticky Match® in place of quickmatch for their lance work. In case you're not familiar with this product, it is a clear plastic wrapping tape about 1 3/4 inches wide with a 1/4" bead of 2Fg black powder sandwiched in the middle by a 3/4" piece of plastic tape. This makes matching lances a breeze compared to older methods of pinning or stapling.

I wanted to try out the Sticky Match® but the only distributor of this product I was able to find was in California, and they were selling it only by the case. Curiosity got the best of me and I ordered a case. When it arrived there was a little more match than I had bargained for; the case contained twenty 60' rolls of Sticky Match®. This is a lot more match than I use in a normal season of backyard fireworks displays, so I began experimenting with other uses for it. Two of the best and most novel uses are described below.

Sticky Match® Roman Candles

I am using the Sticky Match® in Roman candles, not to ignite bundles of them, but in the construction of the candle. If you're like me, you appreciate a Roman candle that uses candle comp. between shots rather than Chinese visco. That rich gold spray of sparks really adds to the beauty of the candles. The only draw-back to this is how to convey the fire from the burning composition to the lift charge when you have a cylindrical shot like a salute, comet, hummer, or similar device in the tube.

This is where the Sticky Match® really makes constructing these candles easy. In the inexpensive Chinese candles a length of small visco runs the length of the candle. The shots are separated by sawdust, hence no gold sparks. This does allow for placing cylindrical shots in the tube without worrying about pre-ignition. In older American and premium candles the shots are separated by candle comp., which acts as fuse. The candle comp. is composed of potassium nitrate, sulfur and mixed charcoal to impart the golden sparks. Refer to Figure 1. As can be seen in the drawing a small lift charge sits below the star and a small amount of meal powder surrounds the star to quickly ignite the lift and propel the star out of the casing. The candle composition fuse separates the shots to prevent rapid firing.

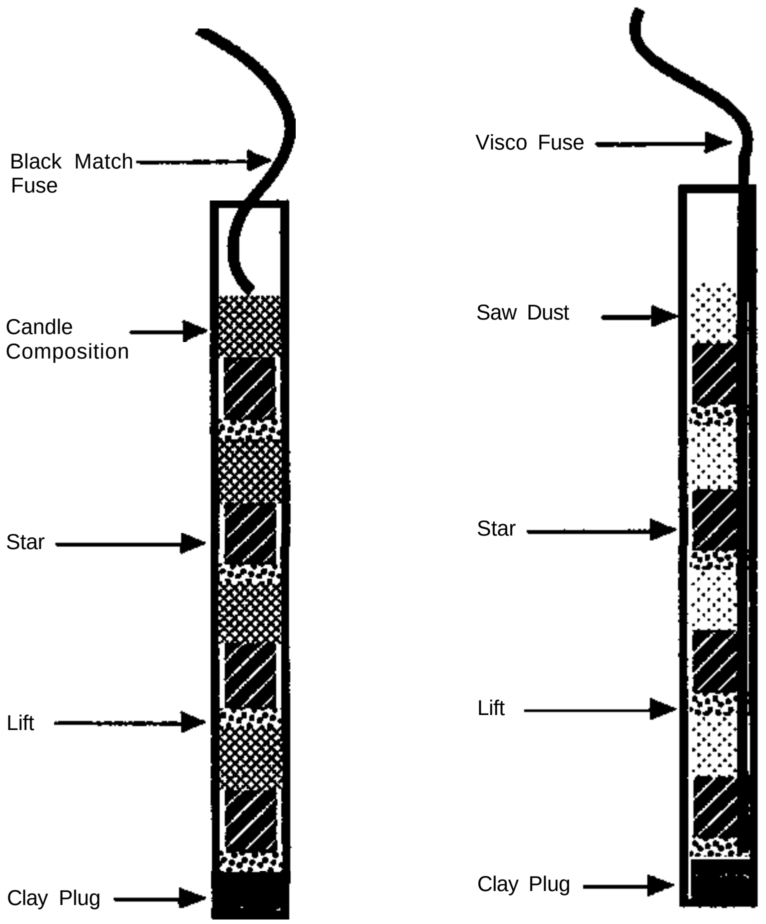
The problem with this method becomes obvious if you try and work a sufficient amount of meal powder around a large cylindrical object like a hummer or salute. This is where the Sticky Match® come in. Refer to Figure 2. In the drawing I have wrapped a Super Big Pig firecracker with a piece of Sticky Match®. The key is to allow a little of the Sticky Match® to overlap each end of the firecracker or other device.

In the case of a firecracker simply wad up the fuse with the Sticky Match® and lay it on top of the lift charge. If a hummer or similar device with a fuse emerging from the side of the case is to be ejected, be sure to run the Sticky Match® over the fuse and it will be ignited as the flame makes its way to the lift charge. Refer to Figure 3.

Sticky Match® Stars

I have also found a use for Sticky Match® with stars. If your stars are slightly undersized for the tube, Sticky Match® can be wrapped around the star to increase its diameter. Another benefit of doing this is that the star doesn't spend as much time burning in the tube as an unwrapped star does as the fire is communicated to the lift charge much quicker.

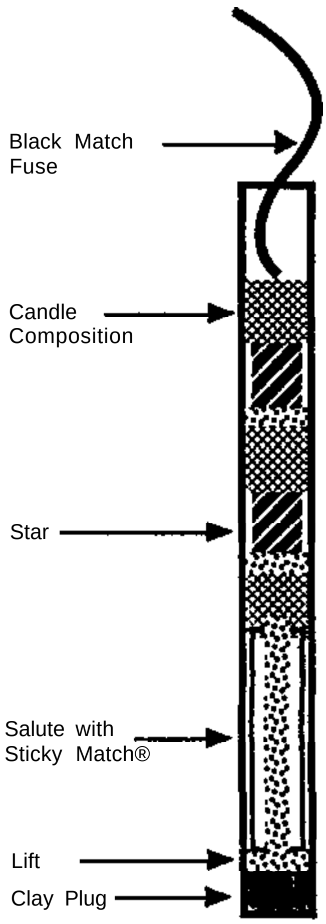
These are only a few uses for this novel product that I have found helpful. I'm sure that 111 find more with the nineteen 60' foot rolls that I have left. BS



Original Roman Candle

Chinese Roman Candle

Figure 1



Sticky Roman Candle

Figure 3

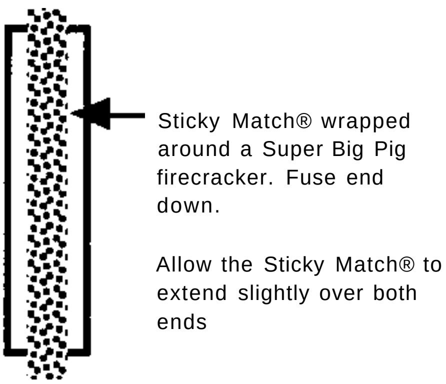


Figure 2

THE NOMATCH® FRONT TECHNIQUE

Most readers know something about the Nomatch system for firing fronts, but it's not clear that everyone understands how it is actually used in prepping a show, nor its benefits.

Nomatch is an ignition system that uses the ultra fast signal speed (6500 ft./sec.) of shock tube to distribute an internal non-destructive, bright light shock signal along the 1/8" diameter plastic tube to terminate inside a Nomatch all purpose igniter (API). These igniters are 5/32" o.d.. x 3/4" long aluminum tubes specially crimp connected to various lengths of shock tube leaders. The aluminum tubes are first formed with an air tool to close one end, then charged with a small amount of ignition powder, and then crimped onto the shock tube output end. The new attachment crimping tool (recently designed for 1999) improves overall performance, prevents powder from leaking back into the shock tube, and eliminates the vent hole of the older version API. By eliminating the vent hole of the older design API, any possible contamination of the shock signal path by foreign material entering the vent hole, is eliminated. Also, removing the vent allows for 100% of the shock energy to concentrate inside the API, improving performance and reliability.

The user inserts the API into the black powder, or quickmatch of the device to be ignited. Success has also been found with directly inserting the API into clay chokes of gerbes and drivers that have a first fire ignition priming to receive the energetic sparks of the API. This has *only* been tried on gerbes that have a plastic end cap to hold the shock tube centered and secure. The API must also be held tight inside the choke hole of the clay nozzle. The alternate method is to relay the API ignition into the gerbe with a short piece of quickmatch. The API functions instantaneously with the shock signal, and performs much like an electric matchhead, producing a spit of flame and sparks. The API differs from an electric matchhead in that it is more energetic and the flame/spark temperature is hotter at 3000°C.

Performance of all ***electric*** match-fired fronts is typically achieved by first prepping all fireworks devices of the front with electric matches inserted into the ignition element of the devices, then taping and/or tying the wires, etc. This work is usually accomplished days or weeks before the show at the fireworks shop. The front materials are then carefully packed in shipping boxes and labeled, then put away in a magazine until the display date. During field set-up of the display fronts, time consuming, and sometimes complex, wire connections are necessary, with circuit testing to finish the set-up. Electric match fronts also require special high voltage capacitive discharge type firing boxes to deliver enough energy to overcome total circuit resistance presented by series wiring of the matchheads and cable wire. This presents a limit to the length of the front depending on the charge voltage of the CD box. Even with the highest voltage CD box available, there is a limit to the length of the front and the number of electric matches that can be fired in series. Not so with Nomatch fired fronts.

Assembly of ***Nomatch*** fired fronts varies slightly but with great time savings benefits. As with the electric match fronts, shop preparation ahead of the display is also typical and necessary. Short lengths of shock tube leaders with attached API's are assembled to the front fireworks devices pretty much the same as would be done with an electric match. In addition, soft silicone rubber couplers are attached to tees, and the shock tube leaders are then plugged into the bottom leg of the plastic tee signal splitters. The shock tube is pushed into the silicone rubber coupler until it touches the barb on the tee. Inexpensive, but necessary rubber finger covers for the index finger and thumb, are available in the Nomatch catalog. These finger tip covers are used to grip the slick surface of shock tube which allows for effortless insertion of shock tube into the rubber couplers. (This is a tool no one using Nomatch should leave home without. But if you do, they are available at all office supply stores). After the Nomatch API leaders are assembled to the front devices, they are packed into shipping boxes and put away in a magazine until the display date, just as with electric matched devices. During field assembly of the display fronts, the tees (already assembled to the API shock tube leaders at the shop) are interconnected with shock tube taken from spools, again plugging the ends of the interconnecting shock tubes all the way into the rubber couplers until they bottom out against the barb on the tees. All connections are checked at this time to make sure none of the API leaders have pulled back from the tees during previous handling. If the interconnection lengths between tees are predetermined and known, shock tube taken from spools can be precut at the shop with the ends capped with vinyl protection caps (available in the catalog). This is necessary to prevent dirt and moisture from contaminating the shock tube core load. Interconnection lengths longer than a few feet should be done in the field to account for set-up variances.

So where are the benefits with Nomatch? The first benefit is realized in safety. Nomatch is immune to those sources of energy that would have no problem igniting an electric match-head: induced currents from lightning, radio transmitters, stadium lighting switch gear, and transformers; stray currents from ground loops; friction from pulling on wires, impact from dropping shells; and electrostatics both in the form of induction from large fields on sheet plastic (or other sources) and conduction from electrostatic discharge of a charged body into the leg wires of an e-match. This first benefit grants peace of mind during storage, transportation, and handling of assembled devices. If the front is to be fired with a Nomatch starter designed to take fire from an electric match (ES-24), the entire front can be set up as inert until it is armed with the insertion of the electric match into the rubber coupler on the starter. The same is true for non-electric hand fired fronts using the Nomatch fused starter (FS-24). The front is only armed and ready to go after the starter is assembled last.

The next benefit realized with using Nomatch is the labor and time savings during field set-up. A crew can set up and interconnect a Nomatch front in about half the time it takes to do the interconnections using wire on an all-electric match front. Nomatch interconnections are plug & play "no-brainers". No worry about high resistance poor wire connections, nor complex series/parallel resistance balancing calculations on complex field layout patterns. No need for ohmmeter trouble tracing. Simply walk the line after set-up to make sure all connections are tight.

The next benefit is that the entire front can be fired with one electric match-fired shock tube starter (ES-24) with a single cue on an ordinary firing panel. However, it is recommend that two e-match starters be used; one on each end of the front, as cheap insurance against any missed or loose connections. On extra long fronts, a few electric match-fired starters are tee inserted into the line and equally spaced along the front. This is done to synchronize timing on fronts longer than 2000 feet. The largest front reported to date by Disney World, has been 6,000 feet with fireworks every 10 feet, and using only 6 electric match-fired starters. It performed flawless. The shock tube signal takes 0.8 seconds to go a mile in one direction which is 5,280 feet. On the Disney front, a CD box was used to fire the 6 electric matches due to the high resistance of 6,000 feet of series wiring even though there were only 6 electric matches. Thus for Disney, there were actually 5 fronts going at the same instant (e-match at each end, 4 in between). Therefore, the entire front fired in less than 0.2 seconds, hardly an eye blink.

Another benefit is that the Nomatch system is waterproof after set-up in dry conditions. Assembly must never be done in the rain. Here, I mean the interconnections at tees and rubber couplers are waterproof should it rain after set-up is complete. The API and starter aluminum tube connections to shock tube are not waterproof. The API's are protected after placement into the fireworks devices, and these devices are normally covered with foil or plastic in the threat of rain. The starters must be protected from rain by placing a small plastic bag over the starter assembly. The bag is then gathered closed and taped against the shock tube. A stick is placed in the ground, and the assembly with plastic bag is taped to the stick such that the opening end of the bag faces down at the ground. This way, water cannot run down the shock tube and into the end of the bag, even if it is closed with tape. With Nomatch, there's no worry about uninsulated wire connections laying in a puddle after a rain storm passes, thereby presenting a short circuit failure or ground current loops.

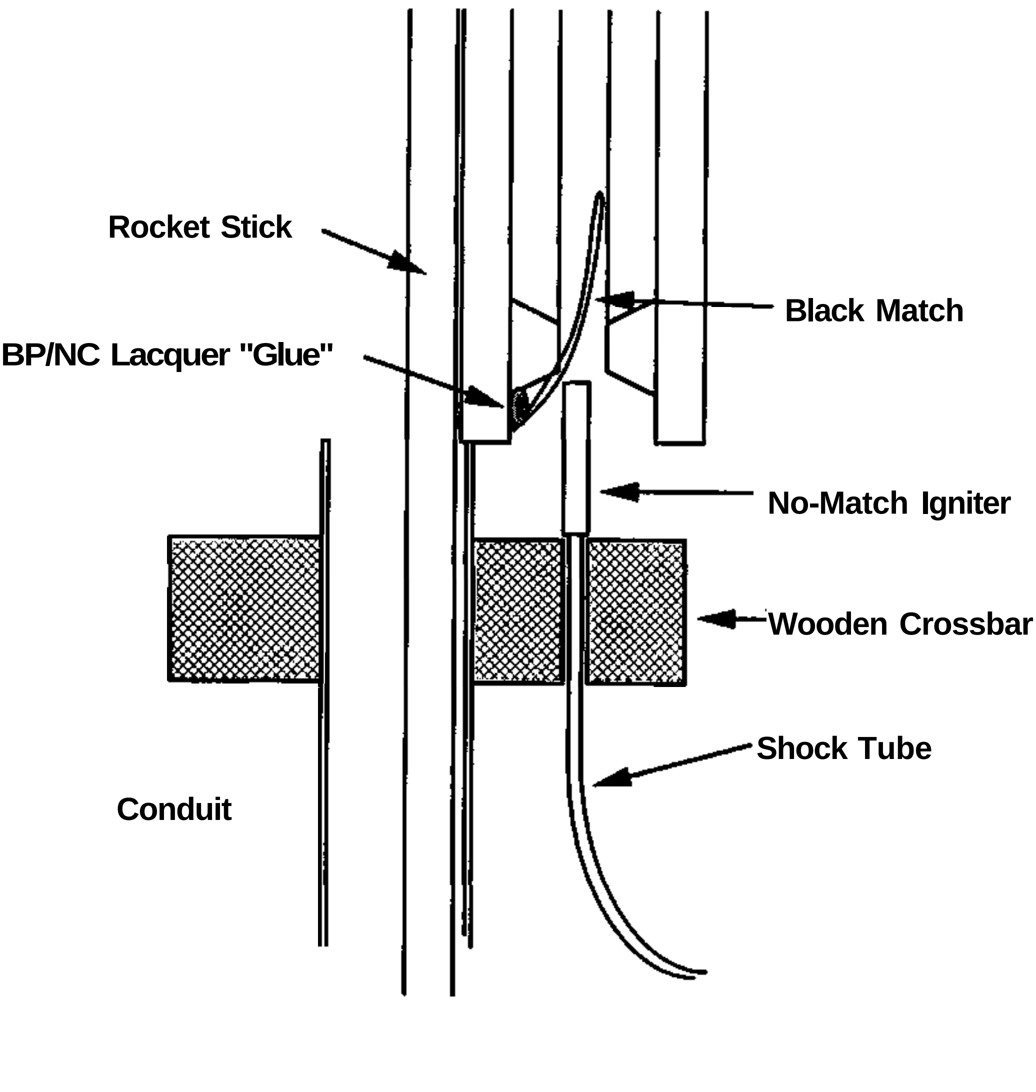
And there you have it! A full description of the Nomatch method of fronts and its benefits. A final note: think flights and salvos of shells; they work just as well. WO

LAUNCHING ROCKET FLIGHTS WITH NOMATCH™

Mark and I decided to contribute a large rocket flight to the PGI convention. Before we really thought too much about what we were getting into, Mark decided to produce the 200 glitter crossettes and the special hole shots to break the headings, and I would create the 50 one-pound Black Powder rockets with attached glitter tail afterburners, assemble them, and figure out how to get them launched simultaneously. Most of my commitment was just a matter of a lot of work, but the launch system required thinking.

I had seen a very impressive demonstration of the simultaneous launch capabilities of Nomatch in Weedsport in the summer of 1996, so I contacted Bill Ofca and asked if he thought Nomatch might be suitable for our project. He'd never used Nomatch to ignite rockets, but offered to provide the materials if I wanted to figure out how to do it. The rest, as they say, is history.

Normally, the fuse for a BP rocket is taped to the stick or in some way fastened to the rocket. This does not present a problem, because the lit fuse is pretty much self-destructing. With Nomatch, however, I would have the problem of a long section of shock tube trailing after my rocket and probably messing up its stability. My solution was to fasten the Nomatch to the launch rack, and have the rocket set down over it, with no direct connection.



In order to make this work, I had to first make the rockets very easy to ignite. This was accomplished by inserting a 2" piece of bare black match up into the rocket nozzle, and holding it in place by gluing it to the inside of the rocket casing below the nozzle with a little Black Powder and nitrocellulose lacquer slurry.

In order to hold the rocket and the Nomatch in a fairly precise alignment to one another, I designed a launch rack made of metal electrical conduit and wood. A wooden crossbar was drilled to fit the conduit, and fastened in place 1/2" below the top of the conduit. This crossbar had another 9/64" hole drilled through it parallel to and 1/2" away from the conduit. The Nomatch igniters were then threaded down through this hole, leaving the metal igniter sticking up next to the conduit. When the rocket stick was lowered into the conduit, the top of the igniter was just at the nozzle of the rocket. See the illustration for a cross section of how this looked.

The first test of this system worked flawlessly, as did the second test, and the third test with a flight of three rockets. By this time, the production rockets with full headings were beginning to come off the line, and so we splurged and fired a final test flight of five rockets. Again it worked flawlessly. By this time we were getting very close to convention time, and had to really grind to get all of the rockets and racks done. Finally we packed it all up and headed for Amana.

During the setup for the final show, we lugged the racks out into the field, pounded in fence posts, and mounted the racks. Each position was fitted with its Nomatch igniter, and the igniters were strung together with tees and lots of shock cord. Each end was then fitted with E-match initiators, and the wires strung back to the control panel.

Finally, late on Friday afternoon, it was time for the rockets themselves. A small crew sat in the shade and taped the sticks onto the rockets, while I ferried them out and loaded them onto the racks. There is a picture of me loading the final rocket into one of the ten-rocket racks on the August page of the PGI 1998 calendar. You can easily see the Nomatch leaders and tees in the picture.

Then it was time to wait. Finally, well into the second half of the show, the moment came. With a whoosh, a row of rockets rose as one in a wall of glitter, and 200 glitter crossettes burst. It worked! After the show I went down to retrieve any mis-fires, and to my delight there were none! Nomatch had achieved simultaneous perfect ignition of all 50 rockets! So is Nomatch suitable for rocket flights? I'd say so... TD

STICKY MATCH™ AIDS SET PIECE CONSTRUCTION

The world of fireworks is about to change dramatically. Your days of spending hours taping quickmatch to lances is over. For hundreds of pyrotechnicians who spend laborious hours tediously assembling set pieces, a revolutionary new design of fuse now can cut preparation time by well over half. Say hello to Sticky Match™!

According to its developers, Sticky Match is the greatest fireworks industry invention since the electric match. Its outstanding feature is that it is self-adhesive when being attached to lance, and the lance is visible through the match! And it doesn't have to be pierced!

Sticky Match is said to be waterproof, so there's no worry on those nights when the dewpoint kicks in and everything gets soggy. They say it will even work in wet weather. They say it is easier to handle than quickmatch, and the ability to see through to the lance is a big plus.

No smoldering paper is left under the set piece because Sticky Match is made of plastic, which is consumed in the burn. This should help in indoor applications, or sensitive outdoor areas. Smoke emissions are said to be less than 50% of old quickmatch. RD

NOMATCH™ DELAYS

IGNITING VISCO FUSE

Experimenting with Nomatch can lead to new discoveries. Such a discovery was recently reported that there is a lot of excitement being generated by the fact that Nomatch API's (All Purpose Igniters) can reliably ignite visco fuse! The technique is simple. The visco fuse is first trimmed with a razor blade to expose a fresh cross section of the visco fuse powder core. This end of the visco is then inserted into a B&C Products silicone rubber coupler (splice) to the length mid point (catalog item SS-100), and the other end of the rubber coupler is wiggled onto the end of the API until it meets the visco in the center. The visco fuse and the API fit snugly into the rubber coupler and do not easily pull out. The coupler is translucent so one can see how far each piece is inserted. When the shock tube fires, the API spits out flame and sparks at 3000°C to ignite the visco in less than a millisecond (1/1000 of a second).

After hearing about this, I set about to do some experimenting. I tested a few dozen pieces of 3/32" o.d. American made visco this way, and sure enough, ignition was successful with each trial. This discovery alone opens up the mind to a vista of display possibilities. While I didn't have any Chinese visco to test, I feel confident the same success can be obtained. Interestingly, my experiments did not require any special priming of the American visco. However, priming with nitrocellulose lacquer and fine grain black powder (or meal dust) can only enhance the results. Imagine all the wonderful Chinese fireworks items that can be used for simultaneous ignition by the Nomatch system. Imagine a flight of 100 rockets lifting off in unison! Rocket flights are an especially exciting new phenomenon now with Nomatch, as the rubber couplers and shock tube API's will de-couple and snap out of the way at the instant of visco fuse ignition! Imagine 20 or more 90 shot Silvery Swallow cakes, hot glue mounted to squares of plywood, and spread out in a line of 100 feet! Snap! The shock tube fires with one ES-24 electric match fired starter, and at 6500 feet per second, all the visco fuses are ignited at once.

IN-LINE DELAYS

Thinking about these possibilities led me to imagine how a delay could be made with Nomatch components and a length of visco fuse. I began to experiment and discovered a way to make a Nomatch in-line shock tube delay: one that pauses the shock tube signal and then restarts the shock tube after the visco burns through. This is something the user can do, as B&C Products has no interest in making these. I first cut a length of visco fuse that will produce the desired time delay, and trim both ends at a slight angle to expose the powder core. I then dip each end quickly in a thin nitrocellulose lacquer and immediately roll it in black powder dust (meal) also making sure the ends are covered. It is then set aside to dry for 24 hours. Next I take an ES-24 electric match fired shock tube starter. Readers who have used these know there is a crimp in the aluminum shell that forms a shallow cup and a cross shaped slit-gap when viewing into the end. This slit normally allows the flame of an electric match (coupled to the shock tube starter-shell with a silicone rubber coupler) to penetrate into the shell to ignite the starter powder. The starter then pops instantly to start the shock tube. Using an artist small paint brush, I coat the ID of the small crimp-formed cup on the end of the ES-24 starter shell with nitrocellulose lacquer, and then dip it into black powder dust to form a primer coating. This too is set aside to dry for 24 hours.

Final assembly requires a shock tube API, 2 silicone rubber couplers (SS-100), the visco delay fuse that was primed on each end, and the ES-24 shock tube starter that was primed and dried. First, I wiggle a silicone coupler onto the flat end of the API until it is centered along the length of the coupler. Next, I insert the visco until it is close to the API inside the coupler. I then wiggle the second silicone rubber coupler onto the primed ES-24 starter shell until it too is in the middle of the coupler. Then I insert the other primed end of the visco into the second rubber coupler until it meets the ES-24 starter shell in the middle. It is important that 2 rubber couplers are used to prevent an API pass fire condition. I made only a few of these delay assemblies and they all functioned perfectly! The basic idea is to ignite a visco fuse with a Nomatch shock tube API, and when the visco burns to its end, the black powder priming performs as a spit of fire (much like an electric match would) to ignite the ES-24 starter, thus re-starting the shock tube signal.

This type of in-line delay might be useful for firing multiple fronts after firing the lead-in shock tube, or multiple single fireworks items (also assembled with API shock tube igniters). Lead-in shock tubes can be fired with FS-24 fuse-fired shock tube starters, or with ES-24 electric match fired starters. The Nomatch system consists of API's assembled to one end of shock tube (available in various lengths), shock tube starters mentioned above, spooled shock tube (500', 1000' or 2500') for lead-in and runs between tees, reusable plastic signal-splitting tees, silicone rubber couplers (splices), shock tube leaders with a starter on one end (fused or electric) and an API on the other end (available in various lengths), and rubber finger tip covers used for gripping shock tube and preventing fingers from sliding while inserting shock tube into couplers. All Nomatch components are inexpensive. WO

FUN WITH NOMATCH™

Nomatch had brisk sales to licensed display operators in 1997. Many have now discovered the awesome speed and power of a shock tube ignition system for shooting fronts, but yet to be discovered is the usefulness of Nomatch as a hand fired show tool.

For those readers who are just now tuning in, Nomatch is an ignition system I developed that utilizes commercially made shock tube lead-in line to send a tiny non-destructive detonation signal silently through 1/8" o.d.. flexible plastic tubing at an incredible rate of 6,500 feet per second! The signal is tiny, non-destructive, and silent; the hollow core of the plastic tube is 1 mm i.d. and dusted with a mere .018 grams per meter of an insensitive explosive material. This equates to 450 one-millionths of a gram per inch!

