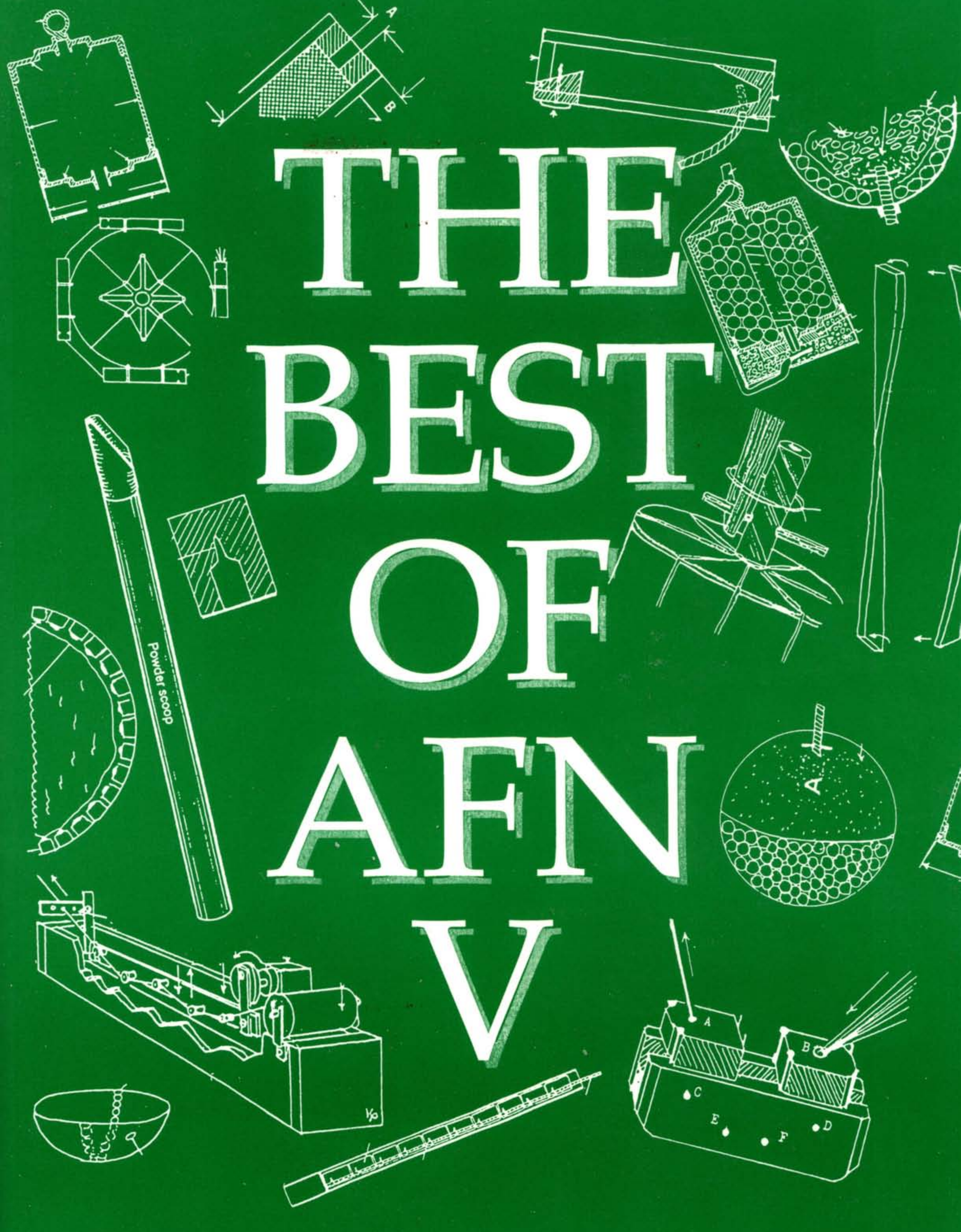
THE BEST OF AFN V



THE BEST OF AFN V

Edited by Jack & Dorothy Drewes

AFN *American Fireworks News*

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PREFACE TO THE 5TH EDITION

The five years that have passed since the introduction of *The Best of AFN IV* have seen an amazing transformation in the 80+ writers whose contributions to the fireworks literature make this book possible. When the *Best* series began we were all still struggling to figure out what it's all about. We didn't even speak the same language! Was it spoulette, or spoolette or Roman fuse or rammed fuse? And why should we bother with it at all when we had perfectly good Japanese time fuse, or blasting fuse, or even visco?

That's all water under the bridge now. Many of the serious pyros of yesterday are the professionals of today, or the serious enthusiasts who may make their living elsewhere but who work the firing line when a display operator calls, or who are working in their spare time on the next innovation in effects. Truly, as fireworks manufacturing in the U.S. moves overseas, it is the contributor to, and the reader of this book who is keeping the fireworks tradition alive.

And that helps to explain how the *Best* series has progressed, or perhaps matured is a better description. We have virtually no more articles on how to make triangle crackers and how to roll your own tubes (with a few excellent exceptions). In fact, many of the articles in this book are advanced fireworks techniques and effects. What a fabulous five years these have been!

So open the book and take a look at the Rockets section. The Basic Bottle Rockets that are found in previous *Bests* are now sophisticated rocket articles that make your heart leap with joy. The old articles about not putting a shell upside down in the mortar are now classy pieces on choreography.

Best V is a fitting progression in our fireworks world, a mirror to see ourselves advanced from the stuttering, stumbling beginners of the past, to the knowledgeable fireworkers of 2005. It's impossible to heap enough praise on the heads of the contributors to this book. This time we show their names. Tell them THANKS! the next time you see them at a meeting or convention.

Jack Drewes, September, 2005

OUR LOVE AFFAIR ON THE 4TH

by Ken Barton

The events of September 11 have left the citizens of the U.S. with a myriad of emotions, some of which have not been felt with such intensity in sixty years. One emotion that towers above all the others seems to be Patriotism. At no other time in recent history has there been so much interest in proclaiming our being "Proud Americans" Perhaps patriotism celebrations involving fireworks would be in order...wouldn't they?

Going back to the turn of the century, even before the many Italian fireworks families settled in Pennsylvania, American began its love affair with fireworks on the 4th. No other effect, even available today, rivals the similarity between fireworks explosions, color, whistles, strobes, and other effects, and those produced in wartime battle. These effects illustrated the struggles for freedom and celebrated the memory of those that died preserving it.

Now it has become time again to re-investigate the celebration of being Americans. In recent e-mail from other pyro clubs, there has been discussion of the display of many American flags, both of the cloth type as well as the set piece type. Some clubs are even speaking of opening their meetings with the Pledge of Allegiance. Perhaps some of us might have even forgotten the words over the years...it's time to learn them again.

If it's a patriotic celebration, fireworks should be there to accompany it. Why only wait until the 4th of July? We should be proud to be Americans EVERY DAY!

If you got 'em - bring 'em. If you don't, buy some.

Maybe in tough times like these we ought to smear a little charcoal on our faces and pose for a photograph with the caption saying,

GOT FIREWORKS!

KB

PRACTICAL USE FOR HIGHLY ENERGETIC MATERIALS AROUND THE HOME

By Jim Longknife

My interest in highly energetic materials extends beyond there use in pyrotechnics and I've often found myself wondering if I could find a practical use for them around the house?

Well I have found one use that satisfies both the pyro in me and serves a useful task around my home.

With this summer reemergence of the West Nile Virus in my area it is prudent to deny the virus its carrier, the mosquito its breading spots in stagnant water.

While yes it is easy to deny the mosquito their breading spots by turning over flower pot pans or buckets and removing trash like paint cans and old tires, what about water catchers that are not movable?

In my yard we have laundry pole socket made of heavy gage aluminum, set in concrete, which accepts a 1 1/4" x 2" rectangular pole to a depth of 14-inches. As this socket has no weather cap it fills with rain water, providing a breading spot for mosquitoes.

My first thought for removal of the water was to get out the "ShopVac" and suck it out. The drawback to this method is after cleaning out the socket I'd have to wash out the vac to remove the stench of fetid water. To my way of thinking, that's to be avoided.

Then that devious part of my mind asked the conscious mind why not use the gas generated by the rapid decomposition of some high energy material to eject the water from the socket? Or put more simply "Lets blow the water out of the pipe with a firecracker!"

In my first attempt I taped three inchers together, matched them with a length of green visco, covered the whole thing with masking tape for waterproofing, and attached this kludge to a long stick.

The first firing of the firecracker kludgeup was less than satisfactory. I backed off quickly after lighting the visco and shoving the charge to the bottom of the laundry pole socket. When the crackers went off the gas generation was insufficient and the water coughed up out of the pipe like a coffee percolator, leaving water still in the pipe. A second charge finished the job.

The next time the socket needed clearing of water I knew from the first tries that I would need something in the salute class to clear the laundry pole socket in one try.

The salutes I've been fabricating are made from 1 3/4" lengths of PVC tubing with an 3/8" i.d. I use thick jell type home epoxy to plug the ends and charge them with flashcracker powder. Ignition can be done by electric match or a good long length of visco.

As before I attach one of these salutes to a long stick to place it at the bottom of the socket. When the powder is ignited the resultant rapid decomposition converts the mass to a gas which produces a twenty to twenty-five foot high geyser of finally atomized water.

Amazingly, there is no loud report, just a sound like a loud cough. After several clearings of the socket by this method even the muck at the bottom has been ejected.

Call it overkill, but there's no mess to clean up, it gets the job done, and provides (admittedly questionable) satisfaction.

One final word of caution, don't stand down wind when doing this or you may wind up smelling like the back water of a swamp! JL

QUOTE OF THE MONTH

I'm not sure I like screening whistle comp. I got a static shock one time while screening it. It was then that I found out the color of adrenalin is brown.

Steve Robertson

DISASSEMBLY OF A SMALL FESTIVAL BALL

By Bob Svenson

Did you ever wonder what's inside one of those consumer fireworks *Festival Bolls?*

A scale wasn't handy when I dissected one so I settled for volume measurements. These little shells are designed to just toss some color in the sky, not for symmetric breaks, so the exact amounts aren't critical.

The plastic hemispheres were made from a green plastic that's fairly pliable (much like the casing used for "Cracker Balls"), rather than the more brittle shell casings most of us have used to construct larger shells. The circumferential joint on the hemis separated easily so I don't believe they were glued together; evidently they rely upon the paper layer to join and seal the hemis.

The stars were round and 1/8" to 3/16" in diameter. I didn't analyze the composition but the stars were rolled around a grain of sand. The stars were loaded in the Poka style, where the stars and burst are just dumped in with no attempt to arrange the stars within the hemi.

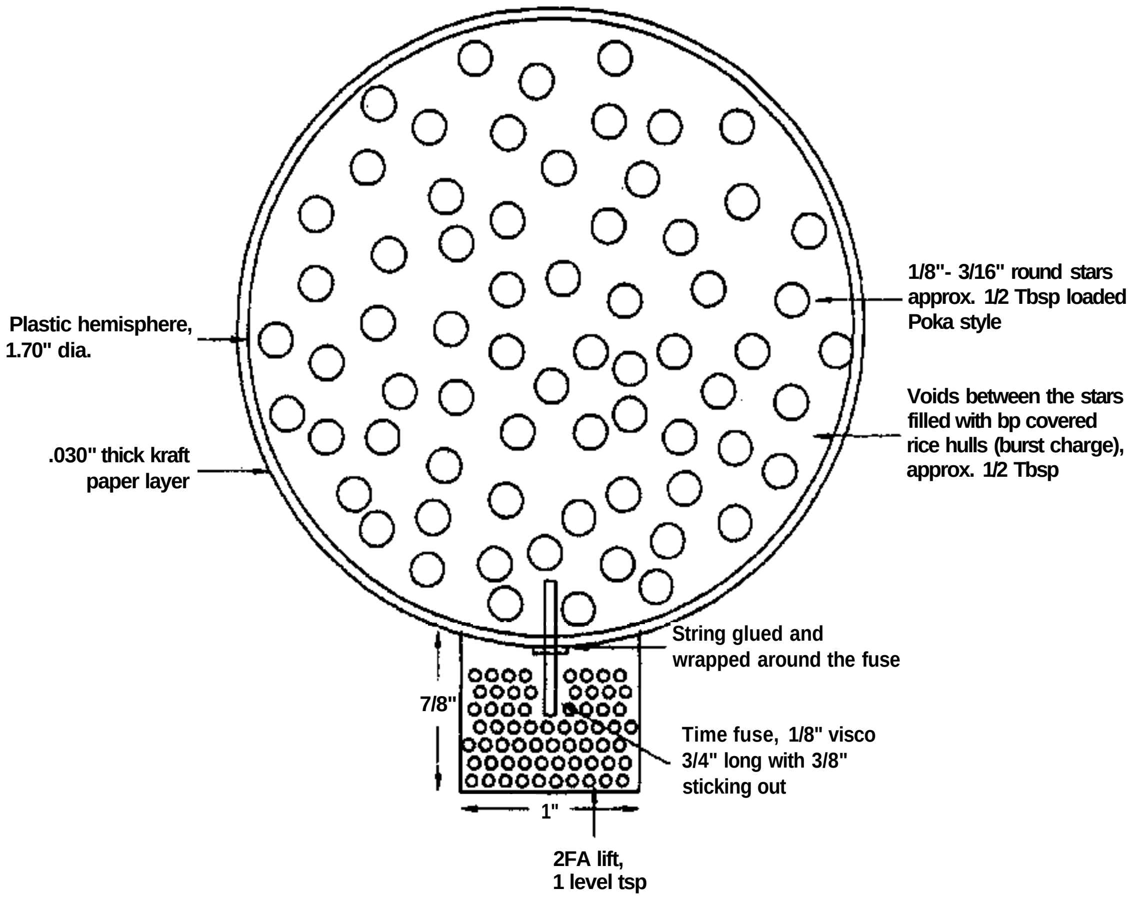
The time fuse was just visco fuse. No priming was noted on the end of the fuse. There is no shoulder molded in the hemi; the fuse was held in place by a piece of string glued and wrapped around the fuse.

The lift was standard 2FA black powder.

The fuse was the normal "fast visco" that is found on most of the festival balls. I'd like to find a source for this fuse because I've found it makes a nice passfire for rocket headings.

No real surprises were found in the construction. I'm sure that with little effort the average pyro could develop a similar device, probably with much better colors and effects.

BS



M-80S, SILVER SALUTES, & CHERRY BOMBS: OH MY!

By Charles P. Weeth

The experience of youth

For most of us "Baby Boomers" born after World War II, we remember the "good old days" playing with all those wonderful "firecrackers". For us firecrackers were M-80s and silver salutes, with an occasional cherry bomb. The M-80s were so powerful they could split bricks, splinter boards and do other such wonders that they of course captured the attention of anyone enthralled with the world around them (meaning anyone alive with some cognitive functions).

I vividly remember my youth in Louisiana outside of New Orleans in the late 50s and early 60's. We'd pool our allowances together or gather empty soda bottles at the construction sites and along the roadways to turn in at the gas station on the highway for a nickel. When we had enough money we'd go buy M-80s or silver salutes. The price was one M-80 or 3 silver salutes for a quarter from the hobby shop just down the highway. In those days if you were tall enough to push the quarter over the counter, you were able to buy them; no questions asked.

Once we made our purchase we would spend hours arguing with each other how we'd play with them. The anticipation was as much fun as the actual event. We'd build elaborate brick and wood structures from scrap we'd find and see if we could demolish them and other such grand pleasures of youth. When we learned the fuses were water resistant we'd drop them in the canals and rivers, float them out on driftwood, toss them in the ditches and grab up the stunned crawdads, snakes and frogs.

We never had anything serious happen to us, but we did have some close calls, especially once ... something I won't go into here.

Of course we also used to play in the railroad yard putting pennies and other things on the rails, diving from the trestles into the canals, playing on old barge wrecks along the Mississippi River, catching 50+ pound snapping turtles (which could take a hand off a small boy) and poisonous water moccasins, swinging from the vines in the trees, building bicycle jumps on the 40 foot high levee, climbing on buildings and roofs, racing homemade go-carts and scooters with lawn mower engines, shooting BB and pellet guns, slingshots and bows and arrows at way too many things, and other wonderful youthful endeavors kids have always engaged in and probably always will too.

Looking back I often marvel that I never broke a bone, had only minor scrapes and bruises, stings and only a few minor scars from all of this activity! The most serious injury I had during this time was a slight concussion from getting hit with a baseball during organized Little League ... and I was wearing a helmet!

I also survived the things some of the older boys in the neighborhood did too. They of course had more "experience" than the younger boys and so had figured out all kinds of things one could do with firecrackers as well as matches, liquid fuels, and other energetic materials.

As in most societies, the bigger older boys often play pranks or "haze" the younger boys and sometimes these can turn into something quite serious. A companion was the victim of a hazing prank during a Boy Scout hiking trip and was severely burned as a result. It's hell to have the real world shatter the illusions of youth!

When my family moved here to Wisconsin in 1965, things were very different. Besides being a lot colder than I was used to (I'd only seen two snowfalls in my life until then and none was more than a dusting), M-80s and even smaller firecrackers had been banned here for quite some time. Up here the kids thought having a Chinese firecracker was a big deal!

These were still readily available from an elaborate distribution network of adults who would pick them up on their travels to those enlightened states where fireworks are still legal. They would sell or trade them with other adults who would sell or trade them to friends, with many going to the market most eager to have them: young gentlemen.

I don't remember ever buying any up here because I considered the prices so high (a penny a piece or so) and the crackers so weak. But if a friend had an entire string, much less a brick, it was considered quite a big deal; you were the guy to be around! It still is the thing to do for young gentleman in June, but it doesn't seem to be like it was before, even with more fireworks available and going off all over.

I came across some boys in the alley lighting firecrackers and bottle rockets a few years ago. They started to scatter when they saw an adult approaching, but one of them knew me so they were eager to show off the fireworks. I asked one kid what he paid for his little IV2" no-name firecrackers and was astounded when he said a nickel each!

Of course I still did much the same things as before only here we had 600 foot bluffs to climb, with caves to explore and trails to race bikes up and down instead of short levees. We even had the proverbial "Suicide Hill" for sledding and tobogganing, something new to me but that I quickly took to. We caught rattlesnakes instead of water moccasins, still dug out an odd snapping turtle in the marsh but they weren't as big, still skinny dipped in the Mississippi River at "Bare Ass Beach", still went to the railroad yards and all the other joyful but risky deeds of youth.

The experience of reality

M-80s, cannon crackers, silver salutes, cherry bombs, and other big bangers have been federally banned since 1966 and they are no long considered "firecrackers" but Illegal Explosive Devices (IEDs). Making them, possessing them for transfer or sale, offering to transfer or sell them or transferring or selling them, assembled or in kit form is a federal felony. The reason was because they not only did all the neat things I described, they could and sometimes did split eardrums, splinter hands and send debris flying and hurt a lot of people. . . . even when they were used properly.

Worse, they were frequently deliberately misused to destroy property, scare or even harm people, which was more often than most people were willing to put up with.

After the school spends another few grand to repair the plumbing again because some knuckle-head decided to flush one down the system, or an entire neighborhoods mail boxes had been destroyed for the third time in a year, or some kid thought it would be funny to toss them into the bleachers at the local basketball game not only scaring the hell out of everyone, but seriously hurting someone in the process, or yet another young gentleman in the county has a hand mangled, eardrum shattered and eye damaged, people's patience wears pretty thin and they want something done to prevent it.

There were also a number of accidents involved in the manufacturing of these firecrackers, since at the time anyone who could mix a few powders in a barrel, glue cardboard tubes together and stick a fuse in a hole could go into business making them. A few horrific explosions at "factories" killed a number of people so now there are much stricter requirements for manufacturing fireworks and even stricter rules for making and handling flash powder in quantity.

Tips for the future

Now that they are banned, there are still some who make them for the black market and they too seem to blow themselves and their neighbors up from time to time. Since they are underground they take few if any precautions in the way they handle and store the flash powder, and thus have a greater chance of having a fatal accident.

While the 50 mg limit for firecrackers seems pretty tame in comparison, and it is, one can still have a lot of fun with firecrackers, and the risks involved are much lower. It has to do with what you expect and with a whole generation having little experience with the bangers. They seem not to know what they are missing, except from their reputation.

The M-80s and M-lOOs and other silly named devices coming out of clandestine factories from up in the hills and even some basements and garages, from Mexico and some Indian Reservations are often cheaply made and their reliability and performance isn't that great. Most of the people who make these have very little understanding of what is required to make explosives, so safety for themselves, their families, neighbors and unknown customers is often compromised.

These IEDs are involved in up to 40% of the annual CPSC estimates for injuries related to fireworks. They are often the types of devices involved in most the serious injuries reported and used by the anti-fireworks people to bash all consumer fireworks. They cause not only lots of harm to people and property, but they damage the legitimate consumer fireworks trade immeasurably.

If you are still bent on having them and so obtain some or make some, don't ever offer or give them or sell them to anyone else, since that is a felony and if you get caught, you will likely be prosecuted. If you obtain the materials to make them yourself, please don't mix or handle flash powder in your house or garage, and use them by yourself and do so outside (sounds silly but you'd be surprised where some people have used them). Avoid tossing them in loose gravel or tall dry grass, keep them away from people and animals, and light the tip of the fuse with a punk (an odorless incense stick), cigarette or cigar (not a lighter or match).

If you are compulsive enough to spend the hours it would take to scrape the powders out of other fireworks just to try to make a bigger bang, remember flash powder is sensitive to heat, flame, sparks, electrostatic discharge, friction and impact ... and even when it is not confined it can go bang.

Never store them in your house or apartment and as with matches and all fireworks, keep them out of reach of children (which means if you have pre-teens or teenagers, locked them up really good). If you give them to your kids, leave them around with access to matches or lighters or otherwise misuse them, be prepared for some serious consequences, especially if anyone gets hurt or there is major property damage.

Remember if you get one with a bad fuse or that is not sealed properly, plan on missing most of your throwing hand and possibly the eye and eardrum on that side of your head too! CPW

CONSIDER THE RISK

by Joel Baechle

Concerning the risk inherent in chemicals, I think the risk of barium nitrate is overstated. There is a tendency to lump the bad with the not-so-bad. Barium nitrate is more likely to make a person disturbingly ill than to kill, unless there is some kind of extreme exposure. People need to understand that traditional inorganic chemicals usually will let you know pretty quickly if they are working *their* chemistry on *yours;* there's nothing more to it than that. Don't breathe it, don't eat it, do wash up afterwards, and don't get it on anyone else!

Don't mistake corrosive sublimate (used in white, "mercury" snakes) for calomel - HgCl (intensifier), that's for sure! Your body can mistake potassium dichromate for calcium and stored in your bones, leading to cancer - a delayed and tragic outcome.

Dechlorane is a wonderful chlorine donor. It is not that terribly poisonous externally, or even in tiny amounts by mouth, but under the skin it is a different story. It was sold under the name "Mirex" for use against fire ants for years. Older editions of the Merck index don't mention it as being particularly bad. The bad news is that it is a teratogen and a mutagen. If one's wife (or friend's wife or employee's wife) is pregnant, consider, realistically, isolating this chemical from <u>everything</u>. I see no particular reason why there would be dechlorane in the green strobe formula. Dechlorane is a low temperature chlorine donor. It is best for reds, and was used for this in military formulas.

As I mentioned in "PyroColor Harmony", Chlorowax is a good substitute for hexachlorobenzene (HCB). If it kills the strobe, less can be used. HCB will eventually "leave" the composition through sublimation, anyway.

Anyone who desires a low-temperature chlorine donor need only grind up some para-dichlorobenzene. Moth balls! They work just fine. Probably bad for you too!

Antimony is an Anglicization of *Antimoine,* which literally means "against the monks". The Friar administered it to the brothers as a purgative, and they evidently ascended to the next realm on the spot! But for the prudent, a fan or a breeze at one's back is sufficient when mixing it.

I recently had my hands full of lead azide and a similarly impregnated canvas bag. Remind me to not wear these clothes to the airport! JB

HOT CHEMISTRY TONIGHT!

by Lloyd Scott Oglesby

Chemistry reactions are a matter of the little electrons that associate with the atoms. In metals, some of the atoms in the crystal are ionized, which results from thermal energy , so at room temperature about 28% of the atoms in a crystal of iron are ionized. There is an empty level of energy available for the electron to move into that is only a little higher so it can move from atom to atom fairly easily. That level is called the Fermi level. It is characteristic of all metals. The surface chemistry is very much affected by that ease of moving the electrons.

All of chemistry can be understood as being electrical, and in the case of the electrochemistry of metals we use that sort of thing to create power cells and capacitors used in electronics, and we encounter electrochemical effects in chemical reactions of metal corrosion.

Fireworks chemistry is much the same. For instance: the crackle effect of metal oxides burned with magnalium. That reaction series begins with simple burning of some of the magnesium from the magnalium, which heats the mix; the metal oxide sort of shorts out the power cell where is the anode and the magnalium is the cathode. Electrons flow rapidly from the magnalium to the oxide, which decomposes and the resulting oxygen gas reacts quickly with the magnalium. It greatly resembles the discharge of a large capacitor and is, in fact, electrolytic, so the energy pulse is very fast. The material is dense so it acts as its own container. A really sharp shock wave results.

You can prove to yourself that both of the oxides that provide that effect go conductive at a transition temperature by molding some of the oxide around two wires and heating that while measuring the resistance or conductance. The transition is very fast. Both of the oxides form ceramic bonds between crystals before the transition so the electrical connections between the particles are excellent. The oxides fuse to form a glass and that glass has a transition temperature where it changes from non-conductor to good conductor.