Shock tube is a super-safe material that is immune to most forms of energy that would have no problem igniting most other forms of pyrotechnics. Enormous quantities of flame, friction, impact, RF energy, etc. have no effect on igniting shock tube. Shock tube can only be set off with a percussive high temperature flame that applies high pressure and high flame temperature simultaneously (percussively) to the core of the shock tube.

Nomatch is a patented product (U.S. Patent No. 5,710,390) that provides for positive reliable initiation of the shock tube signal via special starters attached to shock tube. The Nomatch family also includes all purpose igniters (API) that are factory attached to the terminating or output end of shock tube to function much like electric match heads by providing a spit of high temperature flame and sparks. Also available are Nomatch signal Tees that split the signal down different paths and directions, and silicone rubber splice couplers that provide for an easy plug-in system. Set-up time for fronts can be half of that normally experienced with wiring a totally electric match front. The Nomatch front can easily be started by electric matches or by hand firing simply by purchasing the appropriate Nomatch shock tube starters. Shipping of Nomatch is safe and easy because of its 1.4S DOT classification. OK, now that we know a little about the Nomatch ignition system, let's explore some of its fun aspects.

DISNEY 3,600-FT. FRONT

The folks at Disney purchased Nomatch last year for their July 4th extravagant display. They reported they had used Nomatch to set-up and fire a 3,600-foot front with fireworks set at every 10 feet. In the past they had used all electric matches with incidences of segmented failures. This year's Nomatch front system was fired with only six electric matches equally spaced along the front. They reported that Nomatch was easy and fast to set up and had functioned reliably! Nomatch was fun and a pleasure to use!

NOMATCH SAVES THE DAY

On a large $20,000 display in Pennsylvania last July 4th, one crew reported how Nomatch had "saved the day" for them. Their company had booked too many large displays and did not have enough electrical firing equipment to go around. Nomatch was used to hand fire ten flights of 10 shells each, several "B" cakes, and to start the grand finale. This large display was fired entirely by hand in 20 minutes by an understaffed crew. Here's what they did. They purchased a bag of 20 each Nomatch API-24" igniters, a bag of 50 silicone splice couplers for shock tube, a bag of 20 each Nomatch FS-24" fused shock tube starters, and a 1000' spool of shock tube. Total cost of this order was $70.30 in materials. They used about half in the display or about $35 worth of Nomatch.

When they set up the display, they ran spooled shock tube lead-in line to each of the flight racks, and then back to the area where the lighter would be hand firing shells from the battery of steel mortars. Strips of lath wood were set-up vertically and partially driven into the ground with a hammer next to the steel mortar battery. The fused starters, with 24" of shock tube, were taped to the top of these waist-high wooden sticks. The shock tube lead-in line, running out to the remote flight racks, were splice-coupled to the fused starters on the sticks, with silicone rubber couplers. The order of flight firing in the display was arranged left to right in the order of arrangement of the sticks with fused starters. At the flight racks, the end of the shock tube lead-in line was tied around the end of the rack and knotted to prevent pull-out should someone trip on the lead-in line. This end of the lead-in line was then splice-coupled into a API-24" igniter. The small aluminum tipped end of the igniter was then inserted into the end of the paper piping on the quickmatch chain of the flight. Care was taken to assure the API was against the black match and not caught between the wax paper and craft paper layers. The quickmatch paper pipe was then taped to the shock tube to close the end of the quickmatch.

The Nomatch set-ups for the other show segments, i.e. the "B" cakes and finale, were done essentially the same way. During the display, the hand-firing lighter would simply step over to a waist high vertical stick with a fused starter taped to the top, pull the safety cover, and ignite the Brazilian Mantitor igniter cord of the shock tube starter, with his fusee. Three seconds of fuse burn later, "pop" and a streak of light at mach-9 flashes across the field in about the same time it takes an electric match to function after a button is pressed. The quickmatch chain of the flight ignites and the 10-shell barrage is in the air!

All Nomatch segments of the display functioned perfectly. I know, I was there to witness it all. The crew was enormously happy and impressed with the power of Nomatch. The non-electric show is here, and a reality when there's not enough electrical firing equipment to go around, or for those who believe it's a pain to set-up electric panels and wiring on a hand-fired display.

Of course, keep in mind, there is also electric match fired shock tube starters for those even bigger displays with the fancy firing panels! In these situations, a hybrid display combining Nomatch and electric matches is useful to cut down on the set-up time and labor. WO

MAKING CRACKERS

EXPERIMENTS IN PYROTECHNICS

CONSTRUCTING SET PIECES & OTHER DEVICES FROM CONSUMER FIREWORKS

This article describes an experiment in both the social sciences and pyrotechnics. We decided to hold an Independence Day party to build and shoot our own firework constructions assembled from Class C items.

MOTIVATION.

Ever since the prehistoric days when our ancestors lived in caves, humanity has had a love-hate relationship with fire. We use it to cook and to kill. We use it to destroy cities in war and to celebrate festivals in times of peace.

Fireworks are very much a part of Independence Day, celebrated in the United States on July Fourth. Even those who neither see nor think of fireworks throughout the rest of the year would consider the holiday to be empty without fireworks in the sky.

We have observed that most adults consider fireworks to be a thing that you go and watch at a park. If pyrotechnics are not professional, they are considered to be toys, purchased at stands and fired by children in vacant lots and driveways.

Few adults think of fireworks as something that they can make and enjoy (readers of AFN are pleasant exceptions). We decided to observe what would happen if a group of adults were placed in an atmosphere conducive to low-risk experimentation with pyrotechnics.

DESIGN

The experiment took the form of a Fourth of July party. The guests were invited, but not pressured, into trying to build some interesting new pyrotechnic device by putting together existing "safe and sane" Class C fireworks.

It should be noted that the construction of set pieces and other pyrotechnic devices from consumer fireworks is not a novel idea. It has a long history, and is a frequent topic in AFN.

Assembly from commercial fireworks was chosen to:

- Reduce risk.
- Enhance the probability of success.
- Reduce construction time.
- Attempt to stay within the law.

A work area was set up, equipped with common tools, mechanical components, free "safe and sane" fireworks, and special pyrotechnic components.

The provided fireworks were described, both in terms of what they were intended to do and what extra performance might be coaxed out of them. Samples of some were ignited to demonstrate their performance.

It was emphasized that the builders could use whatever materials were available, in whatever quantity they wished, in whatever configuration they thought might produce pleasing results.

In order to reduce performance anxiety, the organizer (this author) admitted that he had no practical experience in this type of construction; everybody had about equal chances of success.

ITEMS MADE AVAILABLE

An outdoor construction area was set up and supplied with these tools:

- workbench
- drill (battery-powered)
- drill bits (assortment)
- circular saw (battery-powered, midget)
- hammer
- hot glue gun
- extension cord
- tape measure
- pliers
- scissors
- screwdrivers
- staple gun

Safety equipment was available and verbally offered, but not piled up near the tools.

The following mechanical components were made available:

- 4-foot lath (10 pieces were supplied, 8 were used)
- cable ties
- clothes pins
- masking tape
- rubber bands
- string (cotton)
- cardboard tubes (cores from rolls of toilet paper and paper towel)
- duct tape
- spools (from sewing thread)
- film cans (plastic, 35mm film)
- 2x4 scraps
- plywood scraps
- corrugated, from old boxes
- chipboard (plain flat)
- nails
- screws
- hot glue sticks
- staples (for gun)
- thread (heavy duty for carpets and upholstery)

The following special components were made available:

- fuse (visco type)
- igniter cord (Mantitor brand)

SHOOTING AREA
The shooting area was a concrete sidewalk, a traditional location for store-bought Independence Day fun.

Spinning pinwheel fireworks were accommodated by an A-frame ladder with a large scrap of plywood leaned against it. A piece of scrap wood attached to the plywood gave two inches of standoff. Spinners were attached to that scrap with a screw.

The following equipment was available in the shooting area:

- click-start propane torch
- bucket of water
- fire extinguisher (dry chem.)
- garden hose
- spinner support (ladder, plywood, standoff, screw)

In honor of Independence Day, we chose to fly the flag of the Culpepper Minutemen.

SOCIAL OBSERVATIONS
Eight adults attended the party. After chips and dip, the details of the fireworks construction opportunity were announced. All of the males exhibited some interest in construction. The females were interested in watching, but showed no inclination to actually build or shoot anything.

When the construction area was ready, absolutely nobody showed interest in building anything. This author decided to get up and put something together, and proceeded to build a spinning pinwheel device.

Completion of this device seemed to spark some enthusiasm and another male set to work building things. His products turned out all to be wheels, the smallest two feet in diameter and the largest about six feet. Another male joined after about an hour. He specialized in enhancing commercial ground spinners, building three according to one design and one according to another. He also built a pinwheel. The author built three pinwheels, each of a different design, in hopes that one would work well, and a line rocket.

During all of the construction, another male hovered nearby. He seemed to be interested in building something, but vocally expressed his disbelief that he could build anything that would function. Verbal reassurances were unable to overcome his reluctance.

PYROTECHNIC OBSERVATIONS
As a general rule, it appears that consumer fireworks are carefully engineered to produce the effect that they advertise, and absolutely nothing more. If an item is advertised as producing a fountain of fire, don't plan on using it for a driver for a wheel, because the design is probably optimized to produce the fire in as cheap a manner as possible, and that means no significant thrust.

Red Lantern brand "Piccolo Pete" whistles produced so little thrust as to be unusable as drivers for wheels or line rockets. TNT brand "Amazing Fountain" produced nice fire, but insufficient thrust. It is possible that these devices will drive a wheel, if it is precisely balanced and/or several devices are firing at once.

TNT brand "Ground Bloom Flowers" made excellent drivers for wheels. They were also tried as motion bases for TNT brand's "Mad Dog Fire Crackle". One out of three devices built on that principle worked very well. The others appeared to have sufficient thrust, but did not spin. This configuration seems to require a precise weight balance.

Model rocket engines made effective drivers, as one would expect. They must be firmly attached in order to keep them from ripping loose and flying all over the neighborhood.

The "Fire Ants" from China Pyrotechnics were tried as a motion base for a pair of TNT brand "Flashing Fountain" pieces. This didn't work, seemingly because Fire Ants are already built on the edge: adding a little extra weight kept them from spinning.

Lighting an entire package of six Flower Basket brand "Camellia Flowers" at once was very simple and inexpensive, but entertaining.

Due to recent regulatory changes, almost every "safe and sane" device offered for sale was fitted with a visco style fuse. The intent is to reduce ignition from sparks hitting the side of the fuse as well as provide a minimum time for the operator to escape. It also complicated the assembly process since just crossing pieces of visco and tying them together will not guarantee ignition. We got good results by placing the two fuses side by side for an overlap of 1/4" and folding duct tape over the joint.

WHAT SHOULD BE CHANGED, TECHNICALLY?

Next year, we plan to add the following mechanical components:

- aluminum foil
- bailing wire
- counterweight material

The following additional tools would prove helpful:

- wire cutters
- cable-tie installation tool
- trash can (for non-pyrotechnic construction waste)

Next year, we plan to add the following special components:

- black match
- quick match
- steel wool

Since so many of the experimental pyrotechnics were spinning pinwheels, we will invest some time in devising a quick mount and dismount system for them. We also need a better way to manage the fireworks before they are shot. Perhaps a large "ready box" should be built.

TNT brand "Morning Glory" sparkler replacements should be investigated as an inexpensive component of lancework.

TNT brand "Dinosaur Fountains" are pleasant. It wouldn't hurt to try a couple of them as drivers.

WHAT SHOULD BE CHANGED, SOCIALLY?

There was considerable skepticism, or downright pessimism, that a normal person can safely and effectively do something meaningful with consumer fireworks. This attitude is difficult to overcome. It is also somewhat difficult to understand, given that there is no way to lose: all the materials were provided for free; everybody understands that the constructions are experimental, so nobody will call you a fool if the experiment is less than successful; even when a whistle fails as a driver, it still does a great job of whistling.

Next time, we will have some experience to suggest what will and what will not work. Perhaps we should start with a brief discussion of known good techniques and then demonstrate a previously-built example. Add some children. Try to encourage participation by the females.

CONCLUSION

Results were inconclusive. We look forward to repeating this experiment again and again.

DG

CD FIRING BOX FROM SALVAGED PARTS

Part 1 - Basics

"Beware the lightning that lurks in an undischarged capacitor, for it can cause thee to bounce upon thy bottom in a most ungentlemanly fashion." - Unknown

THE PROBLEM

Capacitor Discharge firing boxes are well suited to certain types of electric match ignition and ill suited for others. Experimenting with this technology can be fun and educational, but the cost of a commercial CD firing box can be prohibitive.

CD firing boxes are electrically similar to photographic strobes. Can the strobe unit from a disposable camera be modified to serve as a CD firing box?

BACKGROUND

For more information on Capacitor Discharge firing boxes, consider perusing the following articles:
- *Understanding and Using Capacitor-Discharge Electrical Firing Equipment,* Best of AFN III, pg 159
- *Adiabatic Heating of Bridge Wires,* Best of AFN III, page 185

Other helpful articles:
- *Electric Matches and Squibs,* Best of AFN III, page 155

SAFETY PRECAUTIONS

CD circuits work by generating a high voltage, storing it for later in a capacitor, and discharging it all at once. The high voltage is potentially dangerous and the sudden burst of energy from the capacitor is potentially lethal.

The combination of high energy and sudden release thereof make CD circuits as tricky to handle as flash powder. Know and follow the precautions appropriate for high energy electronics.

Once the strobe circuit board is exposed, it is easy to note and stay away from the dangerous parts (all parts are dangerous). While the disposable camera is being dissected, take care that you don't touch the circuitry by accident. It might be a good idea to wear rubber gloves and eye protection, in case plastic parts or springs jump out.

Avoid touching the flash lamp's glass envelope with your hands. Skin oils will stay on the surface, and cause hot spots that might make the lamp shatter.

Do not look directly into a flash lamp as it fires. The intense light, rich in UV, can damage your eyes.

SELECTING A DISPOSABLE CAMERA

There are numerous manufacturers and models of disposable cameras. They are probably all convertible to CD firing boxes, differing only in the nature of the changes necessary to do the conversion.

In order to be able to provide exact directions, this article deals with just one particular model, the "Kodak FunSaver 35 with flash". The camera is 120mm wide, 55mm tall, and 30mm deep. The plastic body of the camera is boxy, with square edges. The body is enclosed in a cardboard box. It has a switch that you slide and hold to charge the flash.

This article does <u>not</u> deal with the "Kodak FunSaver Pocket", which is slightly smaller, has rounded corners, and has the plastic box partially wrapped in a sticker instead of a cardboard box. The FunSaver Pocket uses an entirely different flash circuit. You press a button to start the charging process, and the camera recharges itself after every shot. The automatic recharge is a hazard rather than a feature when making a single-shot firing box.

If your camera differs in any way from the one described in this article, you may have the wrong model, or the manufacturer may have changed his design. In such cases, you are on your own. Proceed with extreme caution.

SALVAGING THE FLASH ELECTRONICS

Remove the plastic camera body from the cardboard box. Discard the box. Check the battery compartment in the underside of the camera. If the battery is missing, put one in, a 1.5v. AA penlight cell; a picture engraved on the case shows which way it goes in. Find the "charge" switch on the front of the camera and slide it to the "on" position and hold it there. Watch the "ready" lamp until it goes on and stays on steadily. Release the "charge" switch. Now remove the battery and save it for later use. Point the camera away from you and release the shutter. The strobe should flash and the "ready" light go out. This accomplishes two things: we now know that the unit contains usable parts; the energy storage capacitor in the strobe is now mostly discharged. It is time to dismember the camera. This is a good time to put on rubber gloves. The energy storage capacitor still contains about 40 volts, which is plenty to throw a nasty spark.

Hold the camera with the back facing you, as if about to snap a picture. The right side is a compartment that holds the take up spool. If the photofinisher hasn't already pried the door off the compartment and discarded it, do so. Then grasp the right side of the back and pry that off the rest of the body; it has two latches along the bottom and two along the top. Pull hard enough and the back will open like a door, hinged on the left. Pull the hinge tabs out of their slots and throw the back away. This exposes the feed reel in the left compartment. Throw that away. Pry off the clear plastic top and discard; there is one latch in the back and three in the front. Molded extensions of the clear plastic top also reach down and hook into gears and springs. You might need to pry with a screwdriver. Little gears may go flying into space so protect your eyes.

Turn the camera around so that it is facing you, as if to take your picture. You want to remove the plastic piece that covers the front. Examine the left edge and you will see a space between the front cover and the front of the chassis. Pry apart at that point and it will snap, lifting up a little. Keep tugging and it should snap again, the whole front coming off in your hand. Throw it away, along with any loose parts that fall or shoot out.

The right one third of the camera contains the flash circuitry on a board that is roughly rectangular, with an extra finger extending towards the left. Now we have to get it out without getting electrocuted.

The shutter assembly is halfway down the front of the body and about one third in from the left. It has two red trigger wires going from metal contact strips over to the flash circuit board. Using insulated diagonal cutters, cut the trigger wires from the shutter contacts, leaving the wires that attach to the circuit board.

Locate the latches that hold the flash circuit board to the body and cut them off; there is one on the left finger of board that extends towards the shutter and another on the top right corner. Then turn the camera over on a soft insulated surface, letting the board fall out. Dispose of the body and any leftover parts. The circuit board and attached electrical components are all that you want to keep.

Take a resistor, anywhere from 3K to 15K and 2W or better. Use two pairs of insulated clip leads to put the resistor in parallel across the large energy storage capacitor. This will dissipate the remaining charge in the capacitor. Measure the voltage across the capacitor. When it hits zero, which should only take a few seconds, you can take off the rubber gloves.

SO, WHAT DO WE HAVE?

Fig. 1 depicts the circuit board for the flash, as salvaged from a FunSaver. A reverse-engineered schematic diagram appears in Fig. 2.

The circuit is composed of four areas: an inverter to generate high voltage, the energy storage capacitor, a triggering mechanism, and the actual flash lamp. We will soon examine exactly how it works.

Do not be tempted to follow the schematic and cook up one of these from scratch. Inverter and strobe circuits often use oddball components, especially transformers. It's

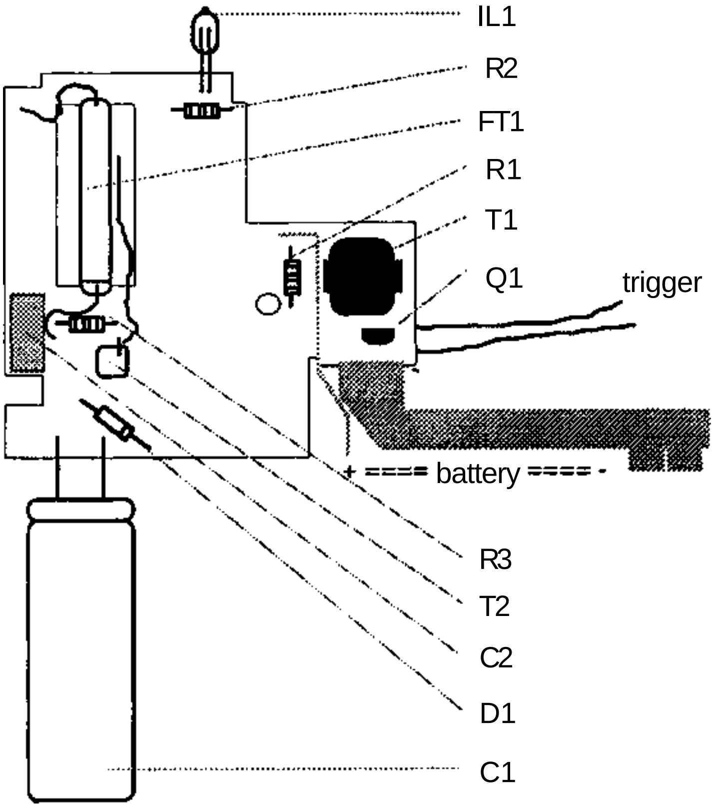


Figure 1 - Drawing of the flash circuit board, component side

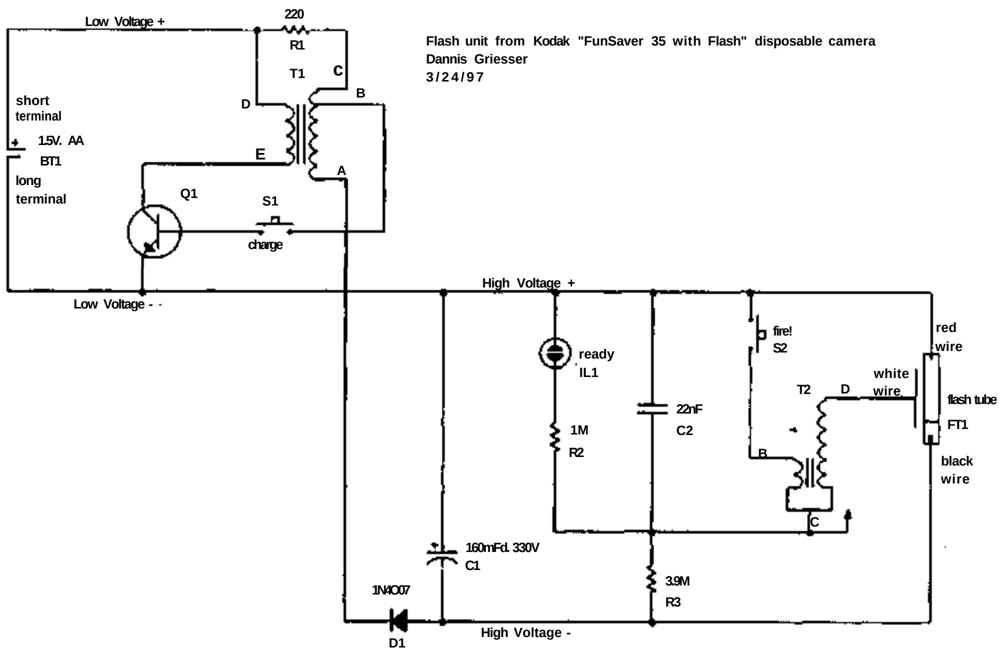


Figure 2 - Flash circuit schematic diagram

much easier to find one of the disposable cameras and cannibalize it.

UNDERSTANDING GAS DISCHARGE TUBES

The circuit contains two gas discharge tubes. Understanding how they function is the key to operation of a photographic flash unit, and thus how the flash can be modified.

We will start with a discussion of the common NE-2 neon lamp. This is a small tube that has two leads that go through the bottom of the glass envelope and attach to metal electrodes inside the lamp. The neon gas that separates the electrodes within the tube makes a poor conductor of electricity. You could try all day to pass 75 volts through the NE-2 and it would act like an insulator. But if you crank the voltage up high enough, the gas ionizes and suddenly turns into a good conductor. This is called the "turn-on threshold" voltage, and is roughly 90 volts for a NE-2. We would see that as an orange glow in the tube, and a meter would indicate that there is plenty of electricity flowing through what was formerly an insulator.

Once the tube fires up, it continues being conductive, even if the voltage is reduced below the turn-on voltage. When you drop to about 60 volts, the NE-2 goes out. This is the turn-off threshold. In order to start it up again, you must get back up to the turn-on threshold. This is an example of the phenomena called hysteresis.

The flash circuit uses a miniature neon lamp, similar to the NE-2, for the "ready" light. The lamp is actually about half the size of a NE-2 and has a higher turn-on threshold of roughly 180V.

The other gas discharge tube in the circuit is the flash lamp. It is a thin cylinder 22mm long, filled with xenon gas instead of neon gas. The electrodes exit at opposite ends of the tube. Like the other gas discharge tubes that we have discussed, the xenon lamp has a threshold at which it will suddenly begin to conduct electricity, but the turn-on threshold is even higher for the xenon flash lamp. Just like the neon lamp, it acts like an insulator until you hit the threshold, then it ionizes and conducts well, even at a subsequently reduced voltage. The nice thing about the xenon tube, however, is that it makes a nice white light well suited for photography.

If you so desired, you could make a flash unit that worked by accumulating energy in a storage capacitor until the turn-on threshold voltage of the xenon lamp is reached. It would then fire, producing all of that nice light. This is a bit of a problem because it takes a while to generate a high enough voltage to fire the lamp and store enough energy in the capacitor to make the flash long enough to be useful. So you might press the shutter release and a little while later, the threshold would be reached and the flash would go off, too late to do any good.

One could put a switch between the storage capacitor and the tube. The capacitor could then be charged in advance to well over the turn-on threshold of the flash lamp. Since this is part of the preparation, it doesn't matter that it takes a few seconds to build up this potential in the capacitor. Closing the switch would then fire the lamp. The problem with this approach is that a huge amount of energy must be switched. This requires a switch built and rated for large current spikes and high voltages (read "expensive switch").

Most photographic strobes use a bit of a trick. They put a voltage across the xenon tube that is lower than the turn-on threshold, but higher than the turn-off threshold. Nothing happens because the turn-on threshold has not been reached. Now, if only you could start the xenon tube conducting, it will continue to conduct and produce light. All it needs is a kick. This is done by introducing a third electrode to the tube, aptly called the trigger electrode. When the shutter is released, a high voltage pulse is applied to the trigger electrode. The pulse is high enough to start ionizing the tube, but doesn't have enough oomph behind it to produce a usable quantity of light. But awhile ago, we set up a potential that was just waiting for somebody to give it a kick, and the flash lamp burns until it drains enough energy from the capacitor to make the potential across the xenon tube drop below the turn-off threshold.

ANALYSIS OF THE ORIGINAL CIRCUIT

Transistor Q1 acts as a switch, turning power on & off to the primary of transformer Tl in accordance with feedback from T1 applied to the base of Q1.

The oscillation applied to the primary of T1 produces a high voltage at the secondary. This is half-wave rectified by D1 and stored in capacitor C1, which charges to roughly 350 volts.

While C1 is charging up, C2 is also charging, through R3. When C2 reaches approximately 190 volts, neon lamp IL1 starts to glow.

At first, IL1 may blink on & off, because when C2 accumulates a potential sufficient to turn on IL1, it fires, draining energy from C2 until it reaches the turn-off threshold and IL1 goes off again.

When C1 charges to roughly 225 volts, C2 charges from it at least as fast as IL1 drains power from C2; the "ready" lamp stays on.

Releasing the shutter closes SW2, dumping all of the energy from C2 into trigger transformer T2, producing an output pulse of approx. 4,000 volts, which is applied to the flash lamp trigger electrode.

The high voltage trigger pulse ionizes the xenon gas in the flash lamp, which begins conducting. Most of the energy in C1 is poured into the xenon lamp, stopping only when the capacitor is exhausted enough that its output voltage falls below the xenon lamp's turn-off threshold of about 40 volts.

CONTINUED...

So far, we have taken apart a disposable camera, salvaged the strobe unit and figured out what's there and how it works.