Thermodynamics would indicate that similar reactions might occur with copper oxide and tin oxide. The copper oxide should give slightly higher energy. Copper oxide does become a somewhat better conductor and at higher temperatures that can make available electro-chemical-type reactions, but the transition is not a sudden, dramatic drop in resistance, so it takes a good additive that provides a chemistry change in the residues of reaction (that make the metal deposit slower to react in the environment and less a hazard to children).

Pure lead is quite reactive and can be pyrophoric in air. But any alloy of lead is very much slower to tract and less likely to give soluble (and therefore) poisonous compounds of lead. The metal is not poisonous but the oxides and more soluble compounds are. In the case of tin oxide, the crystal structure is different energetically; it does not transition to a more conductive condition so only a slow reaction mechanism is possible, and that rather disappointing reaction takes place at higher temperatures. Many metal oxides have significant conductance at room temperature or above, but not all of them have the sharp rise in conductivity at the Curie temperature for their crystals or on fusion. Magnalium doe not have the electrically insulating oxide coat like, for instance, aluminum, so the powdered metal is quite conductive if you press the particles together.

It is actually electrical effects that make so many differences in pyrotechnic reactions. Carbon and charcoal become more conductive at higher temperatures and the glow from the burning charcoal or coal is quite conductive. You can tell that electrostatic and electro-chemical effects are going on in melts involving the carbon fuels by observation of those with the microscope. It is quite interesting to watch as fragments of the charcoal snap apart and swim around violently. For instance, the *senko hanobi* melt reactions have obvious transitions as the electrochemical potential of the melt changes from reduced sulfides to oxidized sulfates. The charcoal particles suddenly leave the central zone of the melt, adhere to the surface until little explosion with the sulfate crystals propel them off the globule. All of that is electrochemical electrostatics.

There is much more of this sort contributing to how our effects actually work. Think about it and do some experiments. You need a good multimeter of the digital type for rigging up your nice, safe electrical ignition systems for experiments anyway. More into this later.

FIREWORKS ARE ENVIRONMENTALLY HEALTHY

by Lloyd Scott Oglesby

All my life I found that fireworks of some kind improve life. If nothing else, they gave me a nice big ridiculous grin. Cares and woes went up in the great blam, my grin readjusted, life got better. Now what I need is to get more fireworks in my life.

I *knew* it was healthy to have fireworks!

In my earlier life I planted over 600 trees. There are a lot of pecan trees in Texas, but many areas of Texas lack zinc in the soil - and pecans are high in zinc. Growers spray the trees with zinc, with potassium nitrate added to help absorption. That leads to the thought of how fireworks chemicals actually help the environment.

If your garden veggies look sick, they are. Same with your lawn and trees. Here are some ideas. Most garden soil lacks iron. Good, old, cheap iron filings work great. A human being contains almost 90 elements, and at least 80 are essential to life. It all comes from the dirt, through the plants, maybe through animals. Fireworks help spread potassium, iron, antimony, and could spread other things that are essential nutrients, such as zinc, copper, chromium, manganese, sulfur, arsenic, magnesium and aluminum. Charcoal contains a large number of trace elements.

And don't forget molybdenum and vanadium. Both are critical to both algae and the little bacteria that fix nitrogen. If a bean field does not produce enough nitrifying bacteria, it may lack one or both of these elements. Wonder what they would look like in a fountain? Yes, fireworks for the ecology! Let's see how that would work.

Ever try adding iron oxide to charcoal fountains? It does make a difference, and so does manganese. Now most plant leaves will feed on tiny dust or smoke particles. Iron filings from foundries where auto axles, camshafts and springs are produced are high in moly and vanadium, so these filings added to fountains are a great solution to your garden's need for them.

Here some other tips for the environment: glass beverage containers are beginning to be made of glass colored with cobalt. Three quarters of the earth's population has diets low in Vitamin B12 because the soil lacks cobalt. If you grind up a few of those bottles and sprinkle the dust around, it will be absorbed fast, the plants will be healthier and so will the people who eat them. Yes, and ground up pyrex glass will furnish enough boron. And remember those old carbon flashlight batteries? A few of those left to crumble up in water will furnish plenty of zinc and manganese.

I may be the only idiot who tried dusting his garden by rigging up a big old electrically started firecracker in the bottom of a tin can full of insecticide. It *does* work if the wind is down. Otherwise it's fun anyway.

Nutrients needed in nanogram or microgram levels are easy to distribute in smoke. Almost any of them can be added to fireworks fountains, and none of them leave the fountain reaction in poisonous form. Burn your nightly fountain!

Fireworks can help nature get things adjusted to a more healthy, less polluted condition for the plants in your garden, and the planet. See, Nature knew we pyros were right all along.

HOW THINGS LOOK TO THE PYROTECH

by Doug Driscoll

blender = black powder mixer
splatter screen = sieve
long teaspoons = chemical scoop
kitty litter = rocket clay
coffee grinder = chemical pulverizer
wooden tongue depressors = disposable spatula
weeds = rocket sticks
powdered sugar = charcoal substitute
used fwks displays = source of tubes
wax paper = quick cleanup
window screen = chemical/mixing sieve
sewing hoop = screen holder

MINI PYRO RESEARCH

IN WHICH THE PYRO DISCOVERS A REASON TO HOARD THOSE FREE SUGAR SUBSTITUTE PACKAGES

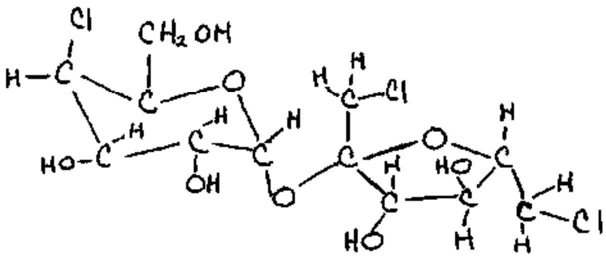
by Richard Dilg

A recent mention on PML[1] of Splenda being a potential chlorine donor for pyro formulations caught my eye. [Charley Wilson came out with a paper on chlorine donors [2] for AFN a little over a year ago. The following could be considered as an attempt at providing updated information to what was presented in that earlier endeavor.]

Background

I spent little time googling on the Net to find out more about Splenda's composition. Splenda apparently is a mixture containing sucralose, dextrose, and maltodextrin, with some impurities.

From one[3] of the sources the technical name for sucralose was given as 1,6-dichloro-1,6-dideoxy-BETA-D-fructofuranosyl-4-chloro-4-deoxy-alpha-D-galactopyranoside. The structure can be depicted as:



Another source[4] gave information of some of the impurities

> The FDA acknowledges that sucralose is produced at an approximate purity of 98%." While that may sound pretty pure, just what is in that other 2%? It turns out that the final sucralose product contains small amounts of potentially dangerous substances such as:
>
> Heavy Metals (e.g., Lead)
> Arsenic
> Triphenilphosphine Oxide
> Methanol
> Chlorinated Disaccharides
> Chlorinated Monosaccharide

Since my Google search just scratched the surface of the well of information on the Net, I located no reference to using Splenda for pyrotechnic purposes.

There may be references but the limited searching done here did not come across any.

First things first

As a fun exercise I thought to first find out the amount of chlorine in sucralose.

To figure the percent chlorine in sucralose, the unadulterated material would have a formula of

$$C_{12}H_{19}O_8Cl_3$$

which would have an approximate molecular weight of

12x12 + 19x1 + 8x16 + 3x35.45 =

144+19+128+106.35 = 397.35

so then the theoretical % Cl =

(106.35 / 397.35) xlOO = 26.76 or 27 %

This is a relatively low percentage of chlorine but is not the lowest when compared with previously used chlorine donors (i.e., reference 2).

Color production investigations

It was rightly already pointed out[7] in the PML that Splenda is rather expensive to be used in pyro formulations. Thus, pyro use of Splenda could be considered as esoteric. The limited investigations here are cursory and are meant to very briefly look into the feasibility of using Splenda as a possible chlorine donor in pyrotechnic color formulations.

My basic approach to checkout the feasibility of using Splenda as a pyro chlorine donor was:

Any or all of the common pyrotechnically produced colors that incorporate chlorine donors could be candidates for study. For several reasons I chose blue color production. Shimizu's paper[8] in Pyrotechnica VI on blue and purple flame compositions lists many systematically studied formulations. Based on these, one generalized blue flame formulation that might prove worthy of utilizing as a starting point is:

$KClO_4$	68 %
Cl donor	11%
Red gum	6%
Cu salt	15%
Glutinous rice starch 5% additional	

This formula was next modified with the intention of focusing in on studying color production. As an off the cuff "first approximation" and over-simplified speculation as to what effect(s) Splenda might have if it were used, one possible modified formula might be

$KClO_4$	68 %
Splenda	17 %
Cu salt	15%

Experimental

Small amounts of three different experimental batches were compounded based on the above to check out color production quality.

Three different copper salts were used :

Mix#l) $CuCO_3$

Mix#2) CuO

Mix#3) Cu benzoate

Results

Test burns using small, unconfined piles of each mix resulted in the following observations:

- Mix#l) Slightly hard to ignite; whitish blue and green color
- Mix#2) Slightly hard to ignite with rough burning; whitish blue color
- Mix#3) Very easy to ignite with fast even burning; baby (sky) blue to whitish blue color

For all three mixes no visual perception of any Na and/or Ca contamination (assumed to possibly be associated with the Splenda, if found) was observed during the burn testing. Also the whitening or whitewashing of the flame color has typically been observed previously in formulations with a variety of copper salts when they are mixed with organic materials that have higher amounts of oxygen content. Nothing new or surprising here.

Conclusions

With the very few experiments performed for this mini study, it would seem that although far from being ideal, Splenda may have some pyro applicability and could be added to listings of pyro chlorine donors. So yes, save those Splenda packets but use them for esoteric pyro pursuits before the EPA decides to sour the works by making Splenda, as it has done with perchlorate, subject to its UCMR (unregulated contaminant monitoring rule) !

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PYROCONICS FOR THE AMATEUR

by Joe Barkley

Fireworks cones are ideally suited for the backyard since they are most impressive when viewed at close-quarters. Most sold-over-the-counter (SOTC) cones are lightly filled with mediocre compositions and command high prices. The pyrotechnist can produce cones for his own use at a very low price that outperform SOTCs while satisfying the creative impulse. The only necessities are a few simple ingredients and ingenuity.

Paper textile cones are the basis of SOTCs and should be used by the amateur. Textile cones work so well for fireworks applications that no one should attempt rolling them from flat paper. The writer has found that some textile mills produce vast numbers of used cones which are considered recyclable paper. Some mills may sell used cones at a very low price or give the artist a number without charge if approached in the right way. The cone obtained should have a small (about 1/16") opening in the tip to act as a nozzle for the fire spray. A cone 8 to 10-inches high works well for this application.

MAKING THE SUPPORT

Loading cones required an easily constructed mold for support. It is well to use all cones of the same size since a different mold is needed for each substantial change in cone dimensions. A rectangular one-ended wooden box slightly larger in breadth than the cone acts as the mold reinforcer. The box can be about 2" shorter than the height of the cone. A 1" nail is driven through the center of the box end to hold the cone in place when the mold is formed. A typical cone is liberally coated outside with Vaseline and inserted into the hollow box, using the nail for centering. The assembly is stood upright on a flat surface while a relatively thin plaster of Paris slurry is poured into the interstice between the cone and the box. A fairly thin plaster slurry ensures a solid mold structure devoid of large air bubbles or voids. Next day the Vaselined cone is gently twisted away from the hardened plaster mold, revealing a receptacle ready for charging cones with the desired compositions. No more Vaseline is needed. The nail is retained to form a slight hollow in the tip of the cone for later insertion of a piece of Visco fuse. Once made properly, the mold can be expected to last indefinitely.

CHARGING THE CONE

Charging cones requires a set of wooden dowels about a foot in length. These will change diameter corresponding to the cone depth. Since tamping is done rather lightly, a rubber tirechanger's hammer suffices and is easy on the dowel ends. Each dowel is marked to prevent tamping above the composition level, which could damage the paper cone. However, a little variance here is uncritical. Textile cones can stand much greater depth of composition than we see in SOTCs, thereby performing longer and with greater effect. The fireworker can experiment with depth to prolong burning time and increase personal satisfaction.

The cone bottom is closed with a thick (1/8") paper disc. Here it is most susceptible to failure as a good cone has considerable internal pressure, accelerating as the surface area of the comp increases toward burnout. Ideally the disc would have a slanted rim to match the cone interior angle, maximizing contact; this is unnecessary except for very high internal pressures. White glue serves well. Care must be taken to wipe the interior of the cone at the attachment point free of comp granules, which weaken the bond. A second glue bead smeared in with the finger reinforces attachment. Ample drying time is necessary for good bonding; a day or longer perhaps.

COMPOSITION VARIATIONS

Useful compositions made from attenuated black powder mixes (ABMs) can form a basis for experimentation. They can be charcoal-rich for sparks or saltpeter-rich for scoria production, simulating volcanic lava. It is helpful to slightly damp these mixes with mineral spirits to eliminate dust during loading and for short-term protection of added metallics from direct saltpeter contact and corrosion. Metallic iron in different sizes and carbon content makes a good additive, creating interesting gold variations. Granular titanium produces wonderful whites never encountered in SOTCs. Titanium is uncomplicated in mixes and works well without coating and fidgeting over exact oxidizer balance. Aluminum powders make wonderful silver sprays when combined with oxidizers in correct proportions, retaining integrity without surface coating. Experimentation with microstars and star chip additives to ABMs opens new fields of artistry.

A very handsome off-on-off silver effect is obtained by charging a cone with gold/charcoal mix to about 1/3 depth, followed by a small pocket of lightly consolidated slow aluminum star mix up against the cone interior, finishing with gold/charcoal.

Shelf life for these cones depends upon additives. Iron compositions rust quickly if unprotected. Slight mineral spirit damping adds some protection. Often we are anxious to witness these effects right away, avoiding complicated corrosion protection. Cone compositions should never be water-dampened as drying time is excessively prolonged and corrosion is encouraged. All ingredients should be dry (water free) before charging to the cone.

SAFETY

ABM mixes can be conveniently prepared in a ball mill, producing a basis for more consistency in fireworks cone performance. Never add iron-containing material or titanium to a ball mill. Additives are best mixed with a consistent ABM *outside* the mill.

Fire sprays from these cones have exceeded twenty feet upward. It is necessary to watch overhead areas and keep them open. Bottom plug blowout can send the cone upward rocket-fashion several feet. The intent is to have fun so take care! JB

BANG BUCKETS

by Bob & Pat Quigley
Uppa U.S. Fireworks Co.

Always looking for new, safe and convenient ways to shoot fireworks, we came up with a "high tech" idea a few years ago.

Using an empty plastic 5-gal. bucket, we centered up a 3" mortar tube, then filled the bucket three-quarters full of nice, dry sand. This give something to shoot from that is very stable, easy to move around, and especially handy on paved surfaces.

We have been shooting 3" shells, including magnum titanium salutes, from these buckets for several years. The only problem we have found is that everyone falls in love with our buckets and they keep disappearing. You know how you are always looking for an empty tube to shoot pre-display salutes, etc.

This year, while preparing for our private pre-4th of July show, we decided to make up a dozen new buckets. I had just finished the second one when my wife walked by and said, "Gee, those smaller tubes would fit in there too." I immediately realized what a great idea I had just come up with. By putting a 2", 2 1/2" and a 3" tube in each bucket, we now had a triple duty ***BANG BUCKET.*** And if you are careful how you arrange the tubes, you can still use the handle to carry the buckets. This makes it a lot easier for Pat to move them around.

We use these buckets to shoot single salutes or various combinations of shells in flights, and all this can be done without tying up our regular racks.

If the tube should go bad, you just dump the sand out of the bucket and redo it.

So there it is folks, a simple, safe, inexpensive, easy way to build, and very versatile. Always on the cutting edge of technology.

B&PQ

BUCKET PRESERVATION PROJECT

by John MURR Rhame

I did a few cremora pot test shots this weekend. Some folks had been shooting five gallon cremora pots with a full pound of black powder for the lift charge. That much lift works, after a fashion. A one pound lift destroys the bucket, scatters bucket bits and unburned creamer and doesn't produce a nice rolling fireball. I had shot many one gallon and smaller cremora pots with tiny lift charges that didn't bust the container. I assumed an under-one-pound lift charge could produce similar results with a five gallon bucket cremora shot.

I brought nine buckets, e-matches and such to the recent Crackerjacks shoot. John Sagaria contributed 5 pounds of Chinese 2FA black powder. It's labeled 2FA but it's graphite glazed and seems somewhat finer grained than Goex 2FA. The club contributed three 25 pound bags of Land-O-Lakes lambs milk replacement, original donor unknown.

Sean McAndrew and his brother Mike helped me with the test shots. For the first round, we loaded about 4 oz. (1/2 cup) of black powder, one sheet of newsprint as a separator and about 12 pounds of creamer (about 2/3 full in the 5 gal bucket). Four ounces of black powder doesn't quite cover the bottom of the 5 gallon bucket. It is spread out over the bottom of the bucket, the the newspaper is laid in. The lamb's milk replacement was poured loosely into the bucket. We did NOT pack down the creamer.

The test shots were ignited with single Oxral e-matches taped to the center of the bucket bottom. The hood was slid back and I made sure some of the black powder was in direct contact with the e-match. I had considered using a quickmatch leader. We didn't move the loaded buckets and relative humidity was oppressively high, so I assumed there was no significant risk of an ESD accidental ignition under these conditions. If you plan to assemble the buckets in one location and move them to another place, I would recommend using a quickmatch leader to transmit the fire to the bottom of the bucket. Better yet, don't add the e-match until the buckets

have been assembled and placed in their firing positions. The shots fired were assembled with quickmatch leaders.

That's me pushing the button in the still picture of the first test. I'm about 35 feet from the bucket. Mike took this photo. Great timing on the shutter. The fireball measured 60 feet high and 25 feet wide at maximum burn. At brightest burn, the height was 50' feet.

There was very little fallout from the test shots. We found one palm sized piece of newsprint, charred and coated with creamer. We also found some charred pea sized creamer lumps. The only unburned creamer on the ground was the tiny bit we spilled while loading the buckets.

I had gathered materials to make a half dozen tests shots, varying the black powder load. As fate would have it, I guessed right on the first shot. All three of us agreed that the first test looked great. A second test shot with substantially the same loading was fired to prove the first wasn't a fluke. A total of eleven cremora shots were fired in my tests and in a show produced by Joe May that night. Some of the shots in the show used genuine Cremora brand creamer supplied by

Joe. Some of the show shots used the 50 pounds of lambs milk replacement we had leftover from the tests. All shots worked very well and all of my buckets came home a bit dirty but otherwise unscathed. JMR

* * *

SCIENTISTS WARN OF CALF MILK REPLACER DANGER

Large fireballs, long the tool of special effects practitioners, have found acceptance in regular fireworks displays. Easy to make in the field and relatively inexpensive, the effect now is being found during the opening scenes in displays both large and small. The material used until recently has been dairy creamer of various manufacturers, but lately calf milk replacer has been found to be very effective, easily obtained and inexpensive. People producing the effect have been quoted as saying that the higher the fat content, the better the ball of flame. Thus among professional display operators who employ this effect, high fat content calf milk replacer has become the ingredient of choice.

Now scientists at the University of Bern (Switzerland) have issue a report that calf milk replacer is suspected as a source of mad cow disease, bovine spongiform encephalopathy (BSE).

Mad cow disease lodges in the spinal cord and brain of infected animals. Techniques used in the slaughter and subsequent rendering process usually keep the spinal cord and brain tissue separated from other products so that contamination will not occur. Now it has been discovered that tallow rendered from the meat by-products may have accidentally been permitted to become contaminated with central nervous system tissue.

While it is assumed that processing of the tallow at high heat and pressure would kill the BSE organisms, it is suspected that contaminated tallow may have been used to make animal feed.

Tallow and bone meal are used in calf milk replacer to increase the fat content. JD

Identifying such sources is extremely difficult. When the BSE epidemic began in the UK, meat and bone meal were considered the major sources of infection, but when isolation procedures proved ineffective, other sources became suspect.

The process of tracking raw materials from infected animals is also difficult, considering that the feed products produced from animal by-products are made in numerous mills that daily use raw materials from different sources.

Although the risk to US operators is small because BSE is not epidemic in North America, the use of calf milk replacer in cremora bombs should be reconsidered.

Source: International Society for Infection Diseases, found at www.promedmail.org.

ASCENDING FLOWERS EFFECT

by Sam Bases, Delcor Inc.

A question was raised on PML about the ascending flowers effect. A related effect is "parasitic shells", which, while not of an ascending nature, do supplement the main shell. I believe that it was mentioned in a Kosanke(s) article some time ago.

I simply place three or four smaller shells on top of the main shell. These are not tied to the main shell, but are fused and cross-matched to ignite during firing. No lift is used for the smaller shells.

The effect gives, first, a cluster of small shells followed one or two seconds later by the larger and higher main shell. We have tried it several times, to use up some unlifted 2 1/2" shells placed on top of 4s and 5s. There was no jamming in the mortar, and the effect was excellent.

Readers may contact the writer at his e-mail address: delcor@hotmail.com SMB

CRACKLING MICROSTARS

by Kolin Kimbrough

Crackling Microstars, also known as dragon eggs, are a relatively new item to appear in fireworks, showing up around 15 years ago. Since then there has been no shortage. These amusing audible effects can be made with several different formulas, and can also be used in different ways. Most, if not all, imported crackling microstars contain lead chemicals, primarily lead tetraoxide. This, and bismuth trioxide both make good, sharp cracks, but the downside with lead is toxicity, both in dust form and from the resulting smoke. Also, the lead formulation is more sensitive to both impact and friction. But by no means should crackling mixes containing bismuth trioxide be considered "safe". And bismuth trioxide is more expensive than lead tetraoxide, which is probably the biggest reason that the Chinese choose to use the lead.

The formulation that has worked well for me is:

Bismuth trioxide	75
Magnalium (60 mesh)	15
Copper oxide	10

I bind it with a solution of nitrocellulose/acetone or amyl acetate.

Some pyros have reported getting louder pops with the addition of a few percent of atomized aluminum 200 mesh or coarser. The addition of a small percentage of fine titanium can be added for a burst of silver sparks to accompany the pops.

The procedure that worked best for me is:

After weighing out the ingredients, I pass the copper oxide separately through a 30 to 40 mesh screen, discarding anything that doesn't pass. Next I do the same for the bismuth trioxide, then mix the bismuth trioxide and copper oxide together by diapering and passing through the screen 3 or 4 times, diapering between screenings. Finally I add the magnalium to the mix and diaper it until it appears to be well mixed. The mix now should be treated with the same respect as flash powder.

To begin the star making process I use a disposable, preferably burnable container or cup that will resist the solvents. I put a small amount of composition in the container, then add enough nitrocellulose solution (N/C) to the mix until it's the consistency of a thick mud, mixing with a wooden stick. Then I dump the patty onto waxed paper and roll it out like a thin pie crust, about 3/16" thick. It is m rammer. How long the plates are will determine how much composition can be rolled out at one time, necessary to work quickly if acetone N/C is used because it evaporates so quickly. This is why amyl acetate or an amyl acetate/acetone mix is a better choice.

An easy way to roll out a layer of a given thickness is to lay two metal or wood plates parallel to one another that are 3/16" thick, and put your composition between them and roll across with an aluminum rod.

The cake is allowed to dry for a few minutes, then it is cut into cubes. One clever method described to me is to run it through a pasta maker with blades spaced a few millimeters apart. One could also simply remove the plates and cut with a long knife. A popular method that pays off is scoring the lines across and lengthwise to create cubes the best one can, and leaving the patty to further dry. When somewhat close to fully dry (depends on the solvent) the mass is then broken up, creating separate 3/16" microstars.

I prime the stars with the following comp, using a mist bottle with 70/30 water/alcohol, and apply a 2mm layer as one would when making round stars:

Potassium perchlorate	75
Red gum	12
Charcoal	9
Dextrin	4

A 1mm layer of black powder can be applied over this if they are to be used as they are. Or your favorite star composition can be applied over the perchlorate prime if they are to be used as cores for round stars.

What to do with these stars is up to the imagination. I have successfully used them as cores in round stars. Rather than creating a crackling end to the stars, it sounded like a bunch of tiny reports in the sky. The effect will depend on the quality and source of the chemicals used. I have had different results using different batches of magnalium, copper oxide, and different bismuth trioxide. But typically the microstars will give powerful reports noticeably louder than 50mg crackers.

The 60 mesh magnalium tends to create a long delay of 1 to 2 seconds, followed by a loud report. If smaller but more numerous reports, with less delay are desired, 200 mesh magnalium can be substituted.

It is possible to make pumped matrix stars by using these cracking microstars. But to make, say 1/2" or 3/4", one would have better results using smaller 1/8" to 1/16" microstars. A 25% weight microstars to 75% base mix works well. A simple base mix can consist of a charcoal streamer such as:

Potassium nitrate	44
Sulfur	6
Charcoal	44
Dextrin	6

AEROLITES

I had a lot of fun over the 4th with Aerolite comets as described in AFN IV [*Best of AFN IV*, page 54 and *AFN*, October '98]. The down side was having to slip that paper plug into the tube with the time fuse and gluing it to make sure there was adequate containment of the flash charge.

What I came up with was to choke the case with a clay nozzle before adding the BP delay charge. I used a gerb nipple and ram to choke it to 3/8" from the 3/4" i.d. It worked flawlessly! It also increased the spray pressure of the delay charge, so when I added a little titanium, it was truly spectacular!

I got a lot of bang for the buck with such a small, easily made device. I hope this helps others who are interested in making similar items.

QUICK AND DIRTY SMOKE BOMBS

by Carl Denninger

This article deals with those smoke compositions using colored dyes. They are mostly dye with small amounts of potassium chlorate, baking soda and sulfur. I have given myself some pretty oddly stained hands trying to ram these bright colored dyes! But those smoke dyes work so well.