In the following parts of this article, we will build two different kinds of CD firing boxes from the salvaged strobe unit. DG

PART 2 - TUBE VERSION

SAFETY PRECAUTIONS

The combination of high energy and sudden release thereof make CD circuits as tricky to handle as flash powder. Know and follow the precautions appropriate for high energy electronics.

Please read and understand all of part 1 of this series before proceeding further.

CIRCUIT MODIFICATIONS

Now that we understand how the original circuit works, we will consider three sets of modifications. Two of the sets of modifications produce distinctly different CD firing boxes. One uses a mechanical switch to transfer the firing energy to the electric matches, the second uses a gas discharge tube as a switch. Both will be presented because each involves tradeoffs. The switch version delivers nearly all of the stored energy to the electric matches. In return, it demands a beefy switch. The tube version does not require much of a switch, and could even be adapted to firing by computer. In exchange, a substantial amount of energy will remain in C1 after the shot.

The third set of modifications applies to both versions of the CD firing box and is discussed in the remainder of this section.

Start by making sure that C1 is really still discharged by putting your clip leads and resistor across it. Measure the voltage across C1 until it reaches zero. Then solder a 1M resistor across it. This is a bleeder resistor to remove the charge when the unit is not in use. It is a rather poor bleeder, taking roughly 17 minutes to discharge C1 from a full charge to a reasonably safe level of 5V. Since the discharge rate of a capacitor is exponential, getting to zero takes an awfully long time.

Note that the original circuit never actually disconnected the battery from the primary of Tl. It leaves the battery in circuit at all times and puts - "charge" switch SI in series with base drive of Q1. I feel a lot more comfortable with positive, mechanical switching of primary power to a project like this. In order to accomplish this, find the cheesy strip of springy metal that forms S1 on the non-component side of the board. Desolder it and replace it with an insulated jumper.

In the sample FunSavers that I used, the original circuit charged C1 to 343 volts. The capacitor is only rated for 330V. This makes me a little nervous. You might want to upgrade that capacitor or take steps to make sure that it doesn't charge too high.

Desolder and discard the two metal strips that form the battery holder. Get a battery holder of reasonable quality and a SPST NO pushbutton and put them in series where the strips once were. The short strip nestled in the cutout in the circuit board is soldered in two places, one of which is purely for mechanical support. Solder the new positive wire to the old connection that actually goes somewhere. The long strip extending out beyond the circuit board is soldered at two places, which are electrically connected. You can connect the new negative wire to either.

The "charge" switch operates at a low voltage and current. Almost anything will do there.

While you are installing a decent battery holder, you might want to use a larger power source, such as a "C" or "D" cell. This will provide more current and should shorten the charge time. But do not increase the voltage. Doing so would increase the output of the inverter, probably stressing C1 and other components beyond their limitations. In fact, even providing a better 1.5V cell increases the charge level. According to my tests using fresh Duracell brand cells:

	AA cell	C cell	D cell
0 to 300V charge time	14 sec	12 sec	9 sec
Charge after 1 full minute	341V	345 V	357 V
Charge after 2 full minutes	343 V	346 V	358 V

Select your new power source according to your lust for short charge time and how far above the rated voltage you are willing to push a 330V capacitor. Over stressed capacitors have been known to explode.

One of the FunSavers that I dissected would sometimes not start to charge when power was applied. Perhaps the "switch in the base drive" trick makes it easier for the oscillator to start up. If this continues to be a problem, I might add a 22nF capacitor between the base and emitter of Q1 to give it a kick. I have seen such a capacitor on another gentleman's reverse-engineered FunSaver schematic and the circuit board is equipped to accept such a part, although my units did not include it. This particular inverter oscillator seems to be quite sensitive to stray capacitance in the circuit. When running on a test bench, with clip leads here and there, it sometimes failed to oscillate, or oscillated such that charging time was in the order of minutes. Shortening the wiring helped a lot.

The half-wave rectification in the circuit cries out to be replaced with full-wave rectification. This should cut charge time in half. I've tried it, and it doesn't work well. The inverter cir cuit is very touchy and with this change either fails to oscillate, or oscillates at too high a frequency. I don't doubt that the circuit could be modified to overcome this problem, but rather than wade into that swamp, I'll simply note that it isn't as easy as replacing D1 with a bridge rectifier.

Either version of the CD firing box will need terminals to which the electric matches are connected via very long wires. Nice 5-way binding posts look classy, are flexible, and cost a bit of cash. Spring-loaded speaker terminals are inexpensive and convenient. You choose.

ON SHUNTING

A shunt is a deliberate short circuit imposed to keep stray electrical energy from unexpectedly igniting an electric match. Both variations on this CD firing box use a resistive shunt rather than a dead short.

The closer a shunt is to the electric match, the more likely it is to be effective. When a shunt is far away from the match, there is the possibility that the wire in between will act as an antenna, picking up induced energy. Shunting at the firing box with a dead short might actually complete the circuit, sending energy through the electric match.

I have chosen to shunt with a small resistor, in the hopes that it will reduce the current that might flow as the result of induced noise. This practice is open to debate.

THE TUBE VERSION

Disconnect the wire that goes from the flash lamp to the negative side of C1. Hook that side of the flash lamp to one of the firing terminals and the other firing terminal to the negative side of C1. This puts the electric matches in series with the flash lamp. If we could get the tube to start ionizing, it will start to conduct, pulling most of C1's charge through the electric matches and the flash lamp.

The photo strobe trigger circuit remains largely undisturbed in this version of the firing box. Just replace S2 with a SPDT momentary-action switch, using one pole and the corresponding NO throw.

The other pole of the new S2, and this corresponding NC throw, is used in series with a 27-ohm 1/2-W resistor to shunt the firing terminals.

The "fire" switch in the tube version should be better than just any switch from the junk box, since it is switching 300 volts dumped out of the trigger capacitor, but it need not be a brute.

The circuit will function using the existing flash lamp to switch the power to the matches. You might consider replacing that lamp, though, with a quench tube.

A quench tube is yet another flavor of gas discharge tube. Like the flash lamp, it has three electrodes, two of which accept a potential and a third trigger electrode. In fact, a quench tube looks like a cross between a short, fat flash lamp and a NE-2 lamp. The true difference between a quench tube and a flash lamp is that the quench tube is optimized to conduct electricity instead of produce light when it is turned on.

The quench tube is used in photographic strobes that want to illuminate the scene with only as much light as is necessary for correct exposure. Such strobes measure the light returning to the camera and determine when there has been enough. But there is still energy in the storage capacitor and the lamp will continue to turn that energy into light until it falls below the turn-off threshold. So the quench tube is placed in parallel with the flash lamp and storage capacitor.

When the strobe decides that the scene has had enough light, it triggers the quench tube, which shorts out the capacitor, wasting enough energy so that the voltage falls below the flash lamp's turn-off threshold and it goes out.

Since a quench tube is better at conducting electricity than a xenon strobe tube, more juice will get to your electric match if you replace the xenon tube for a quench tube.

TRADEOFFS

The trade-off of this version is that electricity will stop flowing through the electric matches when the xenon strobe tube stops conducting. With this particular unit, that's around 38 volts.

The energy stored in a capacitor is:

$$E = (^1/_2)\ C\ V^2$$

where:

E = energy in joules
C = capacitance in farads
V = electromotive force in volts

Capacitors are commonly rated in microFarads, using the symbol µF. A microFarad is 1x10-6 Farads.

When the strobe is fully charged with a C cell, the energy storage capacitor holds:

$$.5 * (160\mu F * 1F/10^{6}\mu F) * 346V^2 = 19J$$

After a shot, the capacitor holds:

$$.5 * (160\mu F * 1F/10^{6}\mu F) * 38V^2 = .12J$$

The quench tube that I tested kept conducting down to 28 volts. After a shot with the quench tube, the capacitor holds:

$$.5 * (160\mu F * 1F/10^{6}\mu F) * 28V^{2} = .06J$$

Replacing the flash lamp with a quench tube squeezes an extra .06J out of the circuit. That's less that a third of one percent. Unless you have a quench tube or two sitting around the house, like I did, it's probably not worth the effort.

Please be aware that these numbers represent the energy expended from storage capacitor CI. The electric matches don't get all of that. You can *see* where a lot of the energy is going; it is turned into light by the flash lamp. After all, that's what a flash lamp is designed to do.

So how much energy actually does get to the electric matches? Several different experiments could measure it. The high tech way is to fire the CD firing box into a power resistor, use an oscilloscope to capture the voltage across the resistor, square it, and integrate it. The low tech way is to fire into a power resistor and note the increase in temperature. That's grist for another article.

CONTINUED...

The next, and final installment in this series will present a design using a mechanical switch to apply the firing energy to the electric matches. DG

All of these changes are summarized in figure 3.

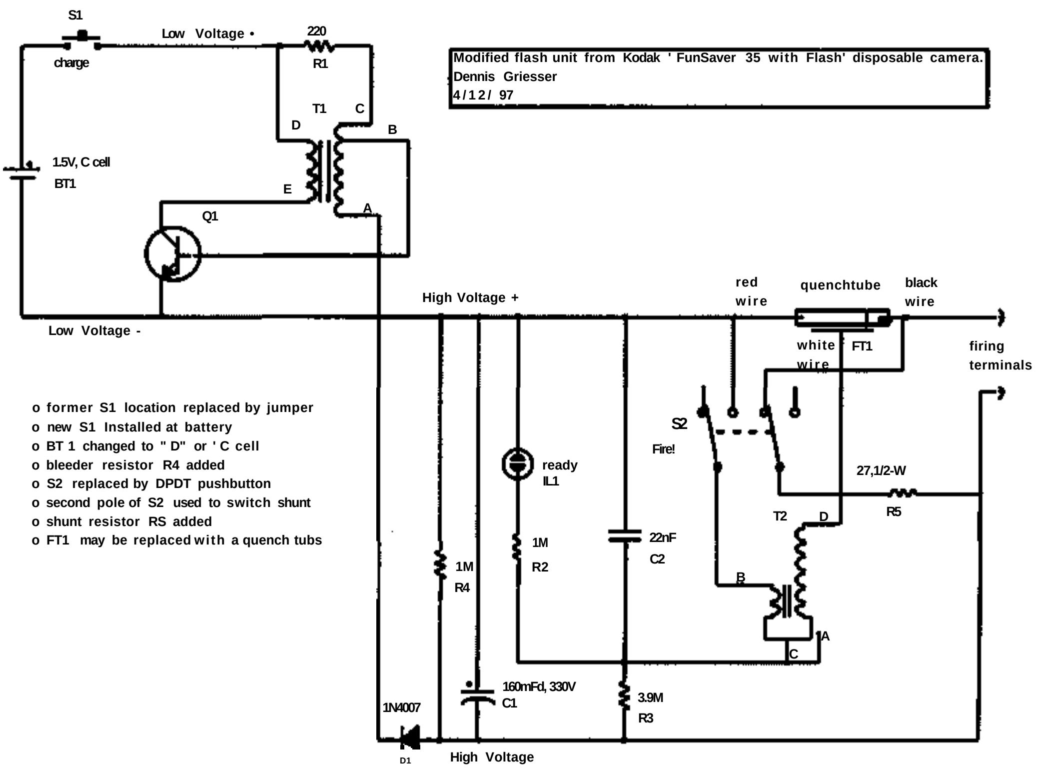


Figure 3 - Tube variation of CD firing box.

PART 3 - MECHANICAL SWITCH VERSION

CONCLUSION

"Amazing Electronic Fact: If you scuffed your feet long enough without touching anything, you would build up so many electrons that your finger would explode! But this is nothing to worry about unless you have carpeting." - Dave Barry, "What is Electricity?"

This final part discusses the use of a mechanical switch to control the application of the firing energy to the electric match.

SAFETY PRECAUTIONS

The combination of high energy and sudden release thereof make CD circuits as tricky to handle as flash powder. Know and follow the precautions appropriate for high energy electronics.

Please read and understand all of Parts 1 and 2 of this series before proceeding further.

THE MECHANICAL SWITCH VERSION

Sacrifice a "Kodak FunSaver 35 with Flash" and perform the basic modifications that are common to both firing boxes.

Remove the xenon flash lamp and trigger transformer T2. Use them for another project some time, or mail them to me and I'll reuse them some day. Remove the trigger wires that went off to the camera shutter. We are interested only in the energy that is stored in C1.

Obtain a SPDT momentary action switch that is capable of switching high voltage and current (see the section entitled "A big honking switch"). This will be the new S2. Hook the pole to one firing terminal. Hook the NO throw to the positive side of C1 through an 8-ohm 20W resistor. Attach the other firing terminal to the negative side of C1. Also attach it to a 27-ohm 1/2-W resistor, the other end of which goes to the NC throw of S2.

Firing through the 8-ohm resistor increases the resistance through which C1 discharges. This, in turn, increases the time constant, providing a longer energy pulse to the electric matches at the end of the shooting wire. It also makes life easier on the firing switch.

The charge "ready" indicator circuit could be simplified, if you so desired - I didn't bother. You might try removing C2 and replacing the R2 and R3 combo with a single resistor calculated such that IL1 comes on when C1 hits firing voltage.

These changes are summarized in figure 4.

A BIG HONKING SWITCH

The one switch that must be capable of switching large amounts of energy is the "fire" switch in the mechanical switch version. There are plenty of switches at Radio Shack and other stores that won't do the job. Light duty switches are likely to fail, sooner or later. If you are lucky, the failure will be due to metal vaporized at the contact point and the switch will simply refuse to conduct any more. If you are unlucky, the contacts will weld themselves closed and when you press the "charge" switch, energy will go into your electric matches. This is a Bad Thing. So the switch must be rated for high current and voltage.

We can come up with a worst-case rating for the switch by assuming 346V fired into 10 ohms.

$$I = V / R$$

where:
- I = current in amps
- V = electromotive force in volts
- R = resistance in ohms

Thus:

$$346 / 10 = 35A$$

I haven't noticed any switches at Radio Shack rated 35A at 350V. Your best bets are auto parts stores and places that carry appliance parts.

But do you really need that high a rating? The capacitor discharges rapidly, and you don't have that 346 volts for long at all! Maybe we can get away with something cheaper.

Some of the strongest inexpensive switches that I have found are snap-action switches of the type that has become synonymous with the name "micro switch". I bought one for 76cent at a surplus store marked as follows:

Matsushita
AV5450542H2
21A 250 VAC
1 HP 125 VAC
2 HP 250 VAC
5A 120 VAC "L"

The 21A looks impressive compared to a lot of other cheap switches, but we are looking for 35A and are using a voltage that's 40% higher. Worse yet, the DC ratings on switches are less than the AC ratings. The only up side is that I don't plan to fire into dead shorts very often. I suppose that this switch will last a bit longer than a lot of other switches, but even its tungsten contacts will melt some day. So I used that switch anyway. It's an experiment. When it fails, I'll let you know how many shots I got out of it.

CONCLUSION

Capacitor Discharge firing might or might not suit your purposes, but by converting the strobe circuitry from a disposable camera you can try it out at little expense. DG

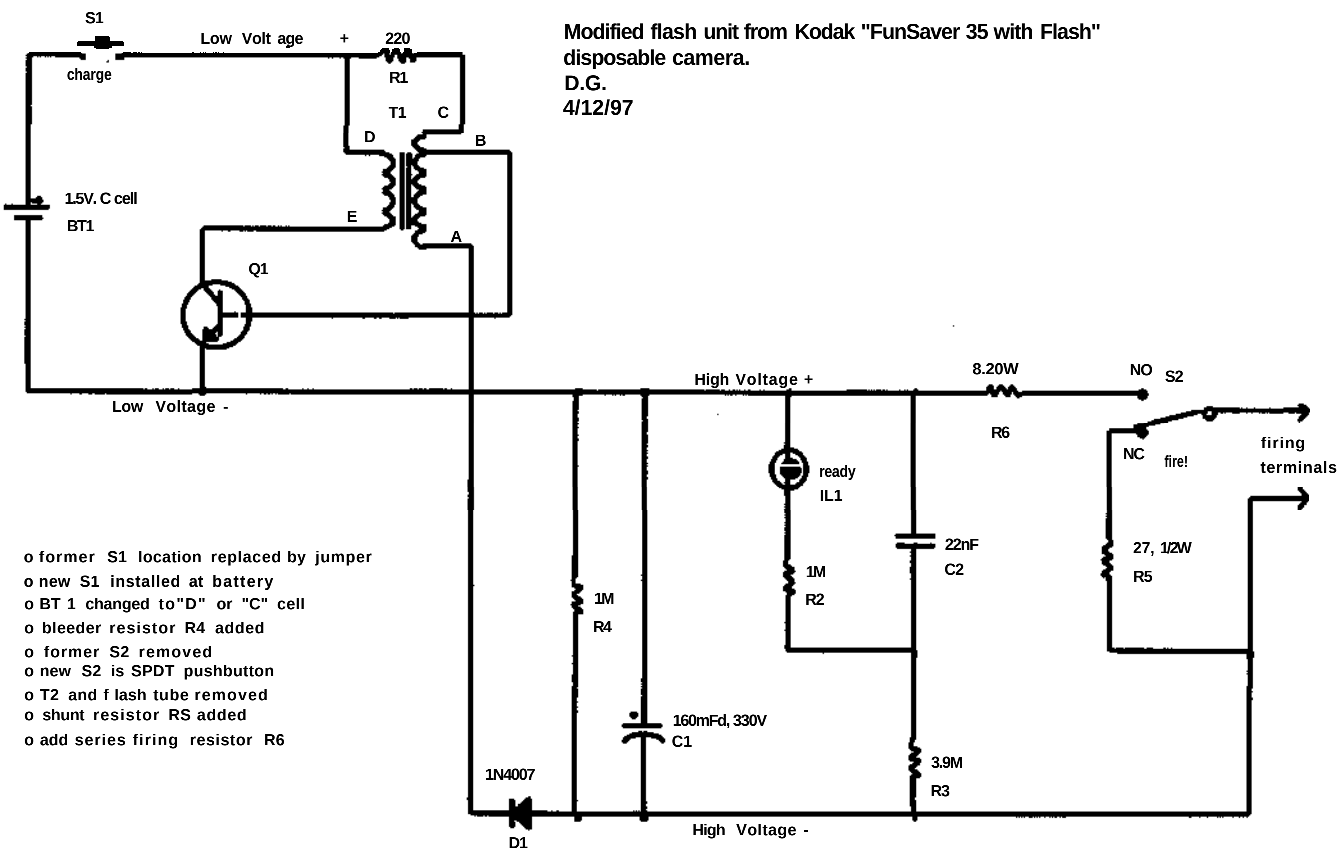


Figure 4 - Mechanical switch variation of CD firing box.

BALL MILLING

SOME SCIENCE IN A BLACK ART

Thirty-three years ago, when I had just become involved in pyrotechnics, I reckoned that there *must* be a better way to reduce chemicals to powder than mortar and pestle. I didn't know there was already such a device suited for amateur use. So I crudely built then what I now recognize as a **ball mill.** It didn't work very well, and it didn't process much material at one time. But it offered an improvement over hours of hand grinding.

Grinding chemicals to reduce their particle size is the foremost reason pyrotechnicians use ball mills. There are other uses; ball mills lend themselves well to mixing and drying operations, too. But size reduction is nearly always why a beginning pyro builds his or her first mill.

Once you decide to build a mill, it soon becomes apparent that there are many opinions on what makes a good mill. Everyone seems to have a different opinion about how ball mills work. Everyone, that is, except the folks who manufacture them.

Manufacturers of ball mills agree both on design and principles concerning the operation of their mills. Across manufacturers, mills look, act, are 'charged', and run nearly exactly alike. Amateur pyrotechnicians can gain from that knowledge.

An amateur pyrotechnician's first ball mill isn't likely to be a very good mill. It's likely to be inefficient. It will probably grind materials slowly, and be noisy and power hungry. It's bound to be pretty inconvenient to use, too.

These potential deficiencies are rooted in the fact that a lot of the information we exchange about ball mills is conflicting or incorrect. Unless you're lucky enough to have access to a well equipped chemistry or biology laboratory, you probably haven't used a well designed mill suited to small-scale pyrotechnic use. Many pyros have never seen a good ball mill before they decide to build one.

Certainly, I had never seen a good mill. Because of the conflicting information available, I decided to research the subject. I discovered that ball mills play an important part in our lives.

Most people use ball milled products - paints, inks, medicines, insecticides, and more. Also, ball mills play an important behind-the-scenes role in our craft; fine-mesh metal powders are manufactured by milling, and most of our chemical suppliers seem willing to supply pre-milled materials. Since ball mills are common in industry, and since manufacturers are very concerned with cost and efficiency, I was sure I'd find a real science underlying their use.

The research went quickly, and rewarded me with opinions and designs which were consistent among several manufacturers. Some companies even supplied me with technical literature and illustrations. What they showed me was a well developed, well documented, and mature technology built more around accumulated experience than theory, but with enough real engineering to keep it out of the category of "black arts". This is a report on what works best for the type of grinding we do, *according to the experts in the field,* and how to build a *really good,* convenient, and efficient mill yourself.

What constitutes a good mill?

A good ball mill should:

- Grind ingredients quickly and to small particle sizes
- Be easy to load and unload, and not messy
- Handle 'normal' batches
- Require little maintenance and few repairs
- Conserve power and grinding media
- Be relatively quiet

"Time-Out" for a little terminology.

Small capacity mills are called "lab" or "pilot" mills, and the type of mill where free containers roll on powered rollers are called "jar" mills; their containers are called "jars". The balls and cylinders of metal or ceramic used inside the jars to do the actual grinding are called "grinding media". The mass of grinding medium and material to be ground is known as "the charge", with the mass of balls known as the "medium charge", and the mass of material to be ground known as the "material charge".

In addition to the performance criteria cited above, a mill should allow our grinding more than one material at a time; that is, a mill should accommodate more than one jar at a time. The grinding jars should be inexpensive enough so that we can dedicate special ones for grinding materials like chlorates. And the cost of startup should fit within an individual's hobby budget.

The first question I asked was, "Will a commercial mill fit these requirements?"

Certainly, most commercially-made laboratory and pilot jar mills will meet all of the performance criteria I listed. But they miserably fail the cost criteria, both for initial setup, and for the cost of jars. An ordinary price for just one 1 1/2 gallon grinding jar for a commercial mill is - brace yourself - over $600. That doesn't include the mill, or any grinding media. A typical mill in a size suited to amateur pyrotechnics costs over $1000. "Rock tumbler" type mills are less expensive, but don't work well for grinding powders.

Well, that seems to point us more or less *directly* to the "build it yourself option! If we're going to build our own mills, we need to know how and why they work. What follows is the detail of what my research into ball mills dug up. I'll finish by giving you details and measured drawings for building your own ball mill of commercial efficiency and capacity, but at a fraction of the cost.

How ball mills work

Method and Myth

Ball mills work by allowing 'balls' of heavy material to fall upon and crush the material being milled. Repeating the action hundreds or thousands of times results in reducing the material to a fine powder. A traditional ball mill does the 'repeat' action by enclosing the whole working mass - balls and material being processed - in a drum, and rotating the drum so the contents are tumbled over one another continuously.

That's pretty, simple. All that's left is:

- what size 'balls'?
- what weight 'balls'?
- should the 'balls' be *balls at all?*
- how far should they fall?
- how fast should they tumble?
- what should they be made of?
- how many of them?
- how much material per load?
- what shape container (jar)?
- how large should the jar be?
- how big a motor to turn it?
- can I afford this?
- can I build this myself?

We get lots of advice from each other, and some from literature. In *Pyrotechnics,* Weingart recommends building a ball mill from a 50 gallon wooden barrel, with 100 lbs of 1" lead balls for the grinding medium. In this, he grinds about twenty pounds of meal powder *by cranking the barrel by hand).* Ooof! That sounds like hard work. And ball mill manufacturers show us that his proportions of capacity vs. material charge vs. media charge are all off-kilter. He had about four gallons of material to grind, and about 1 1/2 gallons of grinding medium in a 50-gallon barrel. Keep those figures in the back of your mind while we take a short excursion into ball-milling theory.

The world, according to ball mill manufacturers

Some pyrotechnists believe a mill works most effectively when balls fall freely from as high as possible. Doing so, they strike one another with great force, and will pulverize very hard materials. This does work best for certain materials, like metal powders, where a "stamping" action is desired. But for general milling, ball mill manufacturers disrecommend this "free-fall" method.

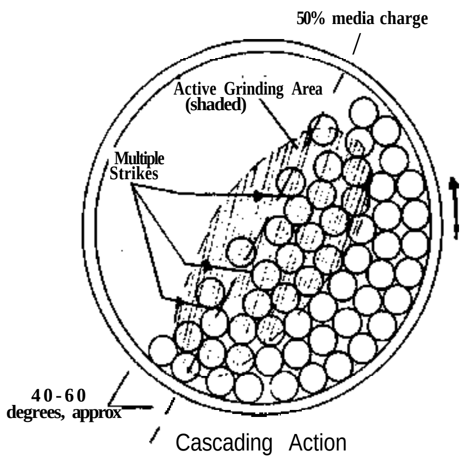
First, since there is only one primary impact for each ball per revolution of the jar, only a tiny amount of material actually gets crushed. Milling is extremely slow. Also, the medium and jar can suffer excessive wear because of the force of the impacts. Mill manufacturers recommend, instead, what's called a "cascading" action.

Cascading is a waterfall-like action where a continuous, fluid sheet of balls and material fall from the top of a pile down a slope to the bottom of the jar. In order to maximize the force with which the balls strike one another, the distance the balls fall should be maximized. This is done by filling the jar 50% full of medium. All manufacturers agree that this amount, known as **the medium charging factor** should vary but slightly, because it offers the longest path from the top of the heap of medium to the bottom. Also, the slope of the heap should be as steep as possible, consistent with keeping the balls each striking several other balls on their way down the slope.

It's this **multiple strike** action where each ball strikes several others on the way down that permits rapid grinding. This grinding action is not reserved to only the surface layer of material. There is a diminishing grinding effect extending to the center of the charge, shown by the shaded area within the charge in **Figure 1.**

The "slope" of the pile is known in construction trades (where material just sits still, in heaps) as "the angle of repose". In milling, where things are constantly moving, it's known as the **angle of break.** The optimum angle of break of the heap is about 40-65° from horizontal. At this angle, balls fall hard and rapidly, but do not break free of the pile to fly to the bottom without hitting others. The correct angle of break may be maintained by a couple of methods.

Figure 1 - Cascading Action



The angle of break will change as the speed of rotation of the jar changes. The slower the rotation, the shallower the slope of the pile. If the jar turns too slowly, balls will simply slide down the sides of the jar, failing to pile up enough to cascade. This causes extremely fast media and jar wear, and is usually manifest by grooving on the inside of the jar, and flat spots developing on the balls. But the jar can spin too fast.

As the jar rotates faster, a speed is reached where the balls actually centrifuge away from the pile, and fly free, without cascading. This speed is called **the critical speed** of the jar, and is calculable for a specific jar diameter and ball diameter. It *does not vary* for different media weights, like lead vs. ceramic balls, but does vary for different ball diameters. Some critical speeds for various jars and media are given in **Table 1,** along with the formula for computing the critical speed.