The answer for me was using aluminum foil from the kitchen. I cut a piece of foil 4 inches by 8 inches. I make a fold across the 4 inch width about 2 inches from the edge and then fold the edges shut, opening the pocket formed, spooning in an ounce or so of premixed smoke composition. The aluminum foil is then wrapped tightly around with several revolutions, slightly packing the powder. The ends are then rolled shut. The whole operation closely resembles rolling your own cigarette but on a larger scale!

To arm this assembly I take a nail and pierce the foil on the side, inserting a length of visco. These devices burn very rapidly, giving a robust 2-second burst of smoke. The aluminum does not burn through so the atmospheric oxygen doesn't get in to oxidize the dye. When I need to dress these up, I squeeze these assemblies into a paper tube 6 inches long with an inside diameter of around three-quarters of an inch.

This method keeps the powder loose, which allows it to burn very fast, the way I like it. The addition of more oxidizer to the composition simply destroys more dye and does little to speed the smoke making process. Someday I hope to use this method to develop daytime mines and shells; a more or less underutilized fireworks arena. Hopefully this will put the color in the sky and not on my hands! CD

SUN ON A STRING

by Joe Barkley

Right after the 1941/5 period, federal wartime prohibitions on fireworks sales to the public were lifted. Relief was temporary since many states rushed in the MODEL LAW, which prohibited use of all fireworks by the general public.

In the brief window of availability, mail order firms such as Spencer Fireworks sold stocks that had remained in escrow since 1941. These sales were made under fear that the MODEL LAW would emasculate the business. Some optimism remained in the hope that domestic fireworks manufacture would continue at pre-war levels, bringing new and exciting goods. As most pyros know, the latter did not happen. We began importing our consumer fireworks.

In 1946 I bought a leftover novelty item that proved itself worthy, and is not generally seen in shops today. Made by Unexcelled, the piece is easily reconstructed by the hobbyist. It is simply a saxon rotating in the horizontal plane by suspension with a piece of string from an overhead support.

Mine were made from a 6" x 5/8" bore rocket tubes with both clayed ends drilled through at slight angles, as hummers are, to prevent premature burnout. Obviously, vent holes are on opposite sides of the case. The composition was separated at the center of the case by a half-inch of hard-rammed clay. A tack was driven through the case wall into this clay. One or two turns of nylon (spark-resistant) string were wrapped around the shaft of the tack before hammering in. All internal sections were hand-rammed, as for a skyrocket, but without a spindle. Piped match was taped to the body and inserted into the ventholes, enabling both ends to fire at the same time.

A tree limb about 8-feet high was convenient for supporting 4-feet of string from the sun.

Interesting variations resulted from inserting time-delays in the match, which delayed ignition of one end until the other was spent. This was enhanced by reversing spin direction by delaying fire to holes drilled on the *same side* of the case.

Two variables had to considered: vent hole diameter and driving composition. The hole was usually 1/8" diameter for the suns just described. Much satisfaction was obtained in experimenting with changing black powder compositions that increased or lowered speed of the device. A most satisfying effect came from adding metals to the driving composition for greater spread. This was often done the same day the pieces were fired, allowing interesting sizes of granular iron to be used without protective coating.

Safety precautions were observed in drilling into black powder compositions, especially those containing iron particles. JB

MORE ON CAP CRAP

By Carl Denninger

Years later another use for cap crap surfaced. A loose packet of about 12 grains are attached to silhouette style steel rifle and pistol targets. A "bullseye" hit produces a satisfying report and smoke cloud. Even the energy from a .22 caliber long rifle reliably triggers the cap crap.

Mixing sulfur with a chlorate is a pyrotechnic no-no. I very carefully mix a small quantity by rolling the mix on a sheet of paper. Any quantity not used immediately is disposed of in a burning barrel with other trash. I never store any of this mixture as it is subject to spontaneous ignition and seems to become more sensitive with age. Many years after the first time I made cap crap, I still find it very amusing. CD

SPIN STABILIZED STARS

by Lloyd Scott Oglesby

When I was young I got into rockets real big in size small, because my parents set a 50 megaton limit on the sound of the ones that didn't made it off the pad. I got all hacked off when bottle rockets no longer came from Japan where they were made better but went up in price to over a cent each. So I began to redesign things.

First I made all the classical styles and found out that the old choked case with a little clay painted into the nozzle was about the best. But it took too long to make them, they costs too much, they did not lift enough heading, and they burned a lot of my chemicals for the performance produced. Comet tubes were more show for the money and effort.

After reading everything in the library and all the military training stuff on rocketry, and all the stuff my friends got from Estes, and everything else I could find, I decided to try out the old German idea that never got adopted. Until a rocket attains about 30-feet-per-second, air drag-type guidance is not very effective. Fins need to be large at low air speed, and tiny at high air speed. Now, stick guidance is also an air drag type. Spin guidance is the most effective, with air resistance energy losses being minimal. So I invented several variances of *bump* rockets and spin guidance rockets. It is easy to get effects like the popular *Colorful Bird,* the small, spin guided rockets that end with a green star. These too suffer from the fault of falling debris, but the effect is very nice.

Usually a comet star loses speed from the instant it leave the tube, but we all get a thrill out of going faster and faster. If you drill a hole in a comet star it develops thrust from comp burning along the side of the indention. If the perforation is off-center, the star tumbles, and that so greatly increases air drag that it slows down quickly. But a comet star with a rocket vent-shaped, partial perforation (that is really well centered) will add considerable speed to the star. It is no trick at all to make a special star pump for forming longer stars, and with a well centered hole that is of considerable surface area so that the burning of the comp produces significant energy, pressure and jet propulsion. The binder needs to be strong if the comp is to develop much pressure. Having no nozzle, the pressure, gas velocity, and impulse will weaken quickly, but if burn rates, the size of the star, and the size and shape of the perforation are all adjusted well, it makes a credible rocket.

If these are fired out of a tube to make sure they get going in the right direction, and fast enough, believe it or not, it's possible to get a stable flight from them. So simple a flame retardant as a painted on layer of white glue works nicely enough to make the performance of these bump rockets acceptable. When fired from a little paper tube they make a bump sort of sound as they start, and are about as quick, simple and cheap as fireworks rockets can be made.

Of course, you can make drivers and fountains the same way. If you already have a crossette pump for forming a star with a central cavity you already have a suitable tool for making these, except that the pump will probably not make stars that long enough. All you need is a block of something between the pin and the tube of the pump.

There are ways to make other tools that work better, and it is not at all difficult to work out tools that make them spin guided. Little ones about the size of bottle rockets are easy to make motorized launch tubes for that spin the tube and rocket, before an electric ignitor starts the lift. Make those quick and easy to reload and you have all the fun of the bottle rocket at far less hazard. No smoldering remains come falling out of the sky; nothing left but smoke. LSO

SHINE ON, OR NOT: THE STROBE STAR

by Mike Workman

My personal favorite star of all time is undoubtedly the strobe star. Unlike glitter, which produces a somewhat random size twinkle or sparkle in the tail of a comet or star, strobe stars behave a lot more like a flashing light, with a fairly constant frequency, and usually very bright, hence the term "strobe". Uniquely, the strobe star produces a single "pulsing" of light, versus glitter stars that fills a volume with hundreds to thousands of smaller sparkles of light.

The problems with making strobe stars are manifold. They can be really finicky, they can be hard to light, and they can be "overlit". Many, especially the ones bound with nitrocellulose lacquer, are a real pain in the butt to cut. Strobe stars work best when cut, and when rolled can be hard to light. Some of the most beautiful strobe stars are made with our friend ammonium perchlorate as the oxidizer, which makes getting them near a black powder, or for that matter any compound containing even a trace of potassium nitrate, a fatal mistake (not explosively fatal, just soggy, as ammonium nitrate is formed which is very hygroscopic). Finally, many strobe stars must contain potassium dichromate, a much feared chemical. In fact, a movie was made about a young lady who discovered workers at a power company were continuously exposed to Cr+6 hexavalent chromium and fell victim to dozens of medical problems, providing the basis for a huge class-action lawsuit. It was a good movie too.

I have endeavored to overcome the above issues because I love strobe stars. As is the usual theme of this feature article, I will share as many tricks as I can with you that made my strobe stars work, tricks that are not in any of the published literature on strobes that I have been able to find.

Bleser's Nitrate Based Strobes

The white strobe of David Bleser's is awesome, and in my opinion should be your first strobe. The reason is that it does not use ammonium perchlorate, it is water bound, it cuts like window putty, it uses magnalium instead of magnesium that requires no coating, and it works like an electronic beacon. This is great stuff. The only thing it doesn't do is turn into a cheeseburger and a six-pack when the show is over.

Recipe - Nitrate based strobe stars. After making a window putty consistency paste, these stars should be cut cubes between 3/16" and 5/16" on a side. Once hard they form great star cores for water/alcohol and dextrin bound KP color comps.

	White	Green
Barium Nitrate	51	53
Potassium Nitrate	7	0
Magnalium 100m	18	12
Sulfur	19	17
Dechlorane		13
Dextrin	5	5
Water/Alcohol 10%	About 8-12%	
Performance numbers		
Oscillation Rate (Hz)	2	3.5
Consumption rate	1	1.3

Now of course, barium nitrate is very toxic. So is dechlorane. Very. So if you're going to wig out over the potassium dichromate coming soon, think about it a little: Barium nitrate will kill you as dead as a door knob. Wear a respirator (I always wear one of the good ones, not a crappy little paper filter for weekend warriors). Keep your hands clean, don't eat or drink where you're working, don't put your finger in your eye, or in your mouth while working with this kind of stuff. If you haven't read the MSDS' for these kinds of chemicals, please do. There is no reason to avoid these chemicals, as long as you treat them with extreme respect. As most of you know, these are but a few of the many which deserve such respect.

Size Does Matter

Most strobe stars are small, about the size of a pencil eraser. The performance numbers in the formulae tables are used to scale the relative size of the star for consistent burn times. If you make strobe stars too big, much more than a quarter inch cube for red ones, you will probably start fires on the ground,

SHIMIZU'S AP STROBE

These strobe stars are a bit fussier. First, let's take a look at the formulae:

	Red	Green	Orange	Yellow	White
Ammonium Perchlorate	50	60	60	50	60
Magnesium, atomized (60-100m)	30	23	30	40	
Magnalium, atomized (100-200m)					25
Strontium Sulphate	20				
Barium Sulphate		17			15
Calcium Sulphate			10		
Sodium Sulphate				10	
Potassium Dichromate	5	5	5	5	5
Performance numbers:					
Oscillation Rate (Hz)	2	3.5	3	3	4
Burn Rate (mm/sec)	4	2	7	10	9

like I have. I have this penchant for making my stars too big. There must be a twelve step program for pyros like me, I just need to find it and enroll. Will we have a secret hand-shake, and can I get my money back if I'm cured before step 12?

The performance numbers above are not transcribed directly from Shimizu, instead they are the author's experience. To get these things to turn out well, there are a ton of pointers which I have found work well:

1) Ball mill the AP and the potassium dichromate together. When complete you should have a very fine, light orange powder. This helps protect the magnesium and helps create a better cake to make cut stars from. NEVER use a ball mill or media that isn't clean, remember that KN and AP don't.

2) Mix (actually they mix fine, you just won't like it). What are we protecting the magnesium from? It turns out that AP and magnesium can form magnesium perchlorate and ammonia. You'll smell this if it happens, and it will ruin the stars. Potassium dichromate inhibits this reaction. Intimacy with the AP is definitely a plus here. Most $K_2Cr_2O_7$ available is very course, large crystals. In this format, it is useless unless ball milled to dust. Given the small amount needed, it is easier to ball mill with the AP than without.

3) Coat the magnesium. Shimizu has a section on coating magnesium in his book. At first, the process frightened me I must admit. Hot water and hot magnesium? Are you nuts? Well, yes if you don't dissolve about 5% potassium dichromate into the water first. The magnesium is heated in an oven to about 250 degrees F. I do small batches at a time, no more than 200 grams. I heat the magnesium in a pie pan. While it is heating, I dissolve the $K_2O_2O_7$ into hot distilled water (about double the weight of the magnesium being treated). Then I add the solution into the pie pan. The bubbling reaction that takes place is forming a chromic coating on the surface of the magnesium, protecting it from attack. Once cool, it's done. I use a large Melita coffee filter setup (marked POISON) to pour the slurry of magnesium, water, and $K_2O_2O_7$ into. The excess solution is reserved for future use (don't use glass, and do mark it POISON before hand). When orange, you still have plenty of $K_2Cr_2O_7$ in the solution. If it turns green, it is now trivalent chrome and much more benign, but won't do squat for the magnesium in future coatings. A solution some shade of brown is just a mixture of the two extremes. The solution should be refreshed if noticeably away from orange. Please don't dump this down the drain unless you convert it first (turn it green by adding Sodium bisulfate to it before throwing it out).

4) I use latex gloves during any operation where I am handling $K_2Cr_2O_7$ based compositions, or solutions.

5) When drying the coated magnesium, don't rinse the excess $K_2Cr_2O_7$ off, it's just another layer between the AP and the magnesium. Let this air dry, very well, for quite some time. I let mine sit a week in **gently**

moving air. Strong air will blow $K_2Cr_2O_7$ dust around your work area. Bad idea.

6) To avoid stirring up $K_2Cr_2O_7$ dust, I add the sulphate salt into the ball mill to integrate it well. Screening stuff with $K_2Cr_2O_7$ is certainly an option, but I like just using the ball mill to do it. Of course I only make 200-400 grams at a time making this option reasonable. I also don't ball mill with my nose on the rollers: get the thing away from everything in case it blows (this is an awfully oxidizer rich mixture making it reasonably safe). Mine hasn't blown yet, but I act like it will. Read Sponenberg's articles in AFNs 220 & 230. I wouldn't put magnesium in a ball mill. I never have and you can't talk me into it.

7) Wearing a respirator, screen the dry, coated magnesium into the composition.

8) The binder for these stars is Nitrocellulose lacquer (NCL). I use the 25% solution in acetone. How much binder? Well, I start with about 15% by weight. Make a putty out of the comp by adding the NCL and kneading it with a putty knife. Without enough binder, the putty is like beach sand and about as easy to work with.

9) Keep your tools and workplace clean. Don't get BP, meal dust, or whatever you've coated your workshop with on these stars: they cannot take potassium nitrate contamination.

10) Spread the putty onto a cutting surface. I use a Teflon coated cookie sheet. I make a ^{l}A" thick cake, and slice the cake into cubes using a razor blade and Shawn Hale's "I suck at this" method. The problem with this stuff is that it is crumbly. Depending on the mesh you use for the magnesium, it can indeed be like cutting beach sand.

11) Here's the saving grace with this stuff: Make cubes. The ones you don't like, the crumbs, the goof ups, can be collected, and turned back into putty again by adding a bit of acetone. The ones you like transfer to a drying sheet. These things dry in a day.

12) Keep the lid on your acetone. Besides keeping it from disappearing into the atmosphere, it also keeps it from absorbing water. You don't want too much water in your acetone.

13) When dry, coat with Shimizu's strobe prime. Whatever you do, don't make the mistake of coating these with a meal prime. They quickly become garbage. The strobe prime is very hot, and contains $K_2Cr_2O_7$ again (sorry) to provide a catalyst for the potassium perchlorate (KP) burn as well as ensure magnesium protection for the strobe star it's being coated onto. How? Well, I use a star roller. I place the little cubes into the barrel, spritz with a 4% solution of NCL and acetone, sprinkle with hot strobe prime, and continue the process until I have about 0.5mm of prime on the strobes if I'm going to coat them with a perchlorate based color composition, 1.5-2mm if I am putting them directly into a shell. Rolling with $K_2Cr_2O_7$ calls for a respirator for sure. I leave off the BP prime because I have had better luck that way. If a color comp is rolled on, I use NCL as the binder (omit dextrin from the color comp). Perchlorate based color compositions can be primed with BP and NCL because the physical separation between the AP strobe core and the prime is at least 4-5 mm or more. Just keep them dry.

14) Once primed and dry, these little guys make great star cores.

15) Don't make the mistake of taking one of these things into some dark secluded place and lighting with a match to test: When they ignite, they will temporarily blind you. It is amazing how much light these little buggers put out. Back up from it a ways to enjoy the strobe and avoid seeing the spots in front of your eyes for 20 minutes. A little strobe prime and a short piece of visco are worth the hassle.

16) If you test these with a star gun, make sure you get enough altitude or you risk igniting whatever is on the ground where it lands. Don't even think that you can ignite the AP strobes without prime. I use the prime below on the nitrate stars as well.

17) Use atomized magnesium only. Granular magnesium will tend to promote continuous burning instead of strobing. Granular *magnalium,* on the other hand, works fine.

SHIMIZU'S HOT STROBE PRIME

This stuff is hot and fast, and easier to light because of the $K_2Cr_2O_7$. I use fine potassium perchlorate (KP) and screen the ingredients together very well.

Potassium perchlorate	74
Red gum	12
Charcoal (AF)	6
Aluminum (American dark)	3
Potassium dichromate	5

Note this does not have any dextrin. This is because it should be applied with 4% NCL spray in a roller. If you intend to use it with a nitrate star and apply it with water, you should add 5% dextrin. If you can get over the $K_2Cr_2O_7$ component, this makes a great hot prime for any occasion (with or without dextrin as appropriate). Use your respirator, clean up well.

Fine Tuning

One of the goofy things about strobes is that each color formula has a different characteristic oscillation rate (pulse rate) as can be seen in the table (performance numbers). Some of these strobes flicker versus strobe (the nitrate green is especially fast). Also, during each burn phase, each strobe consumes differing amounts of itself. For strobes with relatively high consumption rates like the Orange AP strobe, the stars should indeed be made bigger as they consume themselves faster than the Red AP strobe for example. One way to speed up the strobe rate is to use finer mesh metal. Conversely, slowing down a strobe can be accomplished by moving to coarse metal. Another word of caution however, using 60 mesh magnesium will make the star very hard to light. Without prime, a red AP strobe made with 60m magnesium is very difficult to test because it may not light. Another important point, the frequency of oscillation will be different falling through the air than on a test surface. Don't be disappointed in your stars until they are properly primed and tested falling through the air.

Final Note

I endeavored to fill in lots of what were originally "blanks" to me when I first set out to make strobe stars. Hopefully, the rather pedantic descriptions above will save you some of the work that I went through to make good strobe.

References

- Shimizu, "Fireworks, The Art, Science, and Technique"
- Bleser, Dave "Round Stars and Shells"
- Hale, Shawn, WPA Newsletter Jan 1999, "Firefly Stars".
- www.skylighter.com. Web page provides easy access to MSD sheets.

MW

STROBING STINGERS

by Bob Svenson

I recently took my Stinger Missile tooling over to a friend's shop. The intent was to make some Stinger Missiles, however my friend got inventive and decided to try to make a strobing stringer.

As with normal strobe rockets no nozzle was used, he just pressed in about 3/8" of sodium salicylate whistle mix for the first increment and then proceeded to press in strobe mix, stopping about Vi" from the top of the tube (no clay bulkhead was used).

Then, in normal stinger fashion, he drilled an 1/8" side vent into the rocket. The side vent was drilled in at approximately the middle of the whistle mix fuel increment.

(NOTE: it's not a good idea to drill into a live item, and drilling into whistle mix is an even worse idea! Drilling the vent hole prior to loading would be the preferred method. Also note that whistle mix is *pressed,* not rammed.)

A generous amount of 1/8" visco fuse was installed in the vent hole and the rocket was launched from a standard stinger launch pin.

IT FLEW!

Although it flew it could have gone a little higher as it was on the way down before it quit strobing. Still, it was a neat effect and definitely bears further investigation and development!

Perhaps a little more whistle mix is called for. BS

POUR YOUR OWN WHITE STROBE FLARES

It's too bad all flares couldn't be made this way because it is a whole lot faster and less messy than ramming or tamping flares with a dry mix using a wire-and-funnel or ramrod method.

The formula I used to make my 1/4" i.d. flares comes from Dave Bleser's book *Round Stars* & *Shells*, page 22, Formula #26, White Strobe, as follows:

Barium nitrate	51
Sulfur	19
Magnalium 100 mesh (I used 60 mesh in my flares	18
Potassium nitrate	7
Dextrin	5

First task is to make the flare casings and insert a handle about an inch or so up in them at one en. Here's how I do it: Using 40 to 60 lb. brown Kraft paper, I cut it to a length of 8" x 1 1/2 to 2 2 1/2" wide. Depending on the weight of the paper, the lighter the paper the wider the cut. The paper is cut so the grain runs with the length of the tube to be rolled. Many fireworks books tell you how to roll your own tubes, both spiral and parallel rolled; I use the parallel method. The paper is rolled lengthwise one turn around a Vaseline-greased steel rod, 1/4" dia. and about a foot-long. It is a good idea to put a crease in the paper lengthwise about 1/8" from the edge so to make it more easily tuck in under the rod. After rolling the 1 to 1 1/2 turns, I take a small sponge bush and some thinned-down white glue and brush some thinned-down white glue and brush a light but even coat of glue on the rest of the exposed Kraft paper, and complete the roll. Using a piece of wooden 2x4" and my weight, I roll back and forth on the paper-wrapped rod a few times to press it into shape, then quickly remove it from the rod and set it aside to dry for a day or so. The rod is then cleaned of any glue and re-greased to roll another one. Several dozen tubes can be made! A wet towel is used to clean up the area.

At the hardware store I pick up some 1/4" diameter wood dowels 3 or 4-ft. long. Then they may be cut to any length, but 3" works well. It is necessary to lightly sand down the diameter of the wooden dowel an inch or so from one end in order to fit it into the tube, as the tubes have a tendency to shrink a little in diameter when drying. Just enough is sanded off for a tight fit, then glue is applied and the dowel is inserted into the casing bout an inch to let dry a day or two more.

Now it's time to pour!

Each one of my 1/4" diameter flares takes about 10 grams of dry mix (before water has been added) to fill them to the top. 100 grams of dry mix before adding water can make 10 flares.

The flare casings are stood upright in a small cup of sand or some other appropriate way is used to hold them upright. Also needed are a 2-oz. .plastic squeeze bottle with a long nozzle, and a small funnel to transfer the slurry into the squeeze bottle. To stir the mix I use a small, narrow model paint brush with stiff bristles, or a long narrow wooden dowel will do

The white strobe formula is prepared by weight. About 50 or 60 grams of it at a time is put into a 4-oz. plastic cup. A little water is poured in and stirred with the model paint brush. I keep adding water and stirring until all the mix is wet, then add some more water and stir until it is quite soupy, even runny, for it has to flow through the nozzle of the squeeze bottle. This nozzle may have to be cut down some, but not too much, to insert it into the tubes. Next some of the mix is pored from the plastic cup into the squeeze bottle using the funnel to fill it. The nozzle is screwed on and inserted into one of the flare tubes and squeezed lightly until the slurry is filled to the top. I set it aside in a jar or such, in an upright position. The process is repeated until all the flares are filled. If the slurry should lump up or stop flowing, more water is added and stirred back into a soupy slurry and continued to pour.

Before running out of all the mix, I check on the flares that have been sitting for 10 or 15 minutes to see if the need to be filled some more, as they have a tendency to settle down some, in which case they should be topped off with more slurry. Any spillage is wiped off from the outside shaft of the flare, and then they are put to dry in a good shaded place for 2 or 3 weeks. They will burn in a week or so but if they are allowed to dry at least two weeks or more they will strobe bright and last from 2 1/2 to 3 minutes each

In *Round Stars & Shells*, thee is also a formula for strobe ignitors, but I cheat and use a propane torch to light them. It might be unwise to use a common cigarette lighter or a match to light them because while they take a few seconds to ignite this way, when they do it is very bright and very hot and it's possible to get an unwelcome burn. A propane torch comes in handy to light all kinds of fireworks.

These fireworks can be held by their handles, but it is better to insert the handle into a small cp of sand and more the cup to where you want it. I tilt the flare slightly and light it, turning my back to it and watching the trees, utility poles, etc., light up with each very bright flash.

COLORED FLASH REPORTS

by Tony Petro

I gave a seminar in 2003 at the PGI convention, using my version of colored flash reports. I have received quite a few inquiries on the formulas I used. Here they are:

Red

Strontium nitrate	65
Potassium perchlorate	10
Magnesium (2 micron)	36
Parlon	14
Red gum	3
Sulfur	6

Green

Barium nitrate	65
Potassium perchlorate	10
Magnesium (2 micron)	36
Parlon	16
Red gum	7

Yellow

Sodium nitrate	30
Potassium perchlorate	30
Magnesium (2 micron)	30
Parlon	14
Red gum	2
Sulfur	10

All parts are by weight. Five micron magnesium may be used. I always work with small amounts, like gram quantities.

Some people have questioned using the very fine magnesium; I can see that concern if it ever got wet. But I've been using this product for over a year without problems.

The mix is a fairly hot one which will work in a small casing as little as 3 wraps of gummed tape in a 1/4" dia. by 1" long.

These color flash reports are audible and good, but not as loud as regular flash. I like using these with spider or glitter stars, which give a good, contrasting effect. TP

[Pyros working with extra fine metal powders, in this case magnesium 2 micron, find it wise to use extra care in handling the metal No pouring from one container to another. No exposure to static electric and friction situations. And magnesium always requires that water be kept far away, including ambient humidity. Even the water that 100% alcohol can suck out of the air can cause problems, as may sodium nitrate. Ed.]

USING FINE MESH MAGNESIUM IN STARS

By Larry Homan

A question arose about using fine mesh magnesium in stars, so a warning to a fellow worker is in order.