Table 1 - Jar Speeds in R.P.M

JAR DIA.	BALL SIZE	CRITICAL	OPTIMUM
6"	1"	119	77
6"	1/2"	113	73
5"	1/2"	125	81
4"	*1/2"*	142	92

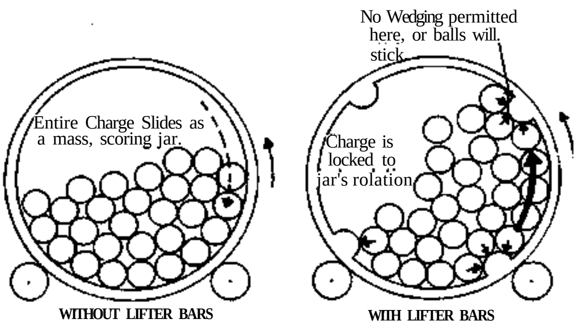
Optimum RPM is 65% of Critical Speed

$$CS = \frac{265.45}{\sqrt{(jar\_i.d.\text{"}-ball\_o.d.\text{"})}}$$

The optimum speed of rotation for a jar is from 45% to 110% of the critical speed, with the variations being caused by factors like the viscosity of the material being ground, and the material itself (how much force is required to grind it). For dry powders, a speed of 65% of the critical speed for the jar/medium is just about perfect. But sometimes, the balls will slip down the jar sides without reaching the desired angle of break, even when the correct speed is maintained.

To prevent the charge from slipping, **lifter bars** are mounted longitudinally in the jar. Lifter bars are very low in height, usually less than one ball-diameter. They are fashioned more like low ribs than paddles, for it is not their purpose to lift and propel balls to the top of the jar. Rather, they serve to "lock" the entire mass of medium and material so that it cannot slide down the side of the jar.

Figure 2 - Lifter bar action



Once the charge is locked to the jar's rotating speed, it can cascade properly. But it cannot grind material unless there is material between the balls when they strike one another. If there is too much material present, it will serve to cushion the blows, and reduce the grinding action. Apparently, there must be an optimum **material charge.**

The ideal material charge is dependent directly upon the **medium charge,** which is, in turn determined directly by the empty capacity of the mill jar. A mass of balls constitutes a mass which is about 60% solid, and 40% space between the balls. If we just ***exactly fill*** these spaces with material to be ground, the balls will be touching (and striking) one another with, on average, *no material between the striking surfaces.* Actually, random actions in the jar will allow some material to be ground, but most of it will seek the available space between balls, and not be ground effectively.

To effectively grind material, we need just enough material covering the striking surfaces so grinding will occur with every impact, yet not enough so that cushioning occurs. There is an optimum amount.

The optimum material charging factor for dry grinding is about 25% of the empty jar's volume. At this charging rate, the spaces between balls are just barely overfilled, but not much extra cushioning material is present. It can be difficult, sometimes, to determine exactly what is the ideal amount of dry ingredients, because some materials, like "stick" charcoal, compact a great deal during the initial phases of grinding.

For ingredients with odd initial shapes or mixed "chunk" sizes, rough reduction to uniform particles should be done before final ball milling. With charcoal, for instance, it's beneficial to break up the sticks to 8-10 mesh before ball milling. A ball mill will break up large chunks, given time, but you run the risk of ending up undercharged, and you may have to add more material during the grind to get the best and fastest grinding action. Wet ingredients are easier to charge, because all of the spaces are filled with fluid, so it's easier to judge volume.

A rule of thumb for wet milling is to cover the grinding medium completely to a depth of one ball diameter. Wet media charging rates can vary from dry rates. Some dry charging rates for various media are listed in **Table 2.** This table gives the amount in pounds of medium per gallon of empty mill capacity in order to achieve a 50% fill. This table is best used when purchasing media. For filling, a table is unnecessary; you can just measure the mill's empty capacity, and use half that much medium. With a mill rotating at about 65% of the critical speed, these charging rates assure maximum grinding speed with minimum jar and medium wear. Experts agree, also, that there is no advantage to running different-sized balls in a jar; all balls should be the same size.

Table 2 - Media charging rates

MEDIUM	SPEC.GRAV.	CHARGE/GAL.
Porcelain	2.38	6 lb
High alumina	3.30	8.5 lb
Zirconia	5.50	141b
Burundum™	3.42	91b
Steel	7.85	201b
Lead	11.35	291b

Charge based on 50% of jar volume.

Burundum is a trademark of Norton Abrasives.

Looking back briefly at Weingart's meal powder mill, we can see that it was drastically undercharged, both with medium and material. He had the respective proportions of medium and material reversed from what would have worked best. And he had (or at least expressed) no idea concerning the most effective speed to crank the mill. The information wasn't generally available when he wrote the book.

To design a good mill and properly charge it, we need to answer the whole list of unknowns encountered earlier. We've answered most of the list by now:

- *What size 'balls'?* All balls should be of the same size. The smaller the balls, the more surface area per gallon of medium, and the more surface area, the faster the grinding action. Balls between 1/2" and 1" in diameter are best for most of the sort of grinding we do. The real issue is whether or not the balls are heavy enough to crush the chemicals we grind. For a mill larger than 4" in diameter, 1/2" steel balls are heavy enough to grind rapidly. Ceramic media work well in 5"+ mills.

- *What weight 'balls'?* The material should be as heavy as possible, consistent with a hardness sufficient to do our grinding but not wear too rapidly. Burundum, zirconia, high-density alumina, and just plain, white porcelain balls are all heavy enough to grind pyrotechnic chemicals in ball sizes over 3/4" in diameter, and jar sizes over 5" in diameter. For smaller mills, or smaller balls, lead or steel balls should be used. Many pyros prefer lead balls because they will not spark; but some fear that lead will wear off into the material.

A properly designed and charged mill will wear the drum and media only very slowly; media wear, even with lead balls, should not be a worry. Antimony hardened lead should be chosen over softer, pure lead. Soft lead will dimple, and limit the fineness of grind. The dimples "hide" pockets of unground material from strikes which would reduce the material, if it was exposed. Harder balls do not dimple as badly.

- *Should the 'balls' be balls at all,* or some other shape? Besides the sphere, another popular shape for ball milling media is the "radiused-end cylinder". It occupies about the same solid-volume in a mass as spheres, and offers a little more surface area per volume. So, it grinds just a bit faster. Radiused-end cylinders are usually more expensive than spherical media, and not tremendously more effective. There is, however, a "hidden" advantage to cylindrical media which we'll discuss in connection with building a mill.

- *How far should they fall?* A 6" inside-diameter mill (gross volume about 1 gallon) is about right for a lot of amateur work. A 6" mill will grind about two pounds (1kg) of dense material like potassium nitrate (11b / pint liq. vol.). Remember that a mill and the medium can be damaged by under charging. If you do a lot of formulation experiments, you need to build some smaller mills. A five-inch mill will grind about a pint of material. A four-inch mill will grind about a cup of material. For a given volume, the efficiency - the grinding speed - increases with the mill diameter. A one gallon eight-inch diameter mill will grind faster than a one gallon six-inch mill, since the balls have further to fall. A four-inch mill will grind a cup of material more slowly than a six-inch mill will grind a quart. The balls have further to fall in a larger mill. They make more strikes per revolution, and thus, do more work.

- *How fast should they tumble?* Dry grinding should be done at about 65% of the critical speed for the jar and medium you're using. Use the table or formula to determine the critical speed for any particular jar/medium combination.

- *What should balls be made of?* alumina, Burundum, steel, lead. The choice is centered around weight and hardness. Antimony hardened lead is heavy enough and hard enough for most pyrotechnic purposes, but high-density ceramic media are easier to clean, and grind somewhat finer. Ceramic might spark, lead will not. Oxidizers will corrode some metal media.

- *How many of them should there be?* For dry grinding, there should be enough balls to fill the mill to 50% of its empty capacity.

- *How much material should be processed at a time?* Twenty-five percent of the mill's empty capacity. If the medium is 40% voids, then a mill 50% full of medium will be 20% full of voids between the balls. A material charge of 25% will fill all the voids, plus just a little to insure that every impact crushes material.

- *What shape (and material) should the container (jar)* be? The jar may be octagonal or cylindrical. Cylindrical mills should have four lifter bars bolted equidistant around their inside surface. For a 6" mill, a typical lifter bar would be as long as the cylinder is long, and about 1/2" square, with its exposed upper edges rounded slightly to prevent them from chipping during milling. They may be made of the same material as the jar.

Commercial jar mills are made of highly abrasion-resistant materials, like alumina or abrasion-resistant steel. They don't have to be. If we assume that the jar might be "disposable" (only in the long-term sense!) then cheaper, easier-to-machine substances are available. PVC pipe can be fashioned into an excellent, durable mill.

- *How large should the jar be? 6"* in diameter by 8" long will accommodate about two pounds of material per grind, for dense substances like potassium nitrate. Smaller sizes can be readily built for smaller batches. Remember, charging is by *volume, not weight,,* so a given volume mill will grind less weight of a less dense material.

- *How big a motor will it take to turn it?* Ah! Horsepower! This is something we haven't even touched upon yet. The volume of a cylindrical mill increases with the square of the diameter. The power required to turn it increases at the 2.6^{th} power of the diameter . . . . . That's all true, but a ^{l}A horsepower motor will handle a two-jar mill just fine! Such motors are available new for under $50, and can be had at many surplus firms for pocket change.

Now you know what the manufacturers of ball mills say works the best.

Next, we consider building a mill:

- *Can I afford this?* Oh, YES! If you stick to the plans I'll supply, the entire mill can be assembled from inexpensive stock components and readily available raw materials which will require little or no custom cutting or machining. You may have everything you need already, in which case, all you'll have to buy is the grinding medium. And if you're willing to alloy and cast your own lead media...

- *Can I **build this myself?*** Yes, you can. No special tool skills are necessary. Critical dimensions are resolved by the design itself, so you don't have to be a machining genius. It will be easy to charge, and easy to unload, and it will be clean to use. When finished, it will be a mill which will both look good and operate like a commercial mill. It will be a mill to be proud of, and one which will make the pyrotechnics hobby more productive and enjoyable.

Technical information was provided by:

* Paul O. Abbe Inc., manufacturers of ball milling equipment
* E.R. Advanced Ceramics, a division of U.S. Stoneware, manufacturers of ball milling equipment
* McMaster-Carr Industrial Supply Co., suppliers of industrial materials
* Fisher Scientific
* Grainger, suppliers of industrial equipment
* Ball milling knowledge was shared by: Guy Lichtenwalter, Murr Rhame, Tom Perigrin, Bill Nelson, and Frank Heasley.

My thanks go to each of these companies and individuals for their helping me in my research.

LES

BURN RATE OF FIREWORKS COMPOSITIONS

by K. L. & B. J. Kosanke

There may be many times when a fireworks manufacturer will want to adjust the burn rate of pyrotechnic compositions. Sometimes this may be for matters of artistry and other times for safety. For example, all of the following are unacceptable:

- Strobe stars that flash with so low a frequency that they fall to the ground still burning.
- Color stars that burn so rapidly that they occasionally explode when a shell flowerpots.
- Rockets that fail to lift-off because their thrust is too low.
- Rockets that explode upon firing because internal pressures exceed the casing strength.
- Salutes that burn like fountains instead of exploding with violence.
- Flash powder that explodes when unconfined, even in small quantity.

In each case, taking action to adjust burn rate should solve the problem.

Burn rates are reported as either mass burn rates or linear burn rates, with units of either the mass consumed per time (e.g., grams/sec) or the distance the flame front progressed per time (e.g., meters/second). In this article, unless stated to the contrary, the term burn rate will mean linear burn rate.

There are at least 15 factors known to affect the burn rate of pyrotechnic explosives; these are listed in Table 1. For each of the factors listed, the change in burn rate is produced by chemical effects, physical effects, or both. The most important of these include:

- The amount of energy required to initiate the chemical reaction (known as Activation Energy and abbreviated as E_A);
- The amount of energy produced by the chemical reaction (known as Heat of Reaction and abbreviated as H_R); and
- The efficiency with which energy is fed back from burning material to that which has not yet started to burn (sometimes called Feedback Efficiency and abbreviated as F_E).

High burn rates are favored by any combination of low activation energies, high heats of reaction and efficient energy feedback. Low burn rates tend to be the result of the opposite in each case.

Table 1. Factors Controlling Burn Rates of Fireworks Compositions.

CONTROLLING FACTOR	E_A	H_R	F_E
Choice of fuel and oxidizer	X	X	X
Fuel to oxidizer ratio		X	
Degree of mixing		X	
Particle size	X		
Particle shape	X		
Presence of additives	X	X	X
Presence of catalysts	X		
Ambient temperature	X		
Local pressure			X
Degree of confinement			X
Physical form			X
Degree of consolidation			X
Geometry			X
Crystal effects	X		X
Environmental effects	X	X	X

Table 1 also shows which of the three mechanisms are typically the most important for each factor by placing an "X" in the appropriate column. Below are a series of paragraphs giving brief explanations of the factors and how they act to control burn rate. It must be acknowledged, however, that some explanations have been greatly simplified, and less common situations may not have been addressed. Any reader wishing a short review of the subject of pyrotechnic ignition and propagation is referred to previous articles [1,2]. For more information concerning how the factors from Table 1 affect burn rates, the reader should consult one or more of the standard reference texts on pyrotechnics [3,4,5,6], or an extensive review article by the authors [7].

Choice of Fuel and Oxidizer

The choice of fuel and oxidizer can significantly affect activation energy, heat of reaction and the efficiency of energy feedback. Some oxidizers (e.g., potassium nitrate) require the input of a large amount of energy to cause it to make its oxygen available to react with a fuel. Other oxidizers (e.g., potassium chlorate) actually produce energy in the process of releasing their oxygen. Thus the choice of oxidizer can have a major effect on the activation energy of pyrotechnic materials. When fuels combine with oxygen, different numbers and strengths of chemical bonds are formed. This can greatly affect the amount of energy produced by the combustion reaction. Energy can be fed back from reacting to unreacted material by conduction, convection and radiation. The choice of fuel and oxidizer can affect all three feedback mechanisms. Metal fuels are good thermal conductors; organic fuels produce much gas, which can increase convective energy transfer; and dark colored fuels, such as carbon, can increase the absorption of the radiant energy.

Fuel to Oxidizer Ratio

When the fuel to oxidizer ratio deviates from its optimum value, burn rates are reduced, and the burn rate continues to fall as the deviation increases. This can be thought of as a result of a lowering of the heat of reaction for the fireworks composition. The heat of reaction falls because, as the fuel to oxidizer ratio deviates from optimum, there is some fuel or oxidizer remaining at the end of the reaction. The result is that less energy is produced per gram of material.

Degree of Mixing

When a pyrotechnic explosive is poorly mixed, it has a lower than normal burn rate. This is because, while the entire volume of pyrotechnic composition may have the optimum fuel to oxidizer ratio, there will be many regions where the fuel to oxidizer ratio is far from optimum. Within each of these regions, what was said above in Fuel to Oxidizer Ratio applies. However, in the final analysis, the heat of reaction may not be significantly reduced, because essentially all of the material eventually comes to react. Nonetheless, time is consumed while the fuel and oxidizer must physically diffuse from region to region.

Particle Size

As the size of individual fuel and oxidizer particles is made smaller, burn rate increases. This can be considered to be the result of reducing the effective activation energy because smaller particles take less energy to be heated to the ignition temperature. Further, there is a physical effect. Only the atoms on the surface of particles are ready to react, and, as particle size is reduced, the fraction of atoms on the surface increases. For most pyrotechnic materials, the particle size of the fuel has the greatest effect on burn rate, and it is difficult to overstate the degree to which the fuel particle size affects burn rate. The reason that the size of oxidizer particles is of less importance is that most oxidizers melt or have decomposition temperatures at or below the ignition temperature of the pyrotechnic explosive.

Particle Shape

Particle shape affects burn rate in much the same way as particle size. Some shapes are easier to raise to the ignition temperature. They also tend to have greater percentages of atoms on the surface. All else being equal, the order, from lowest to highest burn rate, are for particles of the following shapes: spherical, spheroidal, granular and flake. As with particle size, it is the particle shape of the fuel that has the greatest affect on burn rate.

Presence of Additives

Additives are materials used in a fireworks composition to modify its performance in some way. Some common additives are: a binder to hold it together, a stabilizer to retard undesirable chemical reactions, large granular fuels to produce sparks, and agents to produce colored flame or smoke. Usually the presence of additives lowers burn rates and the amount of lowering increases with the amount of additives. Generally this is the result of raising the effective activation energy, lowering the heat of reaction, or both. As an example consider the addition of a carbonate to neutralize any trace amount of acid present in a fireworks composition. The carbonate is neither oxidizer nor fuel and thus does not contribute energy on burning of the composition. Thus, on a pound for pound basis, the pyrotechnic material produces less energy. In addition, upon heating, the carbonate decomposes, consuming energy. This either reduces the heat of reaction or raises the effective activation energy, depending on whether the decomposition temperature of the carbonate is above or below the ignition temperature of the fireworks composition.

Occasionally an additive will increase the burn rate of a fireworks composition. Generally this will be the result of an increase in the heat of reaction or in the energy feedback efficiency. One example of this would be the addition of a small amount of a metal fuel to a pyrotechnic composition.

Catalysts

Catalysts are a special class of additives; they are chemical agents that speed up chemical reactions, normally without being consumed in the process. Pyrotechnically, burn catalysts typically lower the activation energy by reducing the decomposition temperature of the oxidizer. Burn catalysts can be effective in quite small amounts, less than 1%. Some common impurities, such as iron oxide (rust), can catalyze some pyrotechnic reactions.

Ambient Temperature

Pyrotechnic burn rates increase as the ambient temperature rises. In essence this is because the unreacted composition begins at a temperature closer to its ignition temperature. Thus less energy is required to reach the ignition temperature, i.e., activation energy is lowered.

Local Pressure

For gas producing fireworks compositions, the nature and relative position of the flame produced by burning varies as a function of pressure. When local pressure is increased, the flame envelope becomes smaller, the flame is hotter and is held in closer proximity to the burning surface. This increases the burn rate because of an increase in the efficiency of energy feedback. For gasless pyrotechnic compositions, very little if any, actual flame is produced, and generally they are unaffected by changes in local pressure.

Degree of Confinement

The effect of burning of fireworks compositions under confinement is complicated. However, it can be thought of as burning under conditions where, until the confining vessel bursts, the efficiency of energy feedback is extremely high. Thus confinement can act to greatly increase the burn rate. This is especially true for gas producing pyrotechnic materials. For most fireworks compositions, it would be difficult to overstate the effect confinement can have on burn rate.

Physical Form

The physical form of the fireworks composition can make a great difference in its burn rate. This has most to do with the efficiency of energy feedback and was discussed in detail in an earlier article [2]. Generally for gas producing pyrotechnic materials, granulated compositions (with so-called fire paths) have high burn rates; large solid masses of composition (with no fire paths) have low burn rates; and fine powders have highly unpredictable burn rates.

Degree of Consolidation

This is sometimes referred to as loading pressure and is related to the degree of compaction of the fireworks composition as it is made into grains or packed into a device. The effect of loading pressure is to change the efficiency of energy feedback. However, whether higher loading pressure increases or decreases burn rate depends on the nature of the energy feedback mechanism. If it is a gas producing composition and convective transfer is the prevalent mode of energy feedback, high loading pressure decreases the burn rate by decreasing gas permeability. On the other hand, if it is a gasless composition and conductive transfer prevails, higher loading pressure generally increases the burn rate because of an increase in thermal conductivity.

Geometry

Geometric effects are caused by changes in size and shape of the fireworks device. They primarily result in small changes in the efficiency of energy feedback. For example, as the diameter of a fountain increases, a slightly greater percentage of the energy produced during burning is radiated back to heat the burning surface, thus increasing the burn rate. Another example of geometric effect is the "erosive burning" that occurs along a hole or channel running through a comet with an axial hole. For purposes of this article, geometric effect is also taken to include effects such as caused by the thermal conductivity of inert materials in or surrounding the pyrotechnic material. For example a composition pressed into a thin metal tube, or having a metal wire internally along its length, will generally have an increased burn rate compared with that when pressed into a paper tube or without the wire, because of increased energy feedback from thermal conduction.

Crystal Effects

Crystal effects include a number of diverse effects all relating to properties of crystal lattices. One crystal effect is the ability to temporarily store energy in the crystal lattice, during grinding or milling. Following the accumulation of lattice energy, there is a relaxation time during which the stored energy drains away. During the period when significant stored energy still remains, the effective activation energy for the material is reduced, potentially increasing burn rate. Other crystal effects can be the result of using materials with different methods of manufacture, producing different crystal structures and crystals produced that contain different amounts of trace impurities. Another possible crystal effect, which may be important in some transitions from burning to explosion, is the piezo-electric effect. It is felt that this has the potential for increasing energy feedback by converting compressive pressure forces into an electrical ignition stimulus.

Environmental Effects

Environmental effects include such things as temperature cycling and exposure to humidity. For example, temperature cycling can produce cracks in compacted fireworks compositions. This can greatly increase the burning surface area and burn rate. Humidity will generally act to slow burn rate, either with water acting as an unreactive additive or by promoting the slow decomposition of one or more of the ingredients in a pyrotechnic material.

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KL&BJK

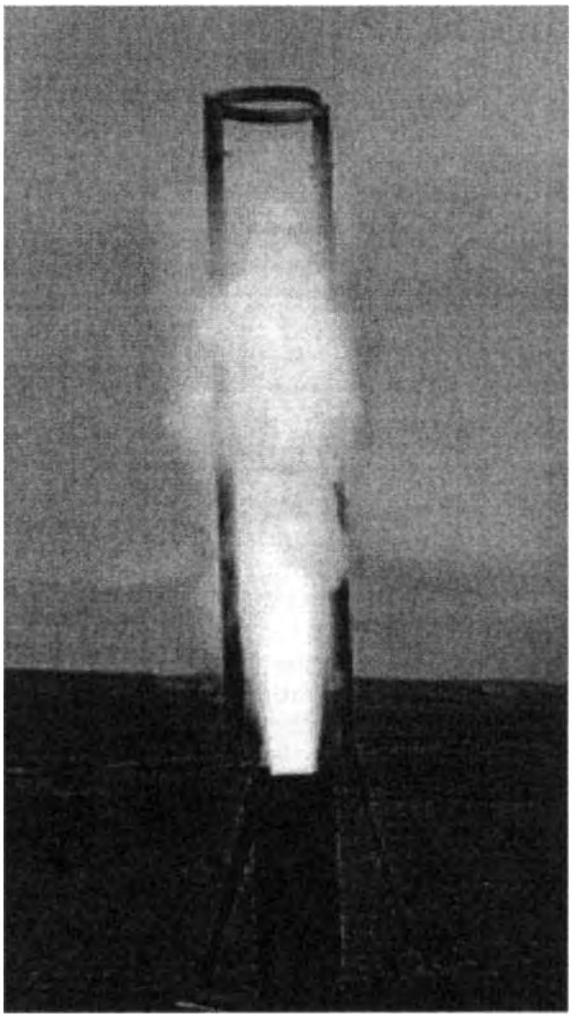
PEAK SHELL ACCELERATIONS

K. L. and B. J. Kosanke

For safety reasons, a fireworks display operator needs to know that aerial shells leave the mortar at high speed. Further, it is important to know approximately where those aerial shells being fired are being propelled. However, it is not important to know the rate of acceleration of aerial shells within mortars as they are fired. Similarly, except to know that the acceleration of aerial shells is great and the resulting inertial forces on the shells are large, a shell manufacturer does not need specific knowledge of the magnitude of those accelerations. Nonetheless, it is sometimes a topic of discussion, and knowledge of these accelerations would satisfy the curiosity of a number of individuals. This short article is intended to help satisfy that curiosity and to help make an important point regarding the manufacture of Lamparie shells. (Note that a longer and much more complete version of this article will appear the Winter issue of the *Journal of Pyrotechnics.)*

Using Newton's second law of motion, if one knows the pressure acting on an aerial shell as it is fired from a mortar, and the diameter and mass of the shell, one can calculate the acceleration it is experiencing. Data such as this was produced during a series of test aerial shell firings, under somewhat typical conditions and for a range of shell types and sizes. These test results were used to calculate peak accelerations. The results ranged from 2.5 to 10 miles/sec^2 and were confirmed by comparing measured and calculated muzzle velocities for the test shell firings. To help put these peak accelerations into perspective, recall that the acceleration due to gravity is approximately 32 ft/sec^2. Thus the acceleration experienced by the shells ranged from 400 to 1600 times the acceleration due to gravity, very great indeed.

When the contents of an aerial shell experience high acceleration, they produce high inertial forces, which are ultimately transmitted to the shell casing. (This is thought to be a cause for the failure of many a hobbyist's early attempts at aerial shell manufacture.)



As an example of the forces that can be produced, consider the case of the recently introduced Lamparie shells. Typically, these are a combination of a salute and a container of liquid fuel used to produce a loud report and an aerial fireball. Considering a liquid fuel with a specific gravity of 0.85, contained in a vessel about 6 inches tall, the liquid pressures produced at the bottom of the container, upon shell firing, result in pressures ranging to nearly 300 psi. Thus it is clear why many liquid fuel containers are not suitable and why the fuel containers themselves typically need to be strongly encased.

KL&BJK

LIFT CHARGE LOSS FOR A SHELL TO REMAIN IN MORTAR

by K. L. Kosanke

I recently needed an estimate of the amount of lift powder that would have to be missing from a spherical aerial shell for it to remain in its mortar upon firing. Since that apparently has never been reported in the literature and because it was easy to determine, a brief study was conducted to discover this. Although there is little reason for the typical pyrotechnist to need the answer to this question, nonetheless it is a somewhat interesting number. Thus, the motivation for this short article.

In this study, only plastic spherical aerial shells were tested and the mortars used were all high density polyethylene. Information about the materials and conditions for the tests are listed in the table below. Each shell size was test fired using Goex 4FA fireworks (blasting) Black Powder. However, because smaller shells are often lifted using finer grained powder, the 3- and 4-inch spherical shells were also tested using Goex 2Fg sporting grade Black Powder. In each case the lift powder was placed in a small plastic bag with a Daveyfire SA-2000 electric match. The bag of lift powder was then taped directly to the bottom of the test shells, thus providing little dead space below the shell other than that resulting from its spherical shape. The shell weights and nominal lift weights were those used in previous studies, and are felt to be typical for spherical shells. The temperature during the tests was approximately 70°F. For each size shell, a series of test firings was conducted, each time adjusting the amount of lift powder until a quantity was found, just sufficient to cause the shell to clear the top of the mortar upon firing.

For the conditions of these tests, it required an average of approximately 14 percent of the nominal lift charge weight to cause the test aerial shells to just barely exit the mortar. There is no estimate of the statistical uncertainty for these results because of the limited number of tests performed.

I am grateful to Alan Broca of Daveyfire, Inc. for supplying the electric matches used in this study. KLK

SHELL SIZE (IN.)	3	4	5	6
Mortar Length (in.)	22.5	22.5	26.5	26.5
Mortar Diameter (in.)	2.98	3.91	4.93	5.93
Shell Weight (lb.)	0.30	0.80	1.5	2.5
Shell Diameter (in.)	2.62	3.72	4.68	5.63
Nominal Lift Weight (oz.)	0.5	1.0	1.7	2.7
Minimum 4FA Lift to Exit (oz.)	0.09	0.13	0.25	0.36
Percent of Nominal	18	13	15	13
Minimum 2Fg Lift to Exit (oz.)	0.07	0.11	—	—
Percent of Nominal	14	11	—	—

DUD SHELL HAZARD ASSESSMENT: NFPA DISTANCES

K.L. and B.J. Kosanke

There is some level of risk associated with all human activities. When the risks (hazards) are below an acceptable level, those activities are generally considered safe. The hard part is not the estimation of risks; there are relatively simple methods to estimate risk. Rather, the hard part is determining what is an *acceptable level* of risk for an activity. For the most part, this article addresses only the easy part, discussing the relative hazards of dud shells falling into spectator areas for different scenarios. The reader is left with the hard part, deciding what level of risk is acceptable and what (if anything) to do about those risks for his displays.

Spectators at a fireworks display may be exposed to a range of potential hazards, one of which is the possibility of a dud shell falling in their midst. However, while an analysis and discussion of this one risk is intrinsically useful, it can also serve a broader purpose, and that is to demonstrate how hazard assessments are performed, and how such information can be used to evaluate and select appropriate hazard management strategies for any risk.

Some fireworks display operators may believe the separation distance requirements of the National Fire Protection Association, in NFPA 1123 (1990 and 1995 editions), are sufficient to assure that dud aerial shells will never fall into spectator areas. Unfortunately, the chance of this happening is not zero; however, the current separation distances do greatly reduce the hazard when compared to that for the distances in earlier versions of the code. This article begins the discussion by quantifying and then comparing the spectator hazard for displays performed with both the earlier and current NFPA separation distances. (A subsequent article will consider the merits of various mortar placements and tilt angle, and the use of even greater separation distances.)

DRIFT DISTANCE

For a number of reasons, an aerial shell follows a trajectory somewhat different from that predicted by the alignment of the mortar from which it is fired. For example, if an aerial shell is fired from a mortar aligned perfectly vertical and with absolutely no wind, one might predict that it would rise straight up into the air. Further, if the shell failed to burst, that it would eventually fall straight down, landing quite near the mortar from which it left. However, this essentially never happens. Probably the single greatest cause for the divergence is the sideways force produced by the tumbling of the shell as it moves through the air. (This is the same force used by a baseball pitcher in throwing a curve ball.) For a dud shell, "drift distance" can be defined as the difference between where the shell is predicted to land, based on simple ballistics, and where it actually falls to the ground, see Figure 1.

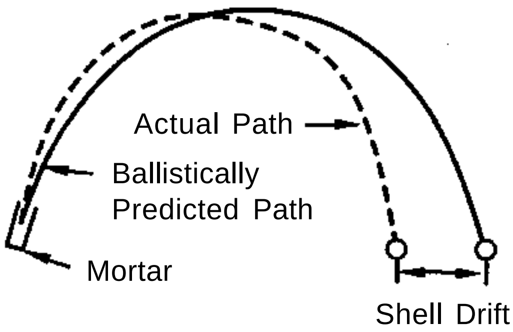


Figure 1. Illustration of drift distance for a dud aerial shell

A number of years ago, results from a series of aerial shell drift studies were reported. [1] (While more than 400 test shells were fired in that effort, and while it seems to be the most complete study reported in the literature, the study was not so extensive that the results should be taken as absolutely correct.) In those studies, it was found that dud spherical shells have an average drift distance of approximately 32 feet per inch of shell size. (For example, for three-inch spherical shells, the average dud drift distance is approximately 3 times 32 feet, or about 96 feet.) Further, it was found that approximately nine percent of the dud shells fall at more than twice the average drift distance, and that approximately one percent of the dud shells may fall at more than three times the average drift distance.

NFPA SEPARATION DISTANCES

Prior to the 1990 edition of the NFPA code, the minimum separation distances (distance from the spectators to the mortars) were relatively short, see Table 1. With the 1990 edition of the code, the separation distances were increased substantially. For vertically placed mortars the separation distance became 70 feet per shell inch (also shown in Table 1). Obviously, one effect of the increased separation distances is a reduction in the potential hazard of dud shells falling into spectator areas. Not obvious, however, is just how significant is that reduction in hazard. Much of the remainder of this article will be devoted to estimating the magnitude of this hazard reduction.

Table 1. NFPA Minimum Separation Distances.

SHELL SIZE (IN.)	PRE-1990 DISTANCE (FT)	POST-1990 DISTANCE (FT)
3	50	210
4	75	280
5	100	350
6	150	420
8	150	560
10	150	700
12	150	840

RISK ASSESSMENT

In performing a risk assessment, consideration is given to both the likelihood (probability) of an event happening and the consequences (severity) of that event, should it occur. [For more information about performing risk assessments, see reference 2.] To illustrate how a risk assessment is performed, and to provide data for the discussion of separation distances, two scenarios will be considered for a somewhat typical fireworks display. In both cases, for simplicity, it is assumed that: spectators are located in one small area immediately adjacent to the display site, the mortars are placed vertically, there is no wind blowing during the display, and only spherical shells of typical construction are used. In both scenarios each size of mortar is grouped together and placed at the minimum distances from spectators as listed in Table 1. In scenario 1, the distances are those from before 1990. Thus the three-inch mortars are all at 50 feet from spectators, the four-inch mortars are at 75 feet, the five-inch mortars are at 100 feet, etc. (see Figure 2). In scenario 2, the distances are those from after 1990. Thus, in this scenario all the three-inch mortars are at 210 feet from the spectators, all the four-inch mortars are at 280 feet, all the five-inch mortars are at 350 feet, etc. The number and size of shells in these hypothetical displays were chosen to be fairly typical for a modest size fireworks display, and are given in Table 2.

Table 2. Dud Shell Hazard Assessments for Two Display Scenarios.

Shell	QUANTITY	Severity	Scenario No. 1		Scenario No. 2	
SIZE (IN.)	Body/ Finale	Scale	Probability	Hazard	Probability	Hazard
3	130/100	1	0.81	187	0.06	13.8
4	65/0	2	0.73	95	0.06	7.8
5	30/0	3	0.71	64	0.06	5.4
6	15/6	5	0.60	63	0.06	6.3
8	8/0	9	0.73	53	0.06	4.3
10	4/0	13	0.79	41	0.06	3.1
12	2/1	17	0.85	43	0.06	3.1
			Rel. Hazard	**546**	**Rel. Hazard**	**39.5**

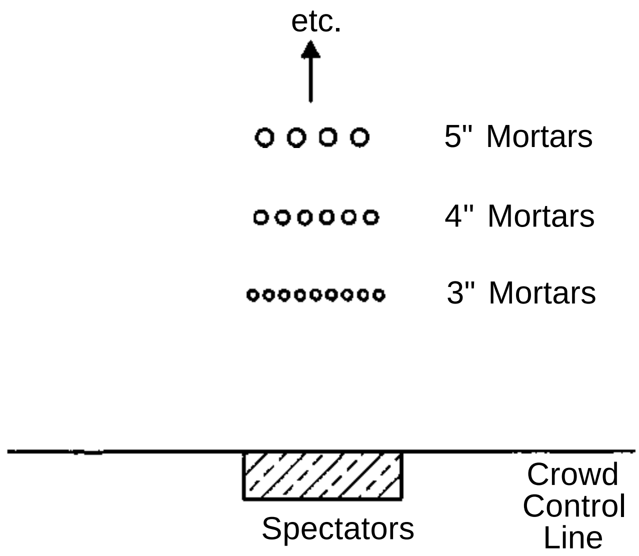


Figure 2. Example of mortar placements for the two scenarios.

The consequences of a dud shell falling into spectator areas arise from two potential hazards, from direct impact of a dud with a spectator, and from the pyrotechnic output of a shell if it ignites. Calculations and measurements suggest the impact velocity of dud shells range from about 90 to perhaps as much as 150 miles per hour, depending on shell size and shape.[3-4] With shell weights ranging from 0.3 to more than 15 pounds, the potential for serious injury or death from the impact of a falling shell is significant.

During measurements to determine spherical aerial shell drift, it was observed that aerial shells smaller than five inches rarely ignite on impact although many shell casings were noticeably damaged (had cracked). For six-inch shells it was found that roughly 10 percent ignite on impact and essentially all shell casings had cracked. For shells larger than eight inches, at least 60 percent of shells ignited on impact and all had seriously damaged casings. However, none of the ignitions observed produced a typically powerful shell burst. In each case, upon ignition, only a fireball was produced with the projection of a few relatively low velocity stars. Nonetheless, for large caliber shells the fire ball dimensions were substantial. Apparently, it was the damage to the shell casings on impact that was the reason for the lack of an explosion.

The accident severity values of Table 1 are relative values, such that values of 2 or 17 are intended to correspond to accidents whose consequences are 2 times or 17 times as severe, respectively, as an accident with a severity value of 1. In part, the relative severity scale in Table 2 is a rough estimate based on the information described in the previous paragraphs. However, information from actual accidents, where dud shells have fallen into spectator areas, was also considered in assigning relative severity values. Nonetheless, relatively little time was spent trying to develop a highly accurate severity scale for this example. (Similarly, not much time was devoted to assigning precise probability values, also in Table 2.) However, the values in Table 2 are reasonably correct and are adequate for use in contrasting the relative hazards of the two display scenarios.

There is no published data to suggest that the probability for any size shell being a dud is different than that for any other size shell. Thus for the purposes of this analysis, it will be assumed that dud probability is independent of shell size. As with the severity values, the probabilities in Table 2 are also relative values. The relative probability values are just the probabilities for dud shells falling anywhere in a 360 degree circle, beyond the distances being considered. Obviously, because the spectators are assumed to all be in a small area in front and because relatively few shells become duds, these probabilities are a gross over estimate. However, since it is only the relative hazard rating between the two scenarios that is of interest, using relative probabilities is acceptable.

Since the severities listed in Table 2 are relative severities, and the probabilities are relative probabilities, the resulting hazards are only relative hazards. For simplicity, in Table 2 and in the remainder of this article, generally the adjective "relative" will not be used but is meant to be implied.

To arrive at the hazard for a single shell of any given size, the severity rating for that size dud shell is multiplied by the probability of a dud shell of that size reaching the spectator area. The hazard rating for firing a number of shells of that size is the number of shells times the hazard for firing a single shell. Thus the hazard from firing the 65 four-inch spherical aerial shells at a distance of 75 feet is: 65 shells, times 2 for the severity, times 0.73 as the probability. This equals 94.9, which is rounded up to 95, in Table 2. Finally, the cumulative hazard for each scenario is just the sum of the individual hazards, for firing the numbers of each size shells.

RESULTS

From Table 2, the relative spectator hazard from dud shells using the minimum pre-1990 NFPA separation distances (scenario 1) is approximately 550, while that using the minimum current NFPA distances (scenario 2) is only approximately 40. Accordingly, within the context of these two scenarios, using the current NFPA distances should account for more than a 90 percent reduction in the hazard from dud shells falling into spectator areas. (Note that large hazard reductions are also found when comparing the old and new separation distances in other more realistic scenarios, such as when the spectators are more spread out around the display site.)

Within the scenarios of this article (aerial shells fired vertically at the minimum allowed separation distances), note that it is not the firing of the largest shells that pose the greatest potential hazard to spectators. This is because, for the relative severity scale used, the greater number of small shells fired turns out to be more significant than the hazards from the few large shells.

DISCUSSION

When the NFPA Pyrotechnics committee decided to increase the appropriate size of fireworks display sites to 70 feet per shell inch, frankly that was just a good guess, based on the general experience of the committee. At the time, there was no known published data on drift distances for shells, or typical shell burst diameters, or how far down range a shell might be propelled from a misaligned mortar. By the time the code was revised for the 1995 edition, some data had become available and could be used to evaluate to adequacy of the 1990 separation distances. However, more importantly, experience with the new distances was beginning to demonstrate that they were probably sufficient to provide for the "reasonably safe conduct of outdoor fireworks displays". Based on that data and experience, the NFPA Technical Committee on Pyrotechnics chose not to make further changes to the separation distance requirements for 1995.

The NFPA Committee is working on the next edition of NFPA-1123. At a recent meeting of the committee's Fireworks Task Group, consideration was given to a proposal (from outside the NFPA committee) to increase the separation distance to 100 feet per shell inch. It was tentatively decided that no increase was needed. In a second article on the hazards from dud shells falling into spectator areas, estimates will be made for the effect of such an increase of separation distance.

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KL&BJK

DUD SHELL HAZARD ASSESSMENT: MORTAR PLACEMENT

K. L. and B. J. Kosanke

The previous article on this topical discussed the general process by which one performs a hazard assessment and then applied it to two fireworks display scenarios. One scenario had mortars of the same size together in groups, with each group located at the pre-1990 minimum National Fire Protection Association (NFPA) separation distances. (See Figure 2 of the previous article if needed.) The other scenario had the same mortar groupings, but this time, each group was located at the post-1990 NFPA distances. The estimated relative hazard ratings for the two scenarios were 550 and 40, respectively. Accordingly, for these scenarios, the new NFPA separation distances should produce more than a 90% reduction in the hazard of dud shells falling into spectator areas.

In the current article, hopefully further insight might be gained by considering a few additional scenarios. To keep from unnecessarily complicating the discussion, each scenario in this article will continue with the same basic assumptions made in the previous article. Each scenario has the same show design (the same number and sizes of shells), has the spectators in small areas immediately adjacent to the display site, and uses the same shell drift data[2] and dud shell severity scale. Thus the relative hazard estimates produced in this article will be consistent with the ones from the previous article.

Mortar Placement

This first new scenario, number three, is more typical of the mortar placements actually used in displays. In this case all the mortars, including finales, are located at the minimum distance required for the largest shell in the display. The hazard assessment result for this scenario is 4.8, and the data for this estimate is presented in Table 1. Recall that the relative hazard from firing any single shell is the product of the severity value times the relative probability of occurrence. To calculate the hazard from firing some number of the same size shells, multiply the hazard for a single shell firing times the number of shells of that size. Then the overall hazard for the display is the sum of individual hazards from firing each size shells. (For a more complete discussion, see the previous article.[1])

At the last NFPA Technical Committee on Pyrotechnics meeting, consideration was given to a proposal from a non-committee member that the minimum separation distances be increased from 70 feet per shell inch to 100 feet per shell inch. The committee tentatively decided not to make the change; however, it might be instructive to consider what effect using the greater distance would have on the spectator hazard from dud shells. To do this, the relative hazards for two additional scenarios are estimated. In one case, scenario four, it is again assumed that there are separate groups for each size mortar that are positioned at the 100 feet per shell-inch distance for that shell size (somewhat like scenarios one and two). In the other case, scenario five, it is assumed that all mortars, regardless of size, are positioned together at the minimum distance for the largest size shell (somewhat like scenario three). The relative hazards for these two additional scenarios are 3.8 and 0.4, respectively, and the data for these are also given in Table 1.

The results for the three new scenarios, compared with two scenarios from the previous article, are discussed below.

Mortar Angling

Mortar angling has obvious safety ramifications for the crew performing manually fired displays. This is mostly because dangerous debris from flowerpots and dud shells are propelled slightly away from the crew and unused fireworks. However, the safety ramifications for spectators are less obvious. To examine this, consider the following display scenario. In this case, assume all the mortars are in one large group at the minimum distance for the largest shell size for angled mortars. This corresponds to an offset of 1/3 the NFPA distance toward the main spectator area, with the mortars angled so that the expected point of fall of dud shells is 1/3 the

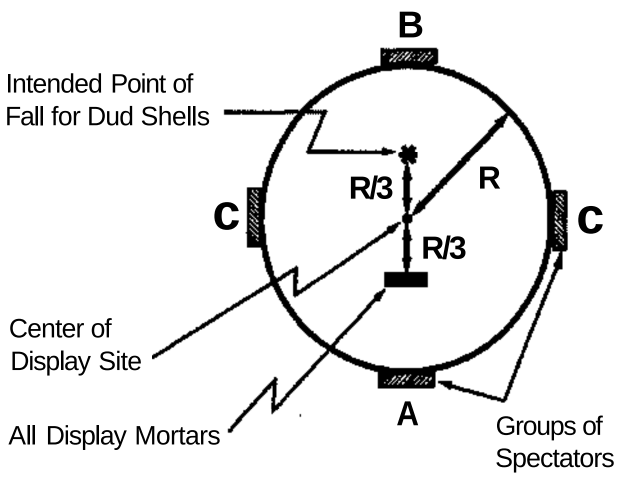
Table 1. Dud Shell Hazard Assessments for Three New Mortar Location Scenarios.

SHELL SIZE(IN.)	NUMBER BODY - FINALE	SEVERITY SCALE	SCENARIO 3		SCENARIO 4		SCENARIO 5	
			PROBABILITY	HAZARD	PROBABILITY	HAZARD	PROBABILITY	HAZARD
3	130-100	1	0.000	0.0	0.005	1.2	0.000	0.0
4	65-0	2	0.000	0.0	0.005	0.7	0.000	0.0
5	30-0	3	0.000	0.0	0.005	0.4	0.000	0.0
6	15-6	5	0.001	0.1	0.005	0.5	0.000	0.0
8	8-0	9	0.004	0.3	0.005	0.4	0.000	0.0
10	4-0	13	0.025	1.3	0.005	0.3	0.001	0.1
12	2-1	17	0.060	3.1	0.005	0.3	0.005	0.3
			Rel. Haz.	**4.8**	**Rel. Haz.**	**3.8**	**Rel. Haz.**	**0.4**

Table 2. Dud Shell Hazard Assessments for Angled Mortars, Scenario Six.

SHELL SIZE(IN.)	NUMBER BODY - FINALE	SEVERITY SCALE	SPECTATOR AREA A		SPECTATOR AREA B		SPECTATOR AREA C	
			PROBABILITY	HAZARD	PROBABILITY	HAZARD	PROBABILITY	HAZARD
3	130-100	1	0.000	0.0	0.000	0.0	0.000	0.0
4	65-0	2	0.000	0.0	0.000	0.0	0.000	0.0
5	30-0	3	0.000	0.0	0.002	0.2	0.000	0.0
6	15-6	5	0.000	0.0	0.010	1.1	0.000	0.0
8	8-0	9	0.000	0.0	0.060	4.3	0.002	0.1
10	4-0	13	0.001	0.1	0.14	7.3	0.020	1.0
12	2-1	17	0.010	0.5	0.20	10.2	0.050	2.6
			Rel. Haz.	**0.6**	**Rel. Haz.**	**23.1**	**Rel. Haz.**	**3.7**

distance past the center of the display site. This setup is illustrated in Figure 1. For the purpose of simplicity in estimating the relative hazard from dud shells, it is assumed there are potentially four small groups of spectators. One group (A) is just the same as in each of the previous scenarios. Another group (B) is immediately adjacent to the display site in the direction toward which the mortars are angled. The last two groups (both designated as C) are immediately adjacent to the sides of the display site. Because the distance from the expected point of fall of dud shells is different for each group, their relative hazards are also different. The results for each group are presented in Table 2.



The cumulative hazard for the collection of spectators in the four groups depends on the number of people in each group. If there are only spectators in group A, such as might be

Table 3. Summary of Relative Hazard Estimates for the Various Display Scenarios.

SCEN. NO.	SEP. DISTANCE	MORTAR PLACEMENT INFORMATION	REL. HAZ.
1	Pre-1990	Vertical mortars in separate groups by size, each at their minimum distance.	550
2	70 ft/in.	Vertical mortars in separate groups by size, each at their minimum distance.	40
3	70 ft/in.	Vertical mortars all in one group, at the minimum distance for the largest shell.	4.8
4	100 ft/in.	Vertical mortars in separate groups by size, each at their minimum distance.	3.8
5	100 ft/in.	Vertical mortars all in one group, at the minimum distance for the largest shell.	0.4
6A	70 ft/in.	Angled mortars all in one group, at the minimum distance for the largest shell, and spectators only in an area behind the mortars.	0.6
6AC	70 ft/in.	Angled mortars all in one group, at the minimum distance for the largest shell, and spectators in areas behind the mortars and on the sides of the display site.	2.7
6ABC	70 ft/in.	Angled mortars all in one group, at the minimum distance for the largest shell, and spectators on all four sides of the display site.	7.8

the case for a display fired from the end of a long pier, then the relative hazard is 0.6. If approximately the same number of people are distributed evenly between groups A and C, roughly what might be the case for a display fired from a beach, then the relative hazard would be the average for those three groups or about 2.7 [1/3 x (0.6 + 3.7 + 3.7)]. If approximately the same number of people are distributed evenly between the four areas, the relative hazard for spectators is the average for each of the groups, or 7.8. These results are discussed further in the next section.

Discussion

Table 3 was prepared to facilitate the interpretation of the results for the various scenarios of this and the previous article. The previous article considered scenarios one and two, with groups of the same-sized mortars each placed vertically at the minimum NFPA spectator separation distances for that size mortar. It was found that using the post-1990 distances (70 feet per shell inch), when compared to the pre-1990 distances, resulted in more than a ten-fold reduction in the relative hazard from dud shells falling into spectator areas (hazard value 550 reduced to 40). Further, for these scenarios, it was found that the greatest cumulative hazard to spectators from dud shells was posed by the smaller rather than larger aerial shells.

In scenario three, again post-1990 spectator separation distances are used, however, this time all of the mortars are assumed to be placed vertically in the same location and at the distance required for the largest size shell. The result is another nearly ten-fold reduction in spectator hazard (40 reduced to 4.8). This demonstrates the important safety advantage of positioning all mortars at the location of the largest mortars. Also, in Table 1 note that in this scenario it is no longer the small shells that present the greatest hazard to spectators. In fact, because of the much greater distance between the small mortars and the spectators, their relative hazard is essentially zero.

This article considered only hazards from dud shells falling into spectator areas. However, similar relative hazard reductions for other potential safety problems are accomplished when all mortars are at the location required for the largest mortars. These safety problems include, debris from mortar explosions reaching spectators, shells being propelled directly into spectator areas from repositioned mortars, etc.

In addition to the spectator safety advantage of locating all mortars together, at the distance required for the largest size shells, there are operational and potential esthetic advantages as well. For manually fired shows, having firing take place in several different places on the site could require several different firing crews. Further it would be more difficult to artistically coordinate the firing from these various crews. For electrically fired displays, firing from several locations will probably require more and longer cable runs. It would also eliminate the possibility of using sand-boxes with various sized mortars intermixed in the same order as the firing cues for the show. Finally, firing each size shell at the minimum NFPA distances results in all shells bursting at approximately the same height in the sky as viewed by spectators near the display site.[3] This tends to result in shells overlapping their bursts in an unattractive jumble of color and allows the use of a relatively small portion of the sky.

In scenarios four and five, using spectator separation distances of 100 feet per shell inch, it was found that the relative dud shell hazards were 3.8 for mortars in separate groups each at their minimum distance, and 0.4 when all mortars are located in one group at the distance required for the largest size. These are each about a ten-fold reduction in hazard compared with the same mortar groupings using 70 feet per shell inch (from 40 and 4.8 for scenarios two and three, respectively). This is a significant hazard reduction; however, an important question is whether this further reduction is needed. Is the problem of dud shells falling into spectator areas sufficiently large that additional measures need to be taken? This is not a technical question, and there is no technical answer for it. However, note that the relative hazard for 100 feet per shell inch separations with groups of mortars each at the minimum distance (hazard value 3.8, scenario four), is about the same as that from 70 feet per shell inch separations with all the mortars at the distance for the largest shell (4.8, scenario three). Accordingly, if some hazard reduction was desired, without having to increase the overall separation distances, the NFPA code could be revised to require that all mortars be placed at or near the distance required for the largest size. Most operators already do this, and these operators must already have the least problem with dud shells potentially falling into spectator areas.

As a final set of scenarios (six-A, six-AC, and six-ABC), the situation of angled mortars was considered. In each case, angling mortars will be safer for a manual firing crew for the reasons discussed above. However, in terms of relative spectator hazards from dud shells, the safety ramifications of mortar angling depend on the distribution of people around the display site. When spectators are located all around the site in approximately equal numbers (scenario six-ABC), it is more hazardous for the spectators than is vertical mortar placement (hazard value 7.8 versus 4.8 for scenario three). Thus, it can be concluded that when spectators surround a display site in approximately equal numbers, the mortars should generally be angled no more than needed for crew safety.

When spectators are approximately evenly distributed around half of the display site, behind and to the sides of the mortars (scenario six-AC), the relative hazard drops to 2.7 which is lower than for vertical mortars (4.8 for scenario three). In this case mortar angling improves safety for both crew and spectators. When spectators are located only in the area behind the mortars (scenario six-A), then there is an even more significant reduction in hazard, to only 0.6. (Note that this is about the same reduction in hazard as for scenario five with its separation distance of 100 feet per shell inch.)

Conclusion

In some ways this and the previous[1] article simply stated the obvious (i.e., duds are less likely to fall into spectator areas if the distance to spectators is greater). Also these articles made a number of simplifying assumptions (e.g., all spectators are in small areas immediately adjacent to the display site boundary). However, hopefully the information on the magnitude of the effect on safety is useful, even if they are estimates based on simplistic scenarios.

There are few if any easy answers in hazard management, and the hard part is not coming up with relative hazard estimates. The hard part is trying to decide when something is safe (i.e., when have the hazards associated with an activity been reduced to an acceptable level). Accordingly, the purpose of these articles was not to provide the answers, but rather to provide information to aid display companies in finding their own answers.

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KL&BJK

USING SALUTES IN BLASTING OPERATIONS

[Brisance (bre-'zance) - Ability of an explosive to shatter its solid confines or surroundings. Ellern/

A question was raised about using salutes for rock removal versus black powder.

Explosives can be categorized according to their *brisance,* which is basically the shattering ability of an explosive to demolish materials. It is determined by measuring the quantity of sand that is pulverized inside of a lead block.

Low explosives, like gunpowder, have low brisance but are superior in their ability to *heave* materials relatively intact. Straight ammonium nitrate is another example of an explosive with low brisance and good heaving ability. That is why the military used 40 lb. canisters of ammonium nitrate (with a TNT booster) to dig deep trenches intending to stop the enemy's tanks by trapping them. Modern quarries still use sodium nitrate based blasting powder (blackpowder) to quarry rocks such as marble which must be broken into large, usable pieces and not shattered into dust. A typical surface coal mine will use ammonium nitrate/fuel oil mixture (ANFO) to remove overburden and to break the coal into useable chunks, as opposed to the fine powder that a brisant explosive would produce.