Fine mesh magnesium has no practical use in fireworks stars. Magnesium in general is for entertainment value in standard color stars. Rolling a mixture of this kind is beyond what is acceptable for a fireworks worker of any kind.

You have the additional problem of finding a fluid with which to roll the stars that will not react with the magnesium. One problem with using finer magnesium to increase reactivity is that one increases reactivity. It will react with water, oxidizers, air much more readily. So the exposure of the magnesium during rolling, with the probable moisture in the rolling fluid reacting with water in the mixture, renders it less reactive and slower and less ignitable as a star. The increased reactivity is worst during a dangerous exposure phase. This mixture would probably be very susceptible to static ignition, never to be underestimated with fine metals. Tossing this dry powder is not recommended. Star rolling can generate considerable static charges when done without water and with poorly designed equipment.

The benefits of finer metal powders in star formulas are always limited by what is acceptable to handle. It is best to increase ignitability and burning rate by adjusting the formula, increasing fuel ratios to a point, limiting inert or inhibiting ingredients, or any of many other ways documented in the literature.

The reverse of these methods is often effective to decrease reactivity. Thus adding more relatively inert cryolite (although not to be ingested) will decrease the reactivity of the mixture, but not the magnesium. Sometimes in the presence of water the "inert" ingredients can increase reactivity of metals. Or one might add a mixture of strontium carbonate and barium carbonate which will give a dirty yellow but in this case (high metal content) will tend toward white. There are many other things that can be done, like wetting with solvent and coating before rolling (only if done right, otherwise can be dangerous). Each thing done to decrease reactivity has its problems with star performance. This is why there are regions of acceptable star performance based on design criteria that often do not produce any one outstanding attribute, e.g., color, burn rate, ignitability, etc.

The problem is always the technique. One still needs to handle this dangerous mix, and there is no safe method that I know of. Beware of the approach. Be careful disposing of it. LH

FINE FIREFLY ALUMINUM

by Harry Gilliam, Skylighter, Inc.

Years ago, Steve Majdali gave us a star recipe for the twinkling silver/white effect known as "firefly." It's a beautiful star when made using the right aluminum. Skylighter provides a slightly modified version of Steves recipe with our firefly aluminum, but so many people have asked for it, that we thought it made sense to publish it. Although Steve's original recipe called for the coarser #CH0150 aluminum, there is no reason it cant be used with the less expensive aluminum we call "Fine Firefly".

Firefly Composition

Potassium nitrate	49
Airfloat charcoal	29
80 mesh charcoal	11
Sulfur	9
Firefly aluminum	5
Dextrin to taste or	5

All parts are by weight. Solvent to bind this star is water or 25% alcohol/75% water. The star can be made more interesting by substituting pine charcoal for the airfloat. Pine charcoal leaves a redder spark trail than other charcoals. HG

FAST WAY TO TEST NEW STAR COMPOSITIONS

by Harry Gilliam, Skylighter, Inc.

Making test batches of stars can be more time consuming than some time-taxed pyros have. Here's a quick way to get an approximate idea of what a star might look like, on the ground at least. This idea may have been stolen from Bill Kimbrough, I believe, like so many other good pyro techniques.

5-10 grams of dry star composition are mixed but not wetted. Then using a 5/16" rammer the comp is packed into a lance tube as tightly as possible. Then the end is lit and watch her burn. Toss it into the air if you want to see what it looks like airborne.

HG

ALL ABOUT COPPER

By Charley Wilson

Copper is element number 29 in the periodic table, located between nickel and zinc, and above silver. It is found native in large quantities, and is perhaps the earliest known metal to man. Copper is one of the best known conductors of electricity and heat, and finds application not only in electrical wiring, but also in cookware and heat exchanger tubing.

Copper salts are used in pyrotechnics to make blue flame. An abundance of chlorine and a fairly low temperature are required to produce the best color. Copper (II) oxide, or black copper oxide, is one of the safest copper compounds to use in practice because it is insoluble in water. Other copper compounds such as copper carbonate will react with acids to form copper salts.

Copper oxychloride is also popularly used in pyrotechnics. It is reported to be soluble in alcohol. In the author's opinion, there is little difference in the coloring characteristics between the oxide and the oxychloride. The oxychloride salt is formed by the aging of the chloride. In some formulations, the oxychloride may work better due to the chlorine content, but this has not been proven.

Copper acetoarsenite, also known as Paris green, is soluble in ammonium hydroxide and slightly soluble in alcohol. It is extremely poisonous. This compound was used by most Italo-American star makers in blue compositions using potassium chlorate as the oxidizer. It may be true that the arsenic component enhances the blue, perhaps by shifting the color toward a truer blue.

Experimental quantities of copper chloride, a starting point for making other copper compounds, can be prepared from copper scrap metal such as tubing and wire. A mixture of muriatic acid from the hardware store with ordinary hydrogen peroxide will react with copper metal to form a beautiful deep blue solution of copper chloride. The addition of sodium hydroxide will yield a gel of copper hydroxide, which when heated will precipitate out black copper oxide. The black oxide can easily be washed free of sodium.

Another means of preparing copper oxide is by electrolysis. Copper wire or tubing is connected to a current source, and immersed in a conductive salt solution in water. At the anode or positive side, the copper metal will be reacted with water to form copper hydroxide, and again the application of heat will convert it to copper oxide.

Much has been made of the danger of copper-containing pyrotechnic compositions. This is largely unfounded when insoluble copper compounds are used. However, the carbonate should *never ever* be used in a composition containing ammonia (such as ammonium perchlorate) to avoid spontaneous combustion.

Copper will form complex ions with ammonia, some of which are dangerous and of little interest to pyrotechnicians. However, one such compound is copper ammonium chloride, or more modernly called tetraamine copper chloride, mentioned in a blue star composition by Weingart.

The color of the copper monochloride emitter in a pyrotechnic flame is actually violet-blue. Many blue star compositions, regardless of the oxidizer used, achieve a blue-white color because of other combustion factors in the flame, such as carbon and hydroxides. New research seems to indicate that high amounts of nitrogen in the flame may produce a deeper color (Issue #10, Winter 1999 Journal of Pyrotechnics for specifics).

There has been a notion among some PGI members that a high temperature flame with a blue (copper) composition will make the flame green. This can actually be described as a white flame. However, the flame produced by copper salts, without chlorine at very low temperature (the ordinary combustion temperature of a fuel) is green.

In any case, the following composition produces a highly saturated color, due to the fact that other luminous stuff, such as carbon, are at a minimum.

Ammonium perchlorate	70
Sulfur	19
Copper oxide	6
Dextrin	5

NEW FLAKE TITANIUM IS BRIGHTER, FASTER

by Harry Gilliam, Skylighter, Inc.

Years ago, there was a great titanium flake on the market made by a company in New England, Suisman Corp. But they stopped manufacturing this great white spark producer. We have been trying for years to find a good, long-term source for small-sized flake titanium, and finally snagged one. This is beautiful stuff. If you have not used flake titanium before in fountains, rockets, stars, or comets, you really ought to try it.*

I am particularly fond of adding this titanium** to meal powder (very fine grained black powder) and using it in my Stinger Missiles (spin-stabilized rockets). It makes a gorgeous rising silver tail. For a fun rocket heading, just insert a bundle of silver flying fish fuse, about an inch and half long in the top and cover loosely with masking tape.

SILVER STINGER MISSILE FUEL

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

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

* Ramming titanium-bearing comp. in drivers, fountains, rockets, etc. is not done. There have been several tragic incidents during pressing of comp. with titanium added, including a fatality when the rammer jammed and the operator attempted to free it. Extra care must be exercised when compressing any comp. containing metallic titanium.

** The new titanium is available in two flake sizes: -10 to +60 mesh, and -10 to -100 mesh. Both are aerospace alloy, i.e., 90% titanium, 6% vanadium, 4% aluminum. They are said to produce slightly brighter white sparks than the pure stuff. Contact Skylighter for details. Ed.

TITANIUM SPARKS EASILY

by Ian von Maltitz

Titanium has unique properties when it comes to sparking.

I have seen this recently in a machine shop where titanium was processed. Any type of dry processing produced showers of sparks, impressive but scary.

Some years ago I acquired a batch of titanium turnings. I found that even cutting with a pair of hand-held snips produced sparks. I haven't noticed the same phenomenon when cutting other metals with snips, including steel, aluminum, and zinc.

Titanium is wonderful stuff, but it has this horrible vice of sparking very easily.

FLOUR PASTE FOR SHELL BUILDING

by Lee Partin

With old fashioned wheat paste wallpaper paste hard to find, why not just cook your own recipe?

1 cup of flour (not self rising) blended into 1 cup cold water until smooth. This is added to 2 1/2 cups of rapidly boiling water, with constant stirring, and immediately taken off the burner after stirring in paste mixture. Stirring is continued for a couple of minutes to keep from sticking to the pan.

I add a teaspoon of alum (potassium aluminum sulfate) to the boiling water as a preservative and to discourage bugs from eating the paper.

This makes an excellent thick paste for shells.

I have found that King Arthur flour makes the best paste.

PICRIC ACID REMEMBERED

By Joe Barkley

Picric acid is an intense yellow crystalline organic acid that was once useful in pyrotechny, but is hardly remembered in the U.S. today.

Picric acid dust in invisible amounts, when breathed evinces the Greek word "picros" (bitter) by which picric acid was named. It forms metallic salts, the most useful in fireworks being derived from potassium and found in pyrotechnic whistles. The classic texts (Weingart, Davis, Lancaster) all mention picric acid whistles and elaborate on their construction.

Two generations back, firework whistles from potassium picrate dominated the market; today potassium perchlorate, benzoates, salicylates, etc., are the principal ingredients. One reason potassium picrate has lost popularity is the necessity for preparing the salt from picric acid and the more basic potassium carbonate.

The market demand for potassium picrate is so low the big manufacturers find no profit in making it, leaving preparation from picric acid to the pyrotechnist ... a thankless small-scale job.

Handling potassium picrate stains hands and clothes tenaciously. Filling whistle cases with the solid creates bitter dust that requires breathing protection. Lancaster (private communication) tells how potassium picrate whistle-making is done in a one-session large-lot if possible, to focus the dirty work and staining, without frequent repetition.

Potassium picrate whistles were used in U.S. commercial fireworks in the 1940s. Example: a small "whistling aerial bomb" containing the explosive projectile strapped to a short picrate whistle by a rubber band, all inside a cardboard mortar.

Picric acid has some shock sensitivity and can explode, as standard impact tests show. However, one hobbyist noticed that powdered picric acid/standard flashpowder mixtures from 2% to 30% picric acid reduced flashpowder effectiveness in salutes (noise and brisance) in direct proportion. Obviously there is no future for picric acid as a booster in flashcrackers.

Many picric acid salts, especially those of heavy metals, must be handled carefully as they are very shock-sensitive.

Will picric acid fade out of fireworks completely? Today's whistles are so much more pleasant to make but improvement in performance is questionable. The future will decide.

MOISTURE PROOFING STEEL FILINGS

by Gerry Gits

About 20 years ago, (or was it 30) we were developing a domestic produced steel cone for commerce (it would be an exercise in futility today). The comp was a basic black powder scratch mix with about 10% commercial iron powder. Source of this powder is not remembered, but it was sold in about a half cubic foot paper lined burlap bag.

To coat this material, we bought an old cement mixer, extracted a burner from an abandoned water heater, and set it into effective configuration with a propane tank. The 100 pounds of iron and 5 pounds of paraffin canning wax were dumped into the mixer barrel, the burner ignited, and the mixer set in motion. After an un-recorded period of time, not more than an hour, the wax was melted. After shutting down the fire, the mix was allowed to rotate till cool. The result was a powdered mass that mixed readily with the scratch mix.

The cones had excellent shelf life and produced sprays in excess of 20 feet, so high, that in some jurisdictions they exceeded the maximum allowable legal height for this type of firework.

The proof of the effectiveness of this process was an informal experiment. A dozen cones hung in the cone charging building. Three years later I saw those forgotten cones, still hanging in the corner, took them down and fired them. They worked perfectly. Dissection of several cones revealed no red oxide or swelling of the comp. This was a test of extreme conditions for the cone building was rinsed out every working morning in order to clean up and remove tramp powder, and to lower the potential for static electric discharge. These conditions were very severe as the room was in a constant state of moistness.

RED PHOSPHOROUS

[As each new generation of hobbyists comes along, a certain number of them will be enchanted by the genie contained in red phosphorous. With stories of torpedoes, Devil-On-The-Walk and other novelties dancing in their heads, they overlook the dangers of Armstrong's Mix and hopefully embrace the idea of experimenting with the red demon. The following, extracted from a U.S. Navy manual *[Naval Pyrotechnics Development},* may shed some light on some of the less obvious dangers.]

Red phosphorous is one of four allotropic forms of pure phosphorous, with the other three being yellow, violet and black. Yellow phosphorous ignites with the oxygen of the air at room temperature. Red phosphorous changes to yellow phosphorous at 200° C and then ignites. When a red phosphorous fire is extinguished, there is always some yellow phosphorous present with the red phosphorous. If water is used as the extinguisher, the fire will start again when residue dries out because of the yellow phosphorous that is present.