A salute is usually filled with flash powder, with perchlorate as the oxidizer. Perchlorate and chlorate based flash powders are considered to be high explosives and possess considerable brisance and so are not the best choice for making a good hole in the ground.

MKDB

STEEL vs CARDBOARD vs HDPE MORTARS

The debate between proponents of metal vs. plastic mortars continues unabated. In making their points for and against, many arguments are focusing on only certain strengths and weaknesses and only for whatever application the individual happens to use themselves. While arguing the physical properties of each is important, it is often forgotten as to who, what, where, when, how and how often these mortars have been or will be used by people.

No one type of mortar will be the best for all applications under all conditions by all operators. Economics have the most to do with the choice and that is often determined by availability. Close behind is the personal preferences of each operator as to how they wish to shoot their show, the terrain and climate of their area, and the amount of space and travel they do between shows. So too the number of shows, the sizes and the methods used.

The risks associated with using different materials and constructions are often assumed and are based on simply what has been done in the past. Most of the materials have not been manufactured for use in the pyrotechnic industry but rather has been used in plumbing, oil and gas, paper or other uses and have been adapted to fireworks use.

Thus most of the hard scientific data regarding the properties of each has been basic physical properties of the substances themselves for their primary use. Tensile strengths, bursting pressures, temperature and moisture variations, flow rates, weight capacity and so on are important, but only when taken in context with the many other variables when used for shooting displays.

What type of plugs are used? How are the mortars installed? How old is the substance? What was it designed for? Is it new or used? What is the source? How has it been stored? Cleaned? How long will it be used? What other factors has it been exposed to?

How will it be used? Will the shells used in the mortars be hand or electronically fired? What kind of climate conditions? How will they be placed? Above ground in racks? What types of racks? In the ground? What type of soil? How often will they be used? How close will the operators be? The crowd?

Where will the mortars be stored? Indoors? Outdoors? What climate? What types of shells will be fired from them? Salutes? Color? Multi break? Experimental? Under what conditions?

STEEL MORTARS

Each has pluses. Steel has been used for generations. It's strong, stands up to lots of abuse and will last a long time. Some operators even brag about being so confident in their mortars they'll stand right next to every shell that goes up!

But steel means massive amounts of weight and high cost which mean that small operators or those who use electric firing where hundreds of mortars are required will be less likely to want to use steel mortars. They are also hard to clean and in humid climates tend to rust. There are some questions on some types of seamed pipe and the thinwall steel.

The other problem is that one manufacturer's well made steel mortar is not the same as another's. There are no standards for plugs or welds. There are no standards for aging or cleaning. Some operators will pick up inferior grades or used pipe to make into mortars. They'll use cast iron pipe and even use screw on plumbing plugs!

Clearly the biggest plus for steel is its strength, when properly constructed. But just as dashboards are no longer hard steel, it doesn't mean that strength guarantees automatic safety. When steel does burst, rare but more frequently with more use and more powerful shells, it is more dangerous. The shrapnel from a steel mortar carries a long distance and can be as deadly as a claymore mine.

This is especially true when the mortar is above ground in a rack. In my opinion, even with the proposed NFPA 1123 guidelines of 150 feet distance from the crowds for a 3" mortar, that is taking too much risk.

Still, I feel that for hand firing, and for large shells and experimental shells, steel that is properly made and placed is the only way to go.

PAPER MORTARS

As for cardboard it's light and it's cheap. Available in the last few decades, mostly because of the increase in the use of cardboard tubes for rolling paper and plastics on, its been great for barrage and finale racks and electronically fired shells. They certainly are not to be used for individual hand firing, although many operators do it.

Cardboard's drawbacks are that it will wear out quickly as the core burns out and widens, and the plug is pushed out, if the moisture and handling don't get to it first. They've been accepted for finale racks and barrages as shows grew in size and the GRAND FINALE grew in popularity.

One major drawback is, cardboard was made to hold massive rolls of weight and the standards are for that. Some are weaker and should only be used to fire one or two times. And again the plugs and how they are installed can be a problem

While cardboard shrapnel is not as dangerous and won't carry as far, I feel that it can cause damage. As larger bores became available we now see 8", 10" and 12" cardboard mortars on the market, with operators placing it above ground. Plugs and racks can blow out, racks and mortars tip over.

Cardboard does have it's place. Salutes, I feel, should be fired from it, as the shrapnel from a buried cardboard mortar that has a shell detonate is not likely to be seriously harmful to even the operator. Finale and barrage racks properly made, secured and sandbagged, with enough distance from the operator and the crowd, are also the most economical and feasible way to go.

HDPE MORTARS

Plastic is another matter. The first efforts with PVC, which is readily available and still used by some, have met with failure. PVC is cheap and light, but very brittle and doesn't stand up to handling abuse as well as cardboard mortars.

The other efforts with HDPE have met with greater success. Slightly more expensive than cardboard but not as easy to find, its pluses are it is light, won't rust and is easy to keep clean. Wooden plugs are easy to install and if cut long enough even when the plug blows out it can be replaced by cutting off the end of the mortar and putting a new plug in. Storage is a breeze as each size will fit into the next and moisture isn't a problem.

It can be placed in racks, buried, or put in troughs. For electronic firing, it will be easier to set up and care for than steel, but last longer than cardboard. Unlike PVC, it is not as brittle, even when the temperature is below zero. When a shell detonates in it, early tests show it will only split or bend.

HDPE has drawbacks though. Made for fluids to flow through, the inside diameter is not always exact to shell specifications, which also vary from supplier to supplier and type to type. If stored outdoors, some legitimate doubts are raised regarding how pliable if left in the sun or extreme heat, as in the southwest or north, that would freeze and thaw the plugs and rust the fasteners.

And just as with cardboard, I feel that HDPE should only be used for finale and barrage racks and electronic firing, never hand fired.

CPW

HDPE MORTARS FOR MULTI-BREAK SHELLS

One question that I am frequently asked is: *Can multiple-break shells be used in HDPE mortars?*

The answer is yes, but what is meant by multiple break? 2 break? 3 break? 4 break? 10 break? the number of breaks is only a nominal measure of the size and power of a shell and the pressures it generates on the mortar. There are many other variables involved, such as the weight of the shell, the tightness of the fit, the amount and type of lift powder, the amount of space between the bottom of the shell and the mortar, and the type of shell (canister vs. ball). As those change, so do the pressures generated, no matter how many breaks there are.

Typically, multiple-break shells are canister shells, although shells of shells and sun & planets are usually round and could be classified as multiple break. A canister shell generates roughly four times the pressure of the same caliber ball shell. The higher pressures for canister shells have to do with the cubic inches of volume available for the lift gasses to fill, as well as the generally high weights of canister shells because they have more volume than a ball shell.

NFPA 1123 (1995) A-2-3.6 recommends thicker walls for steel or cardboard mortars to be used for 2-break cylindrical, but cited "Data not currently available" for HDPE. The field experience has been added to, but not yet updated in the Code.

Many operators fire 2- and sometimes 3-break color or color 85 report shells from 3" and 4" HDPE mortars and have not reported experiencing any significant problems. Some do so every day at theme parks and the mortars have generally held up well for years, including some of the original lighter gauge molded bottom, one-piece HDPE introduced in 1984. The few operators left who use 5" and 6" crossettes, color 8B tourbillions or serpents have not reported any real problems either using HDPE, but typically those shells are lifted with a coarser, slower burning lift powder than their smaller counterparts.

Very few operators fire multiple break or canister shells above 6" from HDPE, so the amount of information available for 8", 10" and 12" is very small. Most operators tend to shoot only ball shells in these calibers from HDPE, and use steel mortars buried in the ground for bigger, more powerful, or heavy.

HDPE can take the pressures in part because such pressures are of short duration and because of the flexibility of the HDPE. There are other problems to consider though, such as the type of fasteners used to hold in the plug in the bottom, and what condition they are in. Rusty old staples or a couple of nails or screws may not be able to take the pressure. Some use bolts all the way through the plug with washers that provide a more even distribution of the pressure and a more secure hold, especially over time.

Some other factors are whether you are at sea level or in the mountains, what is the air temperature, how is the mortar placed (wooden racks above ground or buried in the ground), what kind of bracing you have underneath to support the bottom, etc.

Once in a great while one might see a split or tear in the HDPE or a weakening in the plug fasteners if staples, nails or screws are used (more likely in the 5" and 6"), or if a shell is particularly heavy or tight, or both. If this is a concern, use a small, light cardboard tube, like a paper towel core, on the top of the plug for the shell to rest on. By giving it an inch or two space it should reduce the hammering effect of the lift gasses on the HDPE, as well as the fasteners, without seriously degrading performance.

For heavy shells or salami type multiple breaks, schedule 40, or better yet, schedule 80 steel with a good, heavy bottom plate and recessed welding outside, buried in the ground with sandbags and remotely fired, are usually the preferred method. These types tend to generate very high peak pressures at lift and need to have as much height as possible for proper functioning. CPW

MORE ON MORTARS

My mortar update article generated a number of comments from people all over the country. Many were favorable but there were many questions too. Here is some more detailed follow up.

We've always used cardboard in racks to shoot our shows and have never had a problem. Why shouldn't it be used for hand firing?

Let's take a quick look at the process of hand firing a show. Typically in a hand fired show each mortar will be fired 10 to 20 or more times. That means a lot of reloads into a "hot" mortar every time, except at the beginning. Usually the aerial portions are sandwiched between ground effects and that means quick firing in a short period of time.

Cardboard will burn and begin to unravel a little bit at a time. Some cardboard will last a very long time while some will not, even from the same lot. In the dark, it is difficult to tell and you may not find out how bad it has come apart until there is a problem. With more firings and shorter cooling off periods it will come apart faster and that makes reloading successively riskier with each shot.

A reloaded shell may not fall smoothly to the bottom properly, blocked by the core coming unraveled or a build-up of paper shell casings or both; the mortar itself may be smoldering and cause any loose lift powder to ignite during reloading; the difficulty presented in cleaning out any debris without causing any damage to the mortar itself; and the most common method of having cardboard mortars above ground in racks, presents a shrapnel problem should a flowerpot or detonation burst the cardboard and send chunks of wood with nails or screws, not to mention stars, flying towards the crew.

HDPE really doesn't present those problems since the tests done so far show the sides will just bulge out on detonation, but it has some of its own. HDPE is hard to cut and most are roughsawn and that means a jagged edge. Unless smoothed it may cause the match or shell casing with the lift charge to break or tear during reloading, or force the assistants to place a part of their body over the mortar to avoid this problem. And there are concerns from some that successive hand firing will cause the plastic to heat up and become pliable, causing problems again with reloading properly.

HDPE and cardboard though, present a common problem with hand firing; the plugs. Except for some very neat new 3" and 4" HDPE that are molded into one piece with NO need for a plug, cardboard and HDPE are usually fitted with wooden plugs. With each successive shot the pressure on the fasteners increases. That is especially true as the mortars get older and the fasteners become weaker from rusting away. Visual inspection is next to impossible so there is no way to determine how many shots can be fired prudently by hand firing.

Any significant weakening or plug failure may cause shells to burst lower or send the whole mortar and shell up together. Since the shooter and reloader will be within a few feet, he or she is at the greatest risk of all, even when the mortar is buried. And if the mortar is above ground, a burst mortar may send a deadly chunk of wood plug with nails or screws, flying even greater distances into the crew or audience.

Hand-firing a SINGLE shell during a show from a BURIED cardboard or HDPE mortar isn't as great a problem since it will not be reloaded and is in the ground. This is actually recommended for firing salutes.

Also, when a shell fails to fire from a finale rack or due to an electronic or match malfunction from a rack during an electronically fired show AND still has match hanging from the mortar, most operators will hand fire that shell rather than risk reloading it.

Why shouldn't salutes be fired from steel mortars? It's stronger!

Yes, it is stronger, but salutes are also more likely to burst the steel than most other types of shells. While that is not likely to happen, it represents a deadlier risk to the crew and audience when it does happen. A cardboard mortar that is buried will definitely blow apart if a salute detonates, but is not likely to be as life threatening.

When should steel be used?

Anytime a show is hand fired or for any experimental, multi-break or large caliber shells, it should always be buried and sandbagged. In order to prevent low breaks, these shells are often lifted a bit more and the welded steel plug supposedly helps contain the gasses to get it up higher for the breaks to work where they should.

We've always had people who want to get in as close as possible to the finale. Why should we keep them back to 300'?

Finales are most often fired from racks of cardboard mortars and are usually made up of 3" and 4" shells that are chain fused. Any shell detonation in a mortar or muzzle break will send debris of the racks, plugs and cardboard some distance, and although rare, it is much riskier the closer the crowd gets.

Using most muzzle loading and shotgun ammunition tables as a basic guide for killing effect, 300' or 100 yards is about average for most loads and types. Considering the sizes and weights of shrapnel from steel mortars and the screws, nails and wood used in plugs and racks, it is a fair comparison. Buckshot and deer slugs are potent at greater than 100 yards while birdshot loads are potent at 50 yards. Fireworks debris though is not fired parallel to the ground like guns, so trajectory angles may increase deadly range depending on size, shape, weight, type, turnover, wind, and velocity.

What happens more often though, is a rack or mortar may tip over causing any remaining unfired mortars, which can't be stopped, to shoot directly over or into the crowd. Since 3" shells can reach heights of 200' to 300' and then spread open another 200', you need at least 300' of space plus any fallout as a minimum distance. Since many stars will easily burn through clothing and flesh, it's simply a matter of keeping people away enough to minimize the risks. It also reduces the chances of a dud landing where someone can get to it before you do.

Thus if the wind is blowing to the north, any crowd to the south should be at least 300' away and any crowd to the north 300' plus a fallout zone based on the largest shell being fired in the show and wind velocity. Keep in mind though, wind at setup time may not be the same as at show time and moving thousands of people back in the dark or moving all those racks and sandbags is harder to do than setting up a perimeter farther away in the first place.

It is too much work to bury the big 8", 10" and 12" mortars. We put them in garbage cans and fill them with sand and it's worked fine. Why is this bad?

It's a common practice to use garbage cans or 55 gallon drums, but is extremely risky. While unlikely to happen, a large shell that detonates and does burst a mortar or blow out a plug or weld, whether steel or cardboard or HDPE, the debris is extremely deadly. Many of the fatalities and serious injuries involving fireworks displays have come from above ground placement of large mortars.

This method adds even more metal that is potential shrapnel. It may seem all that sand piled around should be able to contain any blast but don't be fooled; it can't. It will barely slow down those chunks of jagged steel or wads of cardboard or wooden plugs, and* that's not enough to protect you or your audience. This risk is increased as more big shells are being fired and the more powerful these shells become.

By placing the mortar in the ground and sandbagging it, you reduce the risk of shrapnel from such a blast mixing in with people, but you don't eliminate it entirely. The big mortars, even when buried, need to be given plenty of space from the rest of the show in the event you have a problem such as a hangfire, muzzle burst or flowerpot.

Keep more ready boxes and keep them farther away from each other, than the usual 25' and separate by size of shell so an 8" doesn't get loaded into a 10" by mistake. They also need extra time to cool down between shots and if you believe in cleaning them more often, keep your crew closely synchronized. You also don't want to have one being fired while a ready box is open or another battery is being reloaded, as the spread of these shells can be 600' to 1,200' and a flowerpot or low break will easily send large amounts of stars where they shouldn't be.

Also, always have at least two mortars of any size in the event you have a problem. The more big shells you fire, the more mortars you 11 need so you can shift from one to another to allow more time to cool down or switch off, if one is unable to be used for some reason. That means you 11 need more space, distance and fallout area, more crew and stricter management of it all. CPW

NON-SPARKING MAGAZINE INTERIORS

If you are considering designing or repairing the wood lining and "lattice" ventilation lining in your small hobby magazine, try what I did. I'm pretty lazy, and I do not care much for things that require a lot of maintenance. So I set out to find a way of lining my Type 2 magazines where I would not have to paint steel screw and nail heads constantly or reset them back into the wood when they work themselves out. I must face the fact also, that the interior of a magazine takes a beating considering the characteristics of the wood lining.

It can be very humid in the summer, and the wood will absorb water from the air and swell significantly. The next day it could be dry and sunny with temperatures easily over 100° inside the magazine. The wood can lose its moisture quickly and shrink, especially across the gain. Several of these cycles will pull out countersunk heads with ease and then you have a spark hazard. So why not use brass or aluminum fasteners? A little more expensive, but safer.

I ended up with a plan that worked quite well for me. I drilled small holes in the half-inch plate floor for drainage of any standing water, then lined the floor with sheets of plywood. Next, I cut the sheets for the ceiling and held them in place with temporary 2x4s. For the walls I cut plywood to fit but before I put the sheet in place I screwed 1-inch wide boards (that were previously ripped, three from a 2x4) from the back to the inside. I used steel drywall style screws but because they are screwed in from behind, they can never be exposed to the interior surface.

These "lattice" boards provide the necessary ventilation along the walls. They are fun vertically. Then these panels will hold the ceiling and floor boards in place by driving a wooden wedge at the ceiling line. Wedges can be cut from waste pieces of hardwood of a size and taper to meet your gaps. After a hot summer I found my wood shrunk considerably. Wide wedges were cut and installed. As they loosen all that required is a good rap with a block of wood for a hammer.

This method requires no holes be drilled into the sides or ceiling. Should the panels need to be removed to repaint the inside steel or clean up spilled materials or repair a leak, I simply knock out the wedges and the interior wood can be completely and quickly removed, virtually without tools. Please consult your state and federal laws, keep your magazine safe, and spend more time enjoying the hobby. CD

USING HDPE MORTARS FOR REPEAT FIRING OF DISPLAYS

by K. L. Kosanke

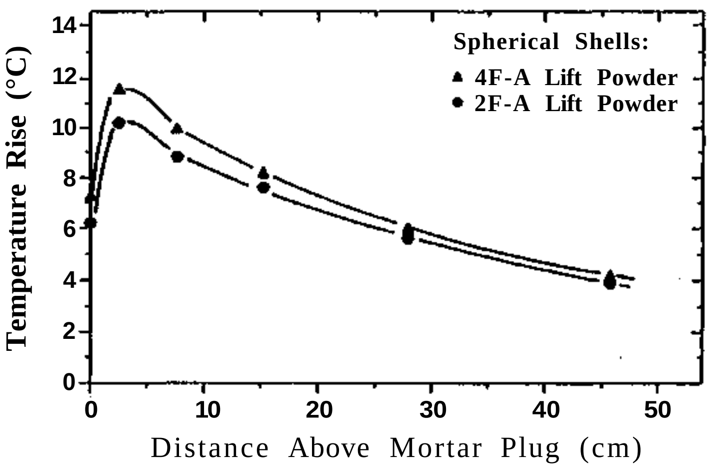
High density polyethylene (HDPE) is a thermoplastic, which simply means that it melts when it gets hot. To make items from HDPE, the raw material is heated, formed into the desired shape, and allowed to cool, whereupon it retains the shape given it when hot. All HDPE mortars are made this way, with some being extruded, cut to length, and a plug attached, while some are blow-molded with an integral plug formed in the process.

All HDPE mortars progressively lose strength as they are warmed toward their melting (softening) temperature. In the course of firing aerial shells from HDPE mortars, approximately 5 percent of the thermal energy produced by the black powder is absorbed by the mortar, thus raising its temperature. For a mortar with a wooden plug, the point of maximum temperature rise is about 1 inch (2.5 cm) above the top of the plug. See graph to the right. As a result of this temperature rise, when an HDPE mortar is not allowed to cool between firings, some mortar strength will be temporarily lost (until the mortar is eventually allowed to cool off). This poses the question as to whether HDPE mortars are suitable for use in displays where they will be fired repeatedly. In an attempt to answer this question, a few years ago Bonnie and I conducted a set of laboratory experiments. The results of this work were reported at the *First International Symposium on Fireworks,* hosted by CANMET in 1992.

For small diameter mortars (only 4" mortars were tested), the results suggested that some amount of repeat firing would not weaken the mortars to the point where a two-fold burst strength safety margin would be lost.

The exact number of safe firings depends on factors such as: the type of shell being fired (cylindrical or spherical), shell and lift mass, environmental conditions (temperature, whether the mortar was rack mounted or buried, etc.), mortar thickness, and rapidity of firing. For most shells, the result was that from 5 to 7 shells could be fired as rapidly as physically possible, but then subsequent firings needed to be spaced from 4 minutes apart (for rack mounted mortars firing spherical shells) to 15 minutes apart (for mortars buried in dry sand firing cylindrical shells).

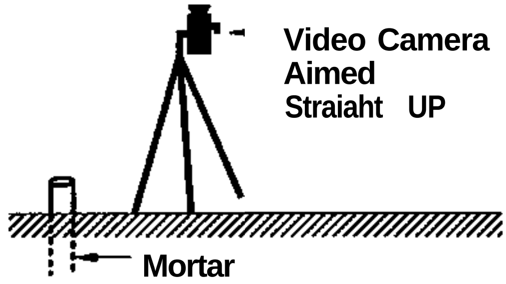
Unfortunately, our laboratory conditions are not necessarily the same conditions found during actual fireworks displays. Further, some have reported that HDPE mortars seem capable of withstanding a significantly greater number of repeat firings than suggested by the laboratory study. Accordingly, actual field measurements should be made to better establish the safety limits for repeat firing HDPE mortars. KLK



SIMPLE MEASUREMENTS OF AERIAL SHELL PERFORMANCE

K.L. and B.J. Kosanke

In designing the most effective choreographed aerial displays, it is useful to know when, where, and how each shell burst will appear. To do this, three aerial shell performance parameters are needed. These parameters are: time to shell burst after firing, burst height above the ground, and burst spread. It can be difficult and expensive to generate these. However, all three can be generated using a slightly modified video camera and VCR. Further, it will generally be possible to collect the raw information during the performance of actual displays; so there is no cost for the test fireworks. This article suggests a method to accomplish this.



The setup for making the video recording is illustrated in Figure 1. A video camera is mounted on a tripod, located in the general vicinity of the firing mortars,[a] and aimed vertically to record the shell bursts. A camera, when set on its maximum wide angle setting, has an approximately 40° field of view. The burst radius of hard breaking spherical shells is about 45 feet per shell inch[1,2] and burst heights are about 120 feet per shell inch.[3] This corresponds to an approximately 40° spread angle. (See Figure 2.) Because of shell drift,[4] bursts may occur somewhat shifted from the point directly in line with the mortar. To be able to calculate a shell's performance characteristics, it is only necessary to capture the central point of the shell burst and its maximum spread in at least one direction (see Figure 3). To improve the chances of capturing a sufficient portion of the shell breaks in the video image, an inexpensive (~$20) wide-angle adapter can be added to the camera lens. This should increase the wide-angle field of view to about 50°.

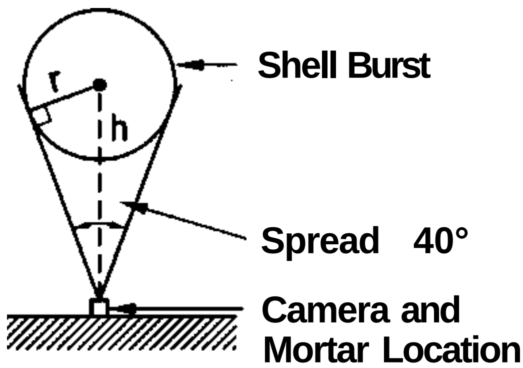


Figure 2. Geometry of a typical hard breaking spherical shell

In the following discussion, it is assumed that the video cassette recorder (VCR) has a time counter (in seconds), a counter reset button, and the ability to advance the tape by individual video fields.[b] It is possible to perform the operations described below without these features; however, that requires a stop watch, would be more difficult, and is less accurate.

Time to Shell Burst

Time to shell burst is the simplest performance characteristic to determine. Using the time counter on the VCR, start timing by pushing the reset button when the shell fires from the mortar. Use either the muzzle flash from the firing (if this can be seen) or the sound of the firing. (Because of the relative closeness of the camera to the mortar, the flash and sound will be essentially simultaneous.) Next, advance the video tape to the point where the shell bursts, and note the time (T_s) on the tape counter. This is the time to shell burst rounded down to the next lowest integer. To determine the additional frac-

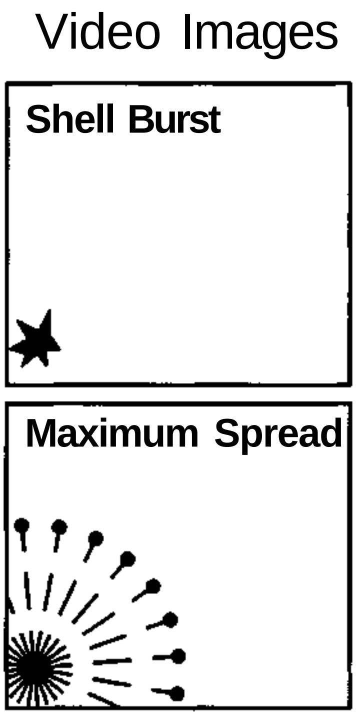


Figure 3. Illustration of the minimum video image requirement to be able to calculate shell performance characteristics.

tion of a second, advance the VCR field by field, counting the number of images (n) until the time counter increases to the next second. The shell burst delay time (Tb) is then

$$(1) \qquad T_b = T_s + \left(1 - \frac{n}{60}\right) \text{ seconds.}$$

Shell Burst Height

One way to determine the height of the shell burst is to measure the time lapse between the appearance of the first light from the shell burst and the arrival of the sound of the burst. (Reference 6 presents a more complete description of the basis for this method.) To be able to make this determination, a slight modification of the VCR is necessary. Almost all VCR's block the sound when advancing the tape field by field; thus this feature needs to be defeated. (It cost the authors $60 to have a video repair shop add a switch to their VCR to accomplish this.)

To measure burst heights, the video tape is advanced to the first field with light appearing from the shell burst. At this point the time counter reset button should be pushed. Next, listening to the sound produced with each advancing field, count the number of fields (n) until the sound of the shell burst is heard. This is not as easy as it might seem. Even when there is essentially no background sound, with each advance of the tape, a sound (something like "chuff") will be heard. The time of arrival of the shell burst sound will be when the chuff sound is suddenly noticeably louder. Identification of when this occurs is made easier if the listener knows about when to expect it. (For 3 or 4-inch shells the time of arrival will be after approximately 25 fields; for 5 or 6-inch shells it will be after approximately 35 fields; and for 8 to 12-inch shells, it will be after approximately 50 fields.) Shell burst height (Hb) is then

$$(2) \qquad H_b = n \cdot D_s$$

where D_s is approximately 19 feet, the distance sound travels in 1/60 second.[c] Because these times are only determined to the nearest 1/60 second, there will be an uncertainly in burst height averaging about 20 feet.

Shell Burst Spread

To determine a shell's spread, it is necessary first to calibrate the video camera's field of view as presented on the TV monitor to be used. To do this, a video recording must be made of (at least) two objects approximately perpendicular to the view of the camera, at a known distance from the camera (D_c), and a known width (W_c) between the two objects. Preferably the two objects will appear near the center of the TV monitor screen.[d] The use of two burning highway flares is often convenient for this. The camera must be set for the maximum wide-angle setting (just as when recording the shell bursts). When the calibration scene is played back, the distance between the two markers as seen on the TV screen, the screen calibration distance (S_c), is measured. A thin transparent ruler may be convenient for this. The needed calibration constant (K) is

$$K = \frac{W_c}{S_C \cdot D_C} \quad (3)$$

When the playback of a shell burst is observed, and the burst spread distance on the screen is measured (S_b), the width of the burst spread in the air (W_b) is

$$W_b = S_b \cdot H_b \cdot K. \quad (4)$$

Recall that Hb is the previously determined shell burst height. Note that W_c and D_c must be in the same units (e.g., feet), as do S_c and S_b (e.g., inches or centimeters), and that W_b will have the same units as W_c and D_c.

The shell burst dimension determined using equation 4 is the "apparent" dimension as seen at the location of the camera. Because of a geometrical effect, which is described in reference 2, this over estimates the true burst dimension by approximately 6%. If desired, the true shell burst dimension (W_t) can be calculated using equation 5.

$$W_t = W_b \mathrm{Sin}\left[\mathrm{Tan}^{-1}\left(\frac{H_b}{W_b}\right)\right] \quad (5)$$

Conclusion

a) One could spend a considerable sum of money on the equipment and test shells to make the above measurements. However, using the method suggested, the cost for equipment is minimal (if you already have access to a camcorder and VCR), and there need be no cost for test shells (if data is collected during displays). Further, any hobbyist collecting and publishing such shell performance data would be doing a service to the industry.

Notes

a) It is not absolutely necessary that the video camera be relatively close to the mortar. However, some calculations will be easier to perform and some results will be more accurate if it is close. The difference between a field by field VCR (sometimes called an AB VCR), which displays 60 video images per second, and a frame by frame VCR (sometimes called an AA VCR), which displays only 30 video images per second, is explained more fully in reference 5.

b) The speed of sound (i.e., Ds) depends on temperature. At 50 °F, D_s is 18.4 feet; at 68 °F, D_s is 18.8 feet; at 86 °F, D_s is 19.1 feet. These values are derived from reference 7.

c) Color TV monitors can generally be relied upon to be approximately linear with respect to the horizontal and vertical scale of images. However, black and white monitors may not be sufficiently linear for reasonably accurate results. If desired, a simple test can be performed by videoing a piece of graph paper and measuring the linearity when viewed on the TV monitor.

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1) K.L. & B.J. Kosanke, "Japanese Shell Break Radii", *Pyrotechnics Guild International Bulletin,* No. 59 (1988).

2) D. Kark, M.A. Willams "Observations on the Perceived Burst Size of Spherical Aerial Shells", *Journal of Pyrotechnics,* 3 (1996).

3) K.L. Kosanke, L.A. Schwertley, B.J. Kosanke "Report on Aerial Shell Burst Height Measurements", *Pyrotechnics Guild International Bulletin,* No. 68 (1990).

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6) K.L. Kosanke, "Determination of Aerial Shell Burst Heights", *Pyrotechnics Guild International Bulletin,* No. 64 (1989).

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KL&BJK

MORTAR SEPARATIONS IN TROUGHS: CURRENT NFPA REQUIREMENT FOR ELECTRICALLY FIRED DISPLAYS

K. L. and B. J. Kosanke[1]

Introduction

The current edition of the NFPA's *Code for Fireworks Display* [NFPA-1123 (1995)] provides some requirements for the placement of mortars in troughs or drums for electrically discharged displays. One requirement is that there must be at least a two-inch separation between individual mortars and between any mortar and the wall of the trough or drum[2,3] (see Figure 1). The NFPA Technical Committee on Pyrotechnics is proposing changes to this requirement in the next revision to the code. This article presents a limited discussion of the rationale for the two-inch separation requirement to aid readers in evaluating the appropriateness of the proposed change.

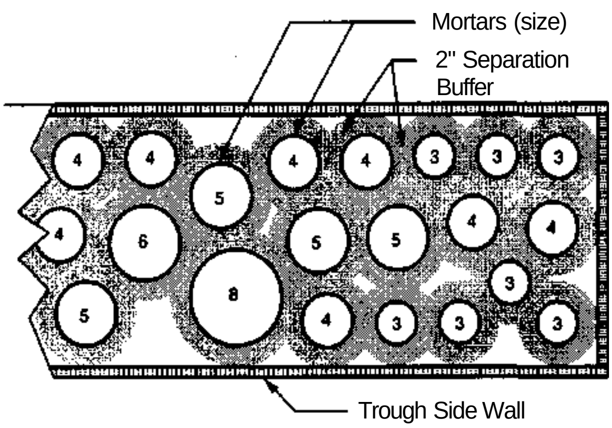


Figure 1. Illustration of mortar placement in a trough using the NFPA two-inch separation. (Overhead view.)

For electrically discharged displays, when mortars are in close proximity to one another, one area of major concern involves a possible aerial shell malfunction within its mortar, wherein the mortar is violently destroyed (a so-called "shell detonation"). Fortunately for star shells, this type of malfunction is quite rare. On those occasions when a star shell functions in its mortar, usually the result is a milder explosion, one where the mortar survives undamaged and the contents of the aerial shell are projected upward, in a mostly harmless display (a "flowerpot").

A violent mortar explosion can be powerful enough to damage an adjacent mortar still containing an aerial shell. This could render the adjacent damaged mortar incapable of successfully launching its shell. However, a greater potential problem is that adjacent mortars, still containing aerial shells, may become dangerously misaligned. Serious misalignment is of greater concern than mortar damage because the probability of this happening is greater, and the possible consequences are more severe.[4] Why this is the case is discussed in the next sections.

There are a large number of ways in which a mortar explosion accident might proceed. Thus, as a matter of practicality, only some of the most likely and consequential scenarios will be discussed. The discussion will be limited almost entirely to a discussion of mortar troughs, when many of the same points apply equally to mortars buried in the ground or in drums. Also, it must be acknowledged that very little direct research has been done on mortar explosions and their consequences. Thus, for the most part, this information is based on accident investigations and general scientific principles.

Consideration of the Hazards from a Mortar Explosion

The energy transferred from an explosion to nearby objects decreases with distance. In large part, this is a manifestation of strong blast pressures dropping roughly in proportion to the area over which they are acting.[5] For example, in Figure 2, if there were a powerful explosion in the mortar, and if there were no intervening materials, the blast pressure at point B would be approximately 1/4 that at point A. However, there are intervening materials, and there is also a loss of energy to those materials in the area of the explosion. In this case, some energy may be consumed in damaging adjacent mortars and in ejecting sand from the trough ("sandbox") and repositioning mortars.

Generally much more force is required to dent or crush a mortar than is required to reposition it. Accordingly, for mortars to be damaged they must be quite close to the exploding mortar. Because relatively few mortars will be close enough to be damaged (as compared with the number of mortars that are close enough to be repositioned) mortar repositioning is considerably more likely to occur than is mortar damage.

For spectators, the potential consequences from a mortar explosion damaging or repositioning surrounding mortars is non-existent, unless one of those mortars contains an aerial shell that is subsequently discharged.[6] There are two ways in which such a post-mortar-explosion shell firing might occur. One is a direct result of the initial shell and mortar exploding; such as the fire and firebrands produced in the explosion causing an ignition of another shell. The other way in which a shell might be discharged is that a firing signal might be sent to the electric match of that shell.

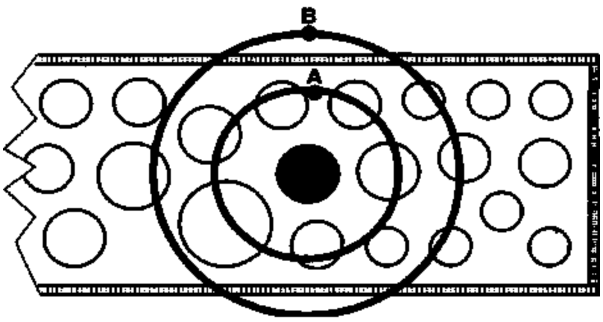


Figure 2. Zones of decreasing blast effect around a mortar explosion.

For spectators, an aerial shell firing after a mortar explosion is only a problem if the shell is discharged from a misaligned mortar that propels it into a spectator area. Given the speed and mass of aerial shells, a collision with a spectator could be fatal. There is also a potential for serious injury from the pyrotechnic output of the shell, should it burst among spectators. In this case there is actually a little less potential hazard from a damaged mortar (dented or crushed) than from an undamaged mortar. This is because, if the mortar is seriously damaged, the likely course of events would be that the discharging aerial shell would also explode in the mortar. Then, the aerial shell would not reach the spectator area to threaten safety.

Accordingly, the major spectator hazard from a violent mortar explosion (wherein a shell fires from an adjacent mortar) is from repositioned mortars, not from damaged mortars. As discussed above, this is because: (1) there will be many more repositioned mortars than damaged mortars; (2) the severity of consequences will tend to be less for damaged mortars because they are less likely to allow an intact shell to exit; and (3) a damaged mortar that is not also repositioned, presents relatively little direct spectator hazard.

Ballistic Considerations for Repositioned Mortars

It is useful to consider what degree of mortar repositioning poses a problem. Figure 3 illustrates the trajectory of aerial shells fired from tilted mortars. These are computer modeled data[7] for 6-inch spherical shells. [Note that the general accuracy of this computer model has been confirmed experimentally.] In this analysis, it has been assumed that the aerial shell bursts 5 seconds after leaving the mortar, and that it disperses its contents with a spread typical of a hard breaking spherical shell.[8]

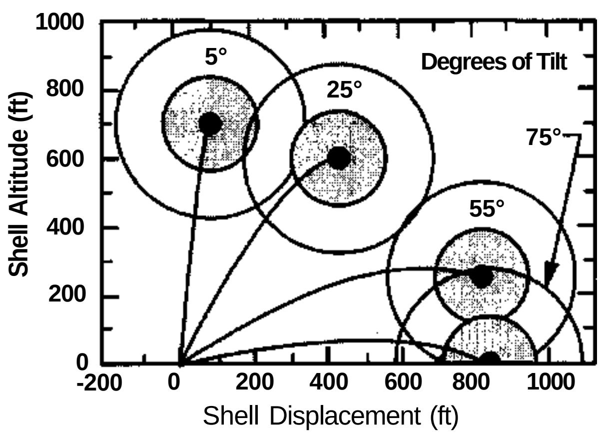


Figure 3. Illustration of the trajectory and functioning of 6-inch aerial shells fired from tilted mortars.

In Figure 3, the location of the shell at the time of its functioning is shown as a large solid dot. At the scale of the drawing, the diameter of the dot is 50 feet and is intended to correspond roughly to the zone of maximum injury potential. In each case the dot is surrounded by a shaded area, corresponding to a diameter of 250 feet, through which there is a much less, but still significant, potential for injury. The still larger circle, corresponding to the diameter of 500 feet, is the approximate maximum extent of burning material from the shell burst and is intended to represent the approximate extent of even minimal injury potential.[9]

For normally functioning aerial shells, it is apparent from Figure 3 that it is not minor repositioning of mortars that poses a hazard to spectators. Of course this is because, the aerial shells fired from those mortars will function far enough above the ground. It is only when the tilt angle (measured from vertical) exceeds approximately 60 degrees that much burning debris is expected to reach the ground.[10]

Conclusions

The exact rationale for choosing a minimum mortar separation of two-inches, and not one or three inches, is not entirely clear (even to members of the NFPA Technical Committee on Pyrotechnics). Nonetheless, the two-inch separation seems to have generally provided a reasonable level of safety for spectators. In a subsequent article, the authors will discuss the possibility of employing alternate strategies to provide an equivalent level of spectator safety in the event of a violent mortar explosion.

Acknowledgment

The authors gratefully acknowledge that Royce Trout of Atlas Enterprises provided some financial support for the drafting of this article.

Notes and References

1) While the authors are members of the NFPA Technical Committee on Pyrotechnics, the thoughts and opinions expressed in this article are only those of the authors.

2) Mortars that are buried in the ground, in troughs, or in drums shall be separated from adjacent mortars by a distance at least equal to the diameter of the mortar. *Exception: Where electrical firing is used, all mortars buried in earth or placed in drums or troughs shall be spaced at least 2 in. (50 mm) nominally apart."*

3) There shall be a separation distance of at least 2 in. (50 mm) or 1/2 the diameter of the mortar, whichever is greater, between the mortar and the trough or drum. *Exception: When electrical ignition is used, all mortars placed in drums or troughs shall be spaced at least 2 in. (50 mm) from the wall of the drum or trough."*

4) For more information on performing hazard assessments, see K. L. & B. J. Kosanke and C. Jennings-White, "Basics of Hazard Management", *Fireworks Business,* No. 129 (1994), or also K. L. and B. J. Kosanke, "Dud Shell Hazard Assessment: NFPA Distances", *Fireworks Business,* No. 178 (1998).

5) For more information on the general subject of attenuation of blast waves, see G. F. Kinney and K. J. Graham, *Explosive Shocks in Air,* Springer-Verlag (1985).

6) For the purposes of this article, no consideration is given to the possibility of debris from a mortar explosion reaching spectator areas. For the most part, when using the NFPA separation distances, this can only occur for steel mortars, and then the two-inch separation will make little difference in limiting the range of the fragments.

7) L. and B. J. Kosanke, "Computer Modeling of Aerial Shell Ballistics", *Pyrotechnica XIV* (1992) and *Selected Publications ofK. L. and B. J. Kosanke, Part 2 (1990 to 1992),* Journal of Pyrotechnics (1995).

8) L. and B. J. Kosanke, "Japanese Shell Break Radii," *Pyrotechnics Guild International Bulletin,* No. 59 (1988) and *Selected Publications ofK. L. and B. J. Kosanke, Part 1 (1981 to 1989),* Journal of Pyrotechnics (1995).

9) The burst spreads of the aerial shells in Figure 3 are shown as being spherical, where actually some would be distorted somewhat because of the motion of the shell at the time of its explosion.

10) When mortars are tilted nearly horizontal, often they will be free to recoil along the ground if a shell fires from it. This has the effect of reducing the distance to which the shell can be propelled; however, that has not been considered in Figure 3.
KL&BJK

COLOR CODING MORTARS
ROY'S CODE

When doing small local shows I often find myself with crews that are largely or completely made up of beginners and near-beginners. This can get a little hairy due to the number of serious errors that could happen. To help prevent such errors, I take several preventative measures. The chief among them is to "take time". I always do pre-loaded shows. That way we can spend the best part of the day loading the mortars with the help of daylight, and making sure everything is correct. However, I have also found the following idea to be helpful.

I have color coded my mortars according to size. When I am boxing up a show, it is a simple matter to color code the boxes (if they are not mixed) or the individual shells (if they are mixed). A quick pass with a spray can does it. Then, when I am out in the field, I don't have to worry as much about a person putting a 5" shell in a 6" mortar. It is easier for a beginner to see that a green shell goes in a green mortar than to realize that there is too much windage when dropping that 5" shell into the 6" mortar.

A lot of people use color coded guns. However, I would like to suggest that the industry consider adopting a standard code. The color code I chose was based on the ANSI Resistor code. This code is an accepted standard in the electronics industry, and can be extended upwards and downwards to any possible size (although we don't need that capability - I doubt if anyone will ever consider building a 2.2K-inch shell). The code is made easier to remember by the fact that it is based around the rainbow colors - Red, Orange, Yellow, Green, Blue, Indigo, and violet. This sequence can be remembered by the name of its discoverer - ROY G BIV. The code is built from that sequence in the following way:

First, the colors indigo and violet are difficult to distinguish. In fact, I have read credible accounts that Newton inserted indigo between blue and violet because 7 was considered to be a more natural number than 6. The bottom end of the scale is extended by adding two "low" colors - black and brown. The top end of the scale is extended by adding two "high" colors - gray and white. Thus, the scale becomes:

0 - black
1 - brown
2 -red
3 - orange
4 - yellow
5 - green
6 - blue
7 - violet
8 - gray
9 - white

This code can be remembered by the mnemonic Bad Boys Rat On Yielding Girls But Virtuous Gentlemen Won't (don't kiss and tell!).

I use a spray can to paint a 2" wide stripe around the muzzle of each mortar. The resistor code uses three colors so that resistances up to millions of ohms can be indicated. However, I just use the last significant digit since there is little chance anyone can mistake a 12" for a 2", or a 16" for a 6". Fractional inch guns (such as a 2 1/2" mortar) are marked with two stripes, such as red above green.

Color coding one's mortars this way has a pleasant side effect. It not only improves safety, I find that I enjoy looking out over racks of colorful mortars. TIP

SHOOTER'S PERSONAL CHECKLIST

What should you bring to a fireworks show if you are to be a new crew member? The answer varies but here are my suggestions.

1. Work clothes and work boots. I suggest steel toe boots that are high enough to give your ankles some support.

2. Shooting clothes. At a minimum you want to wear only 100% cotton, long sleeve shirt and long pants. Many people opt for Nomex coveralls, or a welder's jacket and pants. Avoid nylon and other non-fire resistant man made fibers; if you catch fire these will melt to your skin.

3. Hat. Hard hats are good for shooting; some people wear motorcycle helmets. If I am not in a hard hat I use a PBI hood. A wide brim hat to keep the sun off during setup is always nice.

4. Eye and Ear Protection. The best safety glasses I have found are the Norton-180's by North. They give a wide field of view and are hard to fog up. For hearing protection the muff-type are best for the low frequency attenuation we need. Ear plugs are a second choice. Don't be fooled into thinking that you can protect your hearing by opening your mouth to equalize the pressure. It doesn't work. Some people believe that they are better able to tell if a shell is misfiring without hearing protection, but they also say "huh" a lot if you speak softly. I have seen photos of the inner ear of people with noise induced hearing loss; few of their hair cells are left in their inner ear.

5. First Aid Kit. Don't go overboard, especially of you are not trained in advanced first aid. You want to be able to put a Band-Aid on a cut, that kind of thing. A travel type kit from Walmart should suffice. Leave the trauma packs to the ambu-lance guys.

6. Suntan Lotion - Sun Glasses. Go for the higher SPF numbered stuff. And for sunglasses, be sure they block ultraviolet well. Avoid Blue-blockers however, because rumor has it that these will harm your color vision in time. (Well that's what I heard!)

7. Insect Repellent - Anyone who attended the PGI in Fargo will tell you to get the stuff with the highest percentage of DEET you can find. Many people also have good results with Avon Skin-So-Soft, and you smell better with it on.

9. Hammer and nails - A rip hammer will serve you better in teardown than a claw. I use a claw hammer and carry a Wonderbar for teardown. For nails, use the double-headed type, 6 or 8d should work pretty good. Bring along a pound of longer (say 16d or better) for connecting 2by's together.

10. Tape - Bring duct, electrical, masking, filament and packing tape. Each is needed for different operations. If you don't want to spring for so many, use the above suggestions as a priority order. Don't buy the cheap stuff; they will not serve you well.

11. Scissors - Don't snag your wife's scissors, get a good industrial quality pair. Most of us use electrician's shears. I use Clause (brand) #925's; the best are probably Wiss. Try any good electrical supply house. They are well worth the 15 bucks or so. A razor knife (with a retractable blade preferably) is also a good idea.

12. String - Get a ball or two of good 12 ply cotton string.

13. Stapler 8B staples. WARNING!! - Do not staple into quickmatch; it is a good way to get seriously hurt. The firing of staples into quickmatch can cause ignition of the match either by spark, or in the case of chlorate-based match formulas (some Oriental shells are rumored to use such), just by the crushing of the match by the staples!

Get a staple gun (the type used to put up insulation) at your local hardware store. It is handy for securing polyethylene to your racks in the case of rain. They have a zillion other uses around the site as well but heed my warning!

14. Flashlight - I use several different types for different jobs. The most useful is my Petzl (brand) headlamp. It puts the light right were I need it and leaves my hands free to do other things. A good hand lantern is probably my next favorite (if it has a blinking red light on the back so much the better, as this makes a great dud marker). For use in a ready box an explosion proof model is best. For your first show, whatever you have handy is OK. Make sure the batteries are fresh.

15. 5 Gallon Plastic Pail, with cover - Makes a good tote for your stuff. You can also use it as a seat, shooting line water bucket or emergency soda pop cooler once you add some ice.

That's it. Now you are ready to start working on a crew, enjoy the experience, learn as much as you can and don't be afraid to ask questions. ER

THE WEDDING SHOOT

My niece was to be married in May and I volunteered, as part of their wedding present, to give them a fireworks display on the night before the wedding. As most of my experience had been with small at-home displays, I was a bit trepidatious, but willing to give it my best shot.

I live in the city, so I am limited in what I can shoot, but in the past I have successfully petitioned the local fire chief for a permit to fire Consumer Fireworks and up to 3" shells. I did so again, specifying the time, date and "Class C devices and 3" aerial shells". I received the permit about a month later. I was dumbfounded to discover that my permit read "Class A and B fireworks". I contemplated talking to the club about the possibility of getting something a little stronger, like maybe some nitro for a nice ground bomb, but decided I would be pressing my luck. It just goes to show that you can't expect a whole lot of knowledge from those who are giving out permits.

I rummage through my inventory and found that I had about thirty 3" shells that I had made, been given by a kindly rocketman, or traded at shoots. Not much in quantity, but my shoots are up close and personal, with the audience about five feet beyond the required 210-ft. minimum, so a 3" shell looks a lot bigger. Also, some of the shells had been made with "slow flash", which I was anxious to test, as they were said to produce a lot bigger bang than regular break comp.

From my regular 1.3 sheller I ordered a 36" wheel (with ball bearings yet), a Niagara Falls, two titanium salutes, a 100-shot B Thunder King for the finale, 3" Kanto shells, and some green and red lance. Then I went to work.

The first thing was a set piece. I wanted a neat but simple display, so I got an old 4x8' sheet of 1/2" plywood and stole my wife's brad awl. I made a piece that had a big shamrock in the center, with some left over stabs grouped in the center of it, and the nuptial couple's initials surrounding the shamrock. The shamrock was in green and the initials in red. I used Sticky Match® to connect them, but not ever having worked with it before, I thought you had to have the powder trail right on the match, so I pulled the Sticky Match apart, using only the wider piece. The unintended result was interesting. Instead of lighting all the lances at one time, the smaller powder trail worked like a pointing finger, lighting each lance individually. It gave a bit of grace to the display.

The next thing was a bunch of comets. I'd made some tiger tail comets the wonderful *Introductory Practical Pyrotechnics,* and wanted to try them, so I built some comet racks, aiming them so some would cross in the air, while some went vertically. There were five sets of these, each set wired together, for 30 comets. I made the mistake of leadering the comets with quickmatch, and electric matching the quickmatch, instead of electric matching the lift charge. Consequently, they lifted a few tenths of a second apart because of the variance in the match, and that spoiled the desired effect. But they got oohs and ahhs anyway.

In the cake category, in found some 40 or 50 old aerial cakes, all Consumer stuff, stuff like *Colorful Whirling Whirlwind, Autumn Drizzle, Laser Tank* and other such prizes. Taking a leaf from Irving Snerd's book, I ganged at least four of each kind together, and bound all in the gang with quickmatch and one electric match. (I've since learned a better day - dip four cakes' Visco fuses in a slurry of nitrocellulose lacquer and Black Powder, the wrap them in a square with plastic wrapping tape, avoiding wrapping the outward sticking fuses. Next wrap Sticky Match around the bundle, connecting each fuse. Electric match the Sticky Match and you're done in l/10th the time it takes to quickmatch them, and 100% ignition assurance.)

For ignition I used a great 10 position CD blaster box. I made four of the wooden plug slats that each have ten positions for Seminole wire, and can be quickly connected to the computer cable that connects to the firing box. Thus I can shoot ten shots, quickly disconnect, run over to the next spot, connect to the next slat and shoot ten more. I can do this four times for forty shots, each shot can handle twenty series or parallel electric matches over 500-ft. apart, giving me 800 possible ignitions per display.

To start the show, I put 50 strobe pots in a line along the paved road just in front of the audience, all connected with Sticky Match across the top. These put out a blinding white strobe light, then finish with a small low shower of sparkling gold, red and yellow stars. As they died down I lit a 3" titanium salute that rocked the crowd.

The comets came next, and despite the time problems, lifted well. They also burned a tad long, drifting debris into the loblolly pines at the edge of my property. I watched for fires, saw none, so continued the display.

Next the cakes were lit, and as they died down, the wheel was lit. To keep it from being boring, I hit some more cakes, and was glad I did, because from my firing point, I couldn't see that the three-stage wheel had started burning but was reluctant to turn. By the time the wheel had burned to its third stage, the audience was screaming "GO, GO, GO!" and the wheel finally took off just before the thrusters died. I knew I should have oiled those bearings!

The set piece was next, and it worked beautifully, with the pulsating strobes inside the shamrock surroundeoVby the newlywed's initials bringing gasps of pleasure from the audience. I lit the finale, a series of ten 3" green chrysanthemums and peonies, then a chain of ten 3" variety shells for the grand finale. The final shell was a 3" titanium salute. Glorious! Total show time: 13 minutes.

As I collected my blaster box, computer cables and other stuff and walked back across the road, I noticed a police cruiser had come up the drive. I had a nice chat with the officers, and showed them my permit, but they insisted on having the fire chief come out to the house. After a brief wait, the Chief, the same one who had signed my permit, showed up and we talked. Seems there were 39 calls to the police about the explosions, some from citizens up to three miles away. A friend of my wife's, when she heard the salute, burst into tears and said to her husband, "Sylvia and Wayt are dead - I just know it." She was sure the gas main near our house had exploded.

We decided in the future to delete the titanium salutes; other than that, no problems. The afterglow was especially sweet. I am blessed with understanding authorities, at least for now.

I've been at serious pyro for only two years now, and already have some wonderful memories, the best of which is the good friends I've made and the satisfaction of giving pleasure. WG

SETTING UP & SHOOTING A PYROMUSICAL BARGE SHOW

It wasn't a PGI Convention, but many CPA'ers smelled the smoke August 12th when they assisted in the set-up of a $20,000 electrical show. I had called upon the considerable expertise of the CPA membership to wire a 20-minute pyromusical display to be launched from two barges off the Norwalk Islands. Thirteen members answered the call and assembled at the barge 8:00 Saturday.

First, some background on the show. It was for a wedding; An Englishman and a French woman. His parents live in Wilton and so the show was staged here! They would be on a 92' motor yacht and the show was to be a surprise for her! The plan was for them to motor about for awhile and at 9:00 the live music onboard would give way to our pre-recorded music track and the fireworks would magically appear before them.

To make this happen a four-track tape deck was employed on the 92' yacht. Two tracks of the tape were the music program for the show. These would be played for the wedding party. The other two tracks were the different firing cue tracks that would be broadcast to the two barges on two different frequencies. Needless to say, this was somewhat complicated, but it worked out perfectly.

The show itself included some 340 cues, and over 1100 shells were fired out of individual pipes. The shell list was beefy; one sixteen, four twelves, eight tens, 27 eights, over 100 6's, and lots of other shells.

But let me get back to Saturday morning. On schedule, the Norwalk Fire Marshal escorted me and the shells from the Firehouse to the barge landing. At 8:15 I was pleased to see everyone there and we proceeded to crane our supplies, and then the pyrotechnics onto the barges. Earlier in the week, the mortars had been set on both barges. The large pipes were contained in sand troughs on one barge, and 6" and smaller pipes were kept in racks and troughs on the other barge. It will still take fifteen people a long day to complete the preparation.

The Fire Marshal had inspected the set-up and checked most of my paperwork the day before. He is happy to see me, the CPA, and 3/4 ton of explosives shove off from Norwalk.

Despite the presence of a railroad guru on our boat, we had to wait for the Metro-North train bridge to open, and then we proceeded out through the harbor. Imagine our procession: A 30x90 barge, tied nose to nose to a 180x30 barge, pushed by a 35' tug boat. Atop this platform are countless mortar tubes and fifteen people of dubious sanity. I'm proud to say we stopped traffic, although I think the open drawbridge might have had something to do with it.

At this point we were to meet the Marine Police for an escort out of the harbor. As it turned out they were not available and we braved it alone. Uneventfully, we lumbered out to our position and dropped anchor. At 10:00 we broke out the fireworks and prepared to load.

The mortars were arranged by songs and the boxes were labeled as such. So boxes were placed by the appropriate pipes and the crew went about numbering pipes to correspond with the numbered shells in the boxes. This process does not usually proceed without some tinkering and they were magnificent at making it work.

Teams were assigned to individual tasks and the outcome was great. Because the crew was so experienced, people determined what had to be done instead of distracting others. This is not to say that questions were not asked. THERE IS NO SUCH THING AS A BAD QUESTION WHEN YOU ARE DEALING WITH ENERGETIC MATERIALS. But rather than asking for direction, we engaged in theoretical discussions on the merits of various techniques. This sharing of knowledge and experience is what the CPA is all about.

At 11:00 the Marine Police came out to our encampment to chastise me for not hailing them for an escort when we left the harbor. I would later learn that this little interlude would cost $168.00 (six policeman-hours @$28.00/hr. In the interest of safety, they left and would not return for seven hours.

By noontime it was getting hot and muggy. But it was clear that we had the time and the manpower to finish the job in plenty of time. Some people dipped in the Sound, while most of us just took it easy. I tried a group photo but the camera was out of film. Lesson: Try saying "Oh s---!, I'm out of film!" instead of cheese the next time you really want to get a response from your subjects.

By 6:00 we were pretty much wired in and it was time to check continuity on some 340 circuits. The assistant Fire Marshal was on board and was clearly leaving the show in our hands. And no wonder! - He sees 1100 tubes, numbered and wired. Thicker cables snake back to the firing panel positioned behind a 2x6' barricade. A somber group of Wizards huddle around the panel and grunt at mysterious meter readings. He knows he must trust our witchcraft and truth be known, he simply wants to keep his distance.

Continuity is achieved and the Fire Marshal departs and the Tug arrives to separate the barges and position the larger one. Four persons stay on the large barge and three are delivered to the small one. We are ready.

Immediately I am hailed by the party boat. It is time to test the broadcast of the firing cues. This is the weak link of the event. It's been tested, and we have a back-up, but it is now showtime, and it is an incredible relief when the test tone comes through loud and clear. I am handling a cell-phone to the boat, a marine radio to the Coast Guard, the receiver with the firing cues, and a walkie-talkie to the other barge. Amazingly, everything works.

And then the show beings. My job is simple (40 cues) compared to Phil's (275 cues) and yet I am petrified. I've worked three weeks for this moment and it's here! The first shell calms me and the show proceeds perfectly.

The display ends with the *1812 Overture* and the final shell is the 16". It is big and round but not as big as you might think. At show's end I am reduced to primal bellowing. My -elation is due to the overwhelming feeling of relief; relief from all the concerns that one must have to successfully stage such a show.

The event planner radioes from the party boat with a revue. The only word I remember is "overwhelming" - I guess that means they were pleased.

The final tally: Out of 1100 shells only 5 failed to go off. This was due to wiring pull-outs. A very impressive team effort indeed.

A copy of the videotaped set-up of this display is being made available to the Norwalk Fire Marshal's office for instruction of their officers, and excerpts can be seen in the *Fireworks Video Magazine.* JCW

HOBBY MAGAZINE LOCKS

News reports of fireworks regulatory agencies' over-zealousness have left me paranoid. Unbelievable delays and requirements; sometimes rules and laws which seem to contradict each other. If you make a mistake, you face revocation of licenses and permits, massive fines, imprisonment. This is a tough hobby! Can someone get into your magazine without your knowledge?

Last year I constructed a new Type 2 magazine using the *Construction Guide for Storage Magazines* published by the Institute of Makers of Explosives. As you know these are some very secure boxes, to say the least! But my paranoia kicks in. I was at my locksmith's shop to buy the two padlocks. Double security! I wanted his recommendation on a sturdy, well built pair of paddle locks. He was impressed by the requirement for dual locks and the guarding requirements which prevented a bolt cutter from cutting off the lock or hasp.

I picked out a sturdy set of high quality paddle locks and asked how long would it take him to get this lock open without my key? The answer; 6 seconds! All the other paddle locks he had on display received a similar response. I explained my concern over someone being able to get into my magazine and make changes to the inventory or records without leaving a sign of forced entry and how this might cause problems if I am inspected thereafter.

He recommended a 'mortise' type lock as allowed in the *Construction Guide for Storage Magazines* and a locking bar setup as used on safes, and a lock used on vending machines. The lock cost about $100.00. In my opinion, this was a small cost as compared to the 9,000 pounds of half-inch plate steel it takes to safely protect the maximum of 500 pounds of salutes inside! If you are designing or buying a magazine, please see your locksmith and rest easy at night. CD

THE MAGIC OF PROFESSIONAL PYRO ADHESIVE

There seems to be something magic about the designation: "professional pyro adhesive", which is probably why many hobbyists have tried to duplicate it and often paid good money for a recommended formula. Most of these mixtures are based on sodium silicate (water glass) with the addition of some filler to give body and an attractive color. The main advantage for commercial manufacturers is, of course, that such adhesives set rapidly after mixing, thus speeding production. The disadvantage is that they must be used shortly after mixing or they will get too hard, like the two-component epoxy resins adhesives.

Back in 1978, Big Bruce warned against mixing the sometimes-recommended whiting with the water glass, saying it hardened too fast. This he blamed on impurities, like table salt, in the whiting, so he recommended pure calcium carbonate as the best filler, about 1 1/2 volumes to 1 of sodium silicate.

Actually, if rapid setup is not essential, and time is not of the essence, ordinary white glue such as Elmer's is excellent for use as an adhesive, and does not deteriorate with time. Moreover, it doesn't have to be mixed before use and you can take your time putting the pieces together. However, if one is in a hurry, he might consider hot-melt glue. It also doesn't "powder-out" or crack with time.

One more point. We used to use sodium silicate with no additives as a dip for the nozzles of cone fountains. MPVH

BETTER HYDROGEN BALLOONS THROUGH CHEMISTRY

I was quite surprised to see the references to making hydrogen balloons with lye and aluminum foil in a pop bottle in "Anon Pyro's" recent AFN article. I thought that was my invention! As I recall, I began experimenting with hydrogen balloons in the summer of 1967. At first, I followed the instructions given in a book of "experiments for amateur chemists" I found in a local bookstore. It called for diluted "muriatic" (actually hydrochloric) acid and zinc strips in a pop ("soda" in New York) bottle with a balloon stretched over the top. It worked fine, but my friends and I had no source of large quantities of zinc. We were able to get some zinc by cutting open flashlight batteries and saving the zinc inner linings, but that was laborious and expensive.

I first tried to substitute aluminum foil for the zinc, but the reaction of aluminum and hydrochloric acid produced so much heat that the product seemed to contain as much hydrogen chloride gas as hydrogen. The balloons that were filled with the mixture refused to float. So, I went back to my chemistry books to see if there was something I could substitute for the hydrochloric acid. I found a reference to a reaction between a sodium hydroxide (or lye) solution and aluminum that also produced hydrogen. It worked fine, and my friends and I made successful hydrogen balloons for the rest of the summer using lye and aluminum foil. To fill the larger balloons, we replaced the pop bottle with a cider jug.

About ten years later, I learned that other teenagers in my area had also made hydrogen balloons the same way, so I figured that details of my procedure had traveled through my high school by word of mouth. I wonder if Anon. Pyro also heard about the lye/aluminum foil process from his high school classmates (but it seems unlikely that word of my invention could have traveled as far as Anon Pyro's neighborhood from Orange County, New York). Maybe it was actually a case of "independent invention"!

There were other "science projects" that we undertook that we heard about from other students at my school. One was making hot-air balloons from dry-cleaning bags. All that we needed to do was make a hoop out of thin copper or steel wire to hold the bottom of the bag open. (It was simply taped on with Scotch tape.) Then we attached a piece of wire that went across the opening that had a wad of cotton or paper towel fastened to its center. The cotton or paper towel was then saturated with lighter fluid and ignited. The bag quickly filled with hot air and if the outside temperature was low enough, it rose a considerable distance into the air. This worked well in the winter and spring, but not in the summer. (Of course, any balloon with an open flame beneath it is a fire hazard.)

Another, much more dangerous project was making primitive rocket engines by filling empty CO_2 cartridges with match heads. These engines were made with the small CO_2 cartridges, and ignited with visco fuse. Later, we got some larger cartridges but they exploded quite loudly. I immediately realized that dangerous shrapnel was produced by an exploding CO_2 cartridge and that we were lucky no one had been hurt.

At any rate, the explosions scared us, and we quickly abandoned this foolish line of experimentation. A year or so later, I bought a copy of Weingart's *Pyrotechnics* and learned how to make safe and more effective rockets using rolled-paper casings and slow-burning black powder mixtures. And, of course, my chemistry students now know how to make them, too. ST

COLORED FIRE PRODUCTS BRIGHTEN WINTER FLAMES

Recently we have received some questions about how to produce colored flames in those fireplaces. While not strictly *fireworks*, surely this is a case of applied pyrotechnics, so here's a little article on some ways to make the colored fireplace flames, and a few ideas for perhaps making some bucks from your neighbors by using your pyro wizardry to supply them with colored flame products.

We have made pretty little packets of colored flame materials by taking 6x6" (or larger) squares of decorative gift wrapping paper, putting about 1/2 ounce of various chemicals in the center of a sheet, then gathering the corners and forming it by twisting the four arms and fastening them together with string or leftover gift ribbon. When the logs are burning well, one of these thrown onto them will nicely color the flames.

The chemicals are cheap and mostly easy to get if you think about possible sources and shop around. They are not regular pyro chemicals.

Copper chloride gives bluish-green
Zinc chloride gives an interesting show, as does zinc metal powder
Copper ammonium chloride makes a lovely, soft blue-green.

COLORED FLAMES WITH SAWDUST PRODUCTS

This is an opportunity to take a waste product - sawdust - and use it to produce a really nice fireplace product, and use up some of your surplus pyro chemicals too. Here are the chemicals to consider:

Red - strontium nitrate
Yellow - potassium nitrate
Blue - copper sulfate
Orange - calcium chloride
Green - sodium borate (Borax)
Green - barium nitrate
Purple - lithium chloride
Emerald green - copper nitrate
Yellow - sodium chloride (table salt)

We use sawdust, either from our own shop, a neighbor, or obtainable from a nearby woodworking shop. Also, corncob meal, cottonseed hulls, even rice hulls may be used.

A good place to start is 1 ounce of chemical dissolved in 1 quart of hot water. More chemical could be used, up to a saturated solution, but it is a good idea to watch the costs in a throw-away product like this.

The sawdust is added to the chemical solution and allowed to sit overnight. Then we drain off the liquid (and later return it to the container to be used again), then we spread the wet sawdust over waste newspaper, in a nice, dry, safe location, and allow it to thoroughly dry. Again, the material can be formed into usable lots by putting a couple of tablespoons of it in a decorative paper package. Other ideas should occur to the preparer.

All those pine cones that dropped recently should have completely opened by this time. A walk in the woods (watch out - hunting season is on in most states) should allow for a plentiful harvest of various sizes of cones. Remember to wear some kind of gloves because that pine pitch on the cones is an incredible nuisance.

Besides their decorative utility, the cones are useful for a variety of pyrotechnic articles, including colored fire producers in your fireplace, as fire starters, and even as colored flame fire starters.

The easiest is to simply soak the cones in that same solution as above. It may take some trickery to get the cones in some kind of container and completely covered with solution. Just give it some thought. We soak the cones for quite a while, sometimes even putting a little alcohol in the solution. It may be necessary to increase the strength of the solution. When completely dried, the cones are thrown into the fire, preferably right against a glowing log. You get not only the colored flames, but a nice pine smell too.

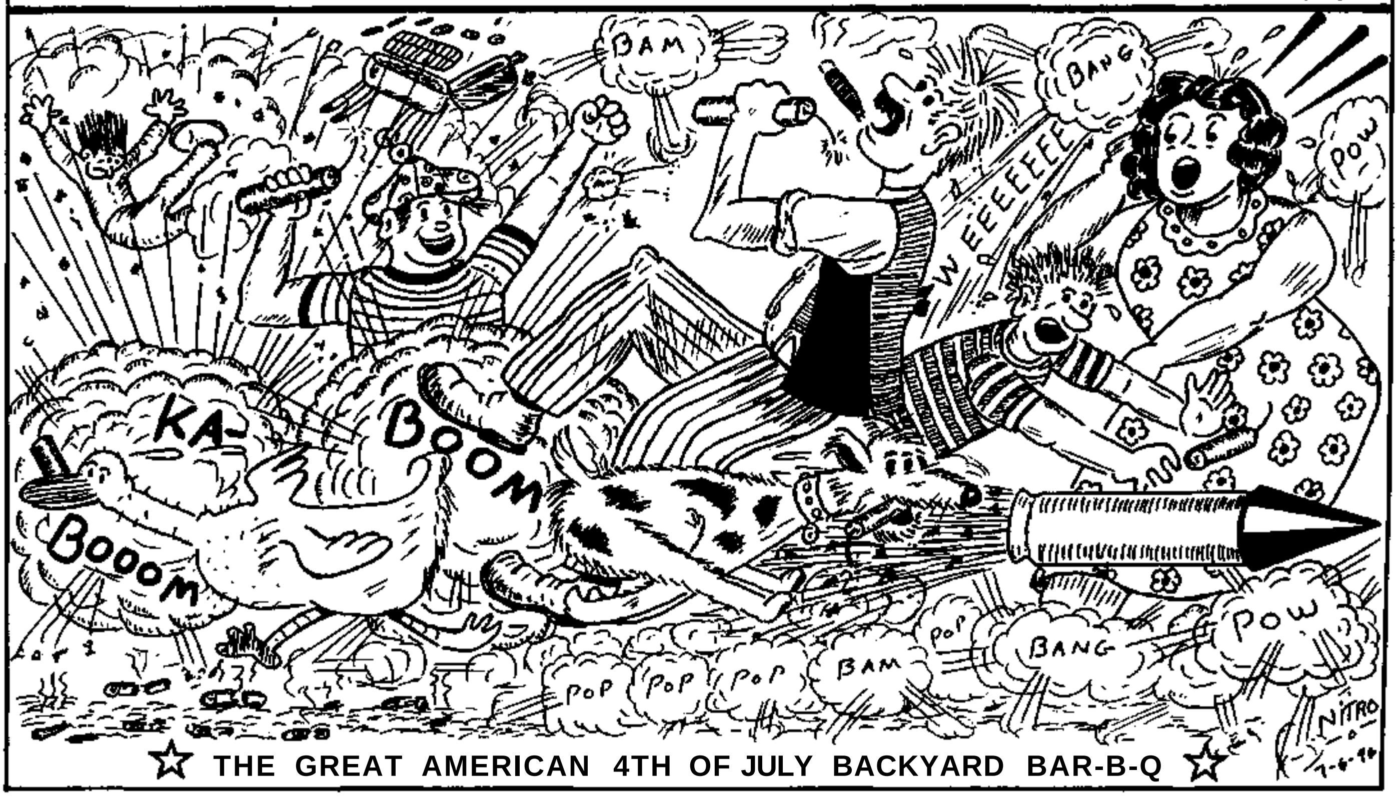
Pine cones may be dipped in melted paraffin. Then when drained and hardened, the cone makes an excellent fire starter. It takes fire readily and usually burns long enough to get your fireplace going. One pound quantities of paraffin can be found at your local supermarket for about $1.49. Larger quantities come directly from the petroleum bulk plants at prices you wouldn't believe.

These fire starters also can be used as colored flame producers by sprinkling some of those color flame chemicals above on the melted paraffin cone before it has a chance to harden.

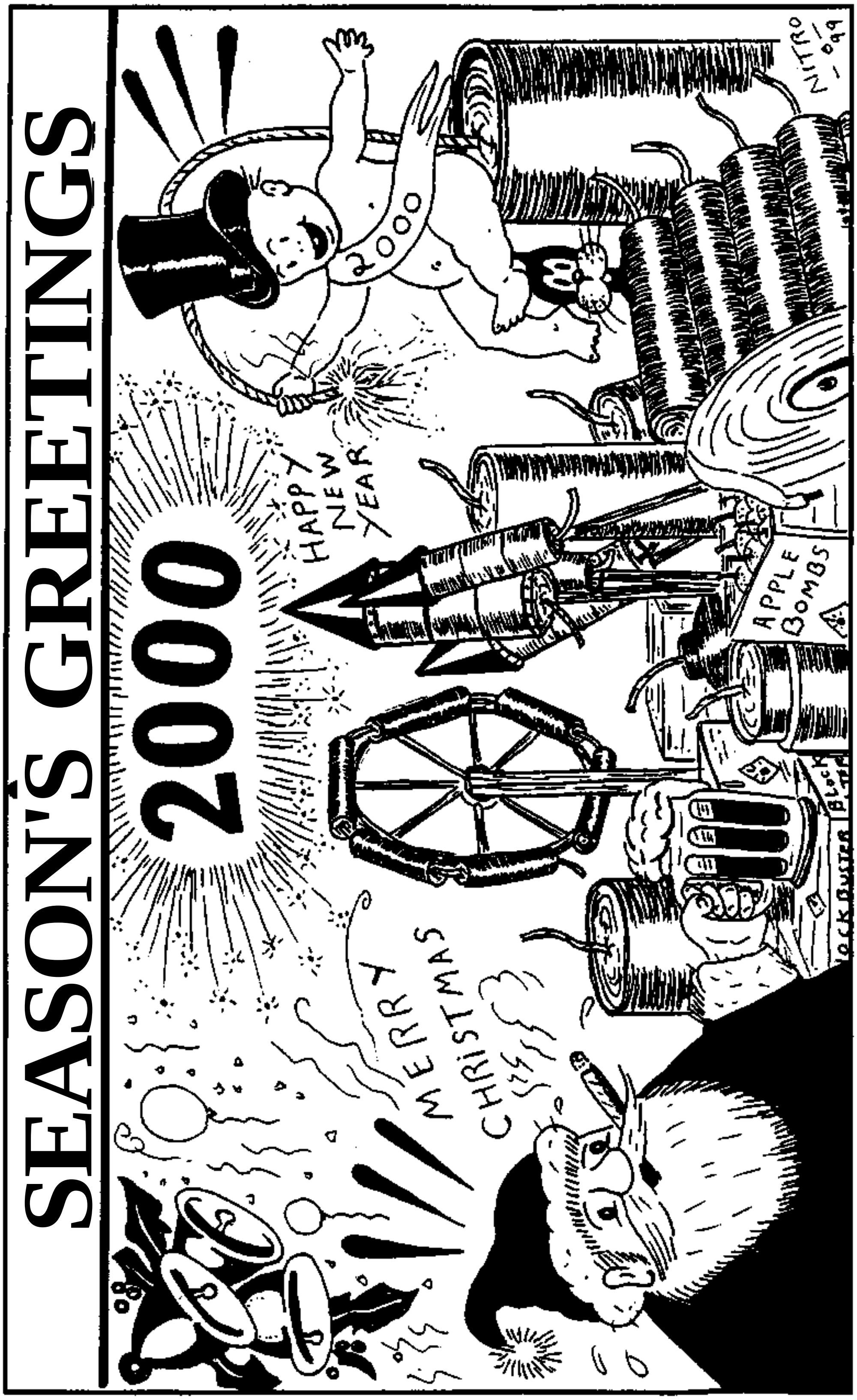
All of these pine cone products can be packaged in plastic bags and a colorful header card can be stapled on, and that's how easy it is to get a cottage industry going. The trick is in marketing these products. If you give a couple of minutes of thought to what kind of stores would carry items like these, you'll see that it is just a case of visiting the stores and selling the owners on carrying your line of pyrotechnic colored flame items. Making them is really cheap, so you can use price as a strong selling point.

If you locate a good supply of coarse sawdust, and make a contact for really cheap paraffin, it's not difficult to get into the fire starter business. Sticks and cubes of sawdust/paraffin can be produced, packaged, and now you've got another item for your line. Who says you can't make money in pyrotechnics? JD

★ A GRAND AND GLORIOUS 4TH TO ALL. ★



☆ THE GREAT AMERICAN 4TH OF JULY BACKYARD BAR-B-Q ☆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HAPPY NEW YEAR
MERRY CHRISTMAS
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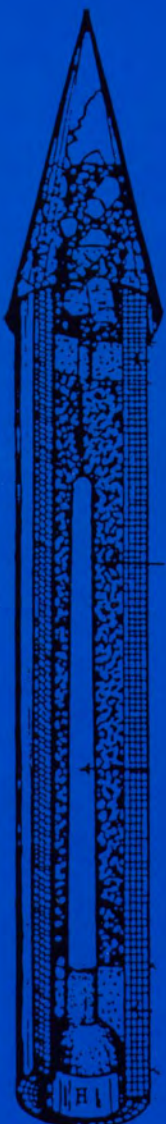
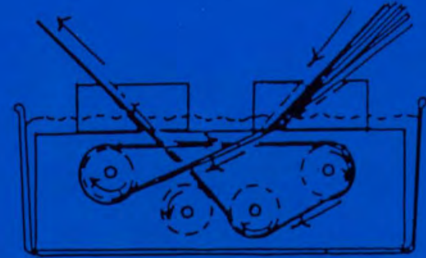
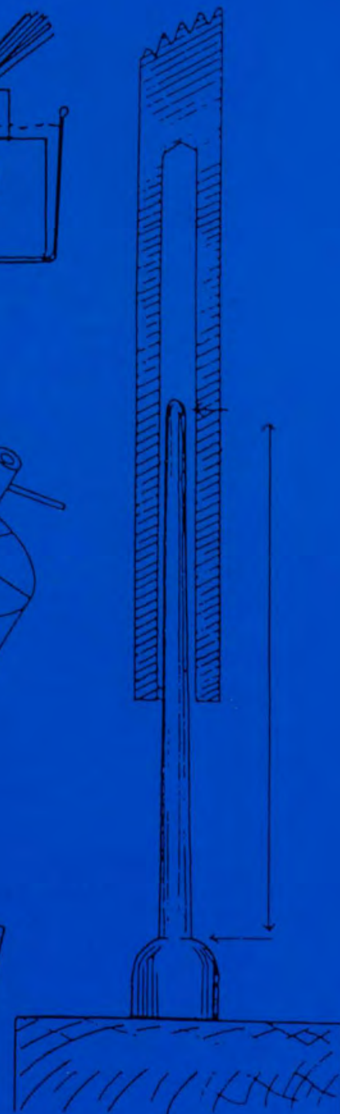
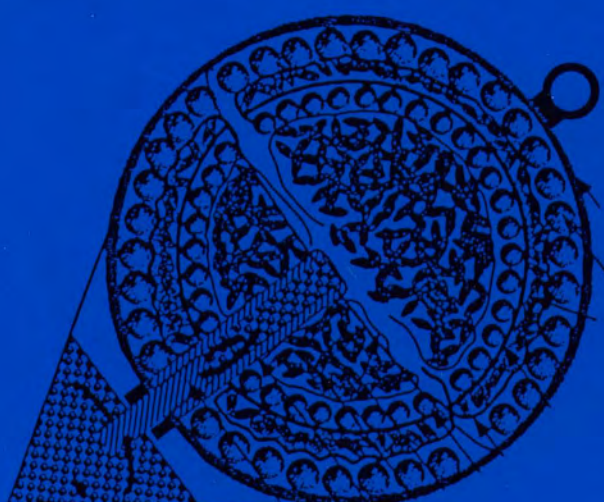
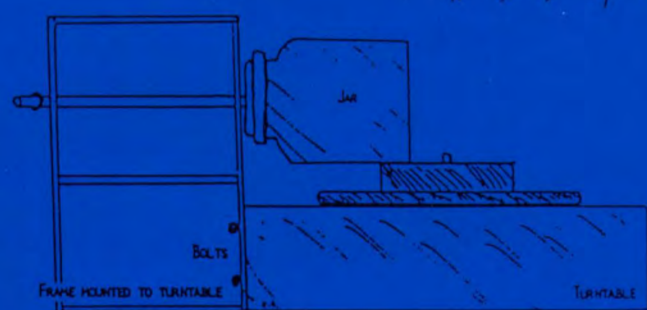
APPLE BOMBS

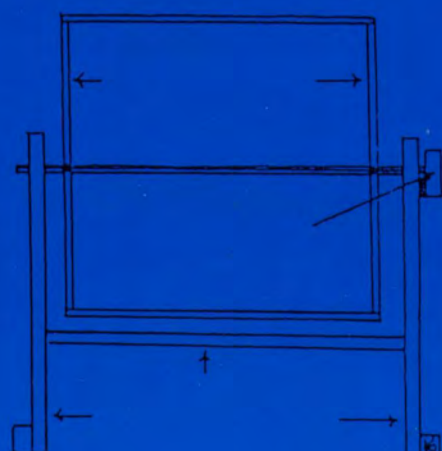


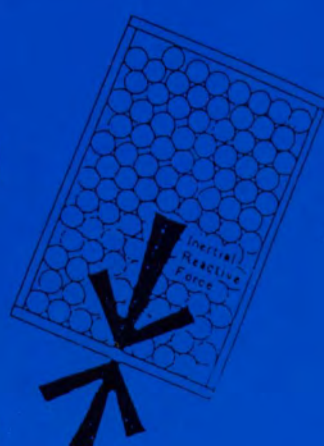












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