Phosphorous has certain toxic effects on the body. An accumulation of it in the body causes a bone deterioration, especially to the teeth and jaw bones. Persons working with this material must be subjected to constant medical inspection and they must not be exposed to phosphorous if they have open sores or cavities in their teeth.

Burns caused by phosphorous usually will increase in severity until the burned flesh is washed with a basic diluent, because phosphoric oxides, which are the products of combustion, combine with water of the skin to form acids. Unless these acids are neutralized, acid buns are added to the flame burns.

While red phosphorous is quite stable at room temperature, the friction caused by a shoe scuffing it on the floor can raise its temperature to the ignition point. Experience has proven that the fire hazard in a red phosphorous manufacturing area can be reduced to minor proportion by washing the area several times a day and that people in contact with this material should be bathed and have their closing changed when leaving the manufacturing area. A fire in a non-phosphorous area of a pyrotechnic plant was caused because a phosphorous worker ate lunch with a non-phosphorous worker. Phosphorous workers who did not change clothes to go home have experienced waking up at night to see their shoes or clothing burning.

PRIMING CHLORATE STARS

We have all seen the statement that chlorate stars take fire so easily that it is unnecessary to prime them. Yet from time to time we also hear from some star makers who say they prime chlorate stars. Recently a reader addressed the question to retired manufacturer Bill Ofca, with the following reply. Thanks to Bob Svenson for providing this info:

(Q) Doesn't priming with perchlorate/-charcoal take away the ignition advantage of chlorates since you got to burn through the perchlorate to get to the chlorate?

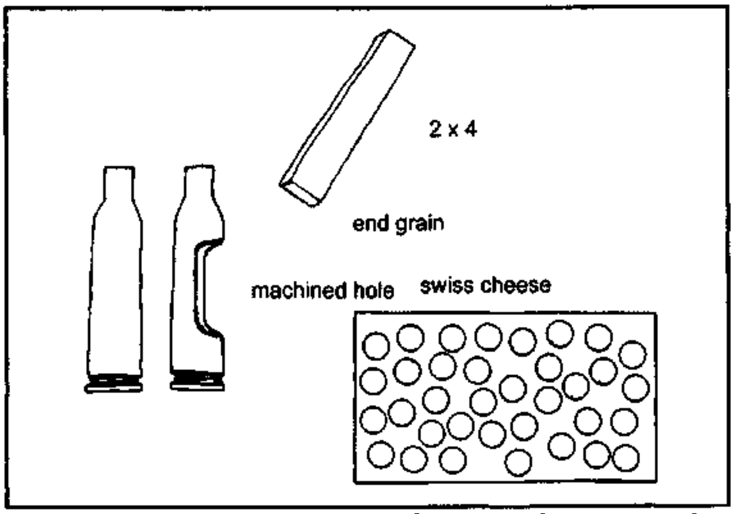
A) Priming with perchlorate/charcoal does not alter the ignition qualities of chlorate stars at all. I believe the reason is because the chlorate is partially soluble in water and in alcohol, with the perchlorate even less so. Some of the chlorate goes into solution and soaks into the charcoal while drying. If machine rolling stars, the perchlorate prime embeds itself into the top layer of the chlorate star where the two mix. As the prime layer grows, water spray coating is necessary to pick up the primer. Rolling the star brings water from the inside of the star to the surface, carrying some of the dissolved chlorate with it. The result is a star coating that has the ignition properties of chlorate by itself, yet is greatly reduced in mechanical sensitivity due to the blend of oxidizers. Cut stars, on the other hand, cannot be coated evenly or entirely. There will always be corners and jagged surfaces sticking through the primer. The reason for using the perchlorate/-charcoal prime is to reduce friction and impact sensitivity when the shell fires and exerts set-back forces onto the stars. WO

CUTTING SMALL PAPER PLUGS

By Carl Denninger

I forever find myself winding paper tubes using pencils and pens as mandrels. Maybe it's because they are just so available or maybe I'm just too cheap to make larger or normal sized, chemical devouring fireworks. Could be too I do not wish to attract too much attention when I'm testing my latest experiments. Whatever it is, it's very hard to find pre-made paper plugs, so I had to come up with my own cutter.

I've used some pretty nice hand cutters that were designed for cutting holes in laboratory rubber stoppers. They were too slow. The answer came from my reloading bench. Empty bottleneck-shaped rifle brass (IE 30-06, 7mm magnum) is the answer, with some modifications.



First I need power and speed. Here I can put my drill press into play. The base of the brass is held firmly by the drill-chuck. Next I select a speed around 1000 rpm. While the brass is spinning I sharpen the *outside* of the neck with a file to an approximate 30° knife-edge. I press the spinning cutter down through a sheet of card stock and into the *end grain* of a block of sturdy wood. The *end grain* is so much more resilient and forgiving to the soft brass cutter than the side grain. With a slight pressure the cutter glides smoothly through the paper, almost effortlessly.

So now you have a disc cut and the next disc will push the last disc up into the shell body. Continuing this would only fill up the shell with discs. However if a large hole is machined or ground into the side of the shell the plugs will spin out automatically as I cut plug after plug. The plugs come out with an extremely smooth, polished edge and very little dust.

Rifle brass has such a neat way of letting you know what diameter discs it will cut. The name of the shell, usually stamped in the base of course, has the diameter of the bullet and thus the disc sizes in English and sometimes metric units. So common bottleneck rifle cases can cut dozens of sizes from 0.17 to 0.50 inches; .30 caliber is my favorite for pencil wound cases.

Good clean brown or gray card stock will cut very well with this cutter. Sometimes I laminate several sheets together with carpenter's glue to get the thickness I want. Paper that has been filled with clay to make it smooth, glossy and printable can be too abrasive for the brass. Likewise, some brands of fiberboard and plywood have too much abrasive dirt mixed in with them and others don't. You should be able to cut hundreds of plugs in between sharpening. Also end grain softwood cuts extremely well. Slice off say a 1/4" thick slab cross grain on a table saw from a low grain soft wood 2x4 and turn it into Swiss cheese in 2 minutes.

The left over wooden skeleton makes a good mold for cylindrically shaped stars of a precise outer diameter. This process leaves a smooth and polished hole that allows the stars to be popped out easily when dry. Pretreating the wooden skeleton by submersing it in a bath of very thin shellac and alcohol solution or PVC dissolved in methyl ethyl keytone will minimize oxidizer lose from absorption into the wood. So next time you're out at the rifle range collect a completed set of pyro plug cutters. CD

BACKYARD RADIOS

by Joe Barkley

Older display catalogs illustrated small rockets flying across the display front, stopping, then returning after an instant of delay, sometimes igniting display pieces on the way down or back. Most spectators were unaware that these little "radios" rode on a thin taut wire supported at both ends. More elaborate variations of the "radio" were mentioned by Weingart as "pigeons". Behavior of these devices is almost uncanny without the observer knowing they were guide by thin wires or ropes.

Given a few unobstructed yards in one direction, the fireworks can erect a wire guide to experiment with radios and pigeons, observing slow and fast motion using various propellant blends and additives such as aluminum.

Materials used by the writer:

Soft steel wire about 1/32" thick, galvanized, obtained in rolls at electric fencing suppliers. A convenient tree or post supports one end. The opposite end should be easily unhooked for mounting the radio. Moderate tension is maintained using about 50 yards of level run. The wire must be smooth between hooks - no kinks. The writer found twisted soft iron wire supports on opposite ends of the radio body to be fireproof and slide well.

Rocket spindle and drift. Spindle is a 1/8" dia. common nail driven through a 1/4" dowel stub base supported by a l"x 1" x 2" pine base. The base is drilled deeply enough to accept the dowel stub anchored with epoxy cement. The sharp end of the nail stands 1 1/2" above the dowel stub. The drift is a 3" length of 1/4" aluminum rod drilled out to accept the spindle.

Radio cases. Red rosin building paper was cut into 2" wide strips about 6" long or shorter, as required. Paper grain direction is crosswise to ease day-rolling, pasted only on the outside turn. Case interior diameter must accept drift when charging.

Charging cases. A 75/15/10 ballmill meal is a convenient base for experimentation by blending with charcoal or smaller amounts of aluminum. Since these ingredients are usually variable in size and quality, exact proportions for optimum results will reward the experimenter. A scoop fabricated from a spend .22 case was used to load successively by ramming, 2 scoops of clay, 1 scoop of 75/15/10 meal, then remaining empty case a 6/3/1/meal blend. The case is charged up to 1/2" of the top and then filled with rammed clay.

Notes: Single radios are ignited with a short piece of visco. Many avenues are open for experimentation. By taping two radios end-on-end and fusing with foil-wrapped visco, the second will come back after a short delay. Or blackmatch also wrapped in foil can be faster. Little Chinese pinwheels can be attached and fused for a mini-pigeon effect.

The writer found backyard radios to be a palliative for complaints by close neighbors who dislike bottle rocket sticks all over their property. Radios make good neighbors. JB

RADIOS OR RATS?

By Rege Survinski

. Here's another viewpoint from a reader:

Back in the 40s, 50s and 60s I fired them in shows. Then we knew them as "rats".

Your description didn't mention that they were connected to a hollow tube [which ran like a trolley on the taut wire].

The case was packed solid with a 75-15-10 mealed powder mixed with ground charcoal (not powdered charcoal!) to the mix of 7 parts meal powder to 1 part ground charcoal.

The case was 3/8" i.d. with a hole drilled in the clay one quarter the diameter of the i.d.

The speed & effect could be changed by adding a little steel or aluminum filings.

I've been making and shooting fireworks since the mid-40s. You brought back a lot of old memories.

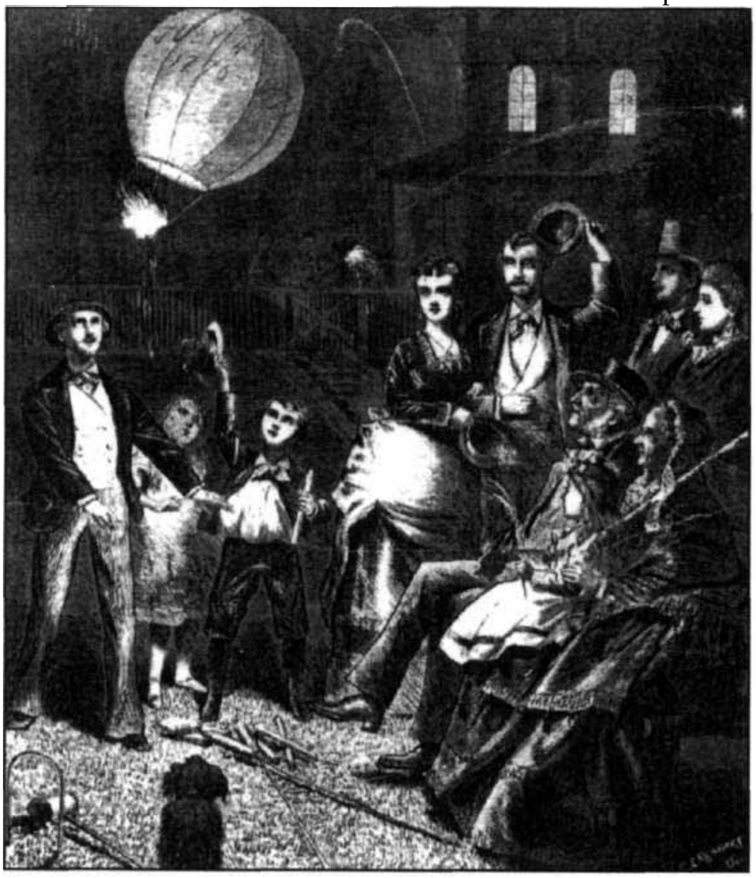
[A beautiful, 5 page article on making line rockets (by Max Vander Horck) appears in *Best of AFN III.*] RS

FIRE BALLOONS...AGAIN?

By Joe Barkley

Most AFN readers are too young to personally recall the diversity of fireworks being offered to the public as late as 1939. World War II spelled the end of fireworks as we knew them.

Fire balloons were popular in some sections of the UK and the US in pre-war days. These little fireworks (?), taking a cue from man-carrying Montgolfier* balloons, operated on the principle of warm combustion gases inflating a light fireproof paper bag situated above the combustion source, causing the device to rise in the air. Demise of these tiny once-popular fireworks was caused by alleged threats to persons and to the environment (fire hazard to property), the latter being the primary excuse for adverse legislation.



Classic fireworks texts (Kentish & Weingart) devoted several pages (Kentish, 7 pages, Weingart, 4) to the design, construction, and launching of fire balloons for the amateur or professional. Performance of larger balloons was enhanced by attaching different payloads to be discharged into the night at the apex of flight.

Through the kindness of Rev. Lancaster, I've had the opportunity to inspect one of the pre-war fire balloons sold as a Pain's "Montgolfier", but dropped from the product line after the war. Different sizes were made and identified by the circumference in feet stamped on the label affixed to the glassine cover of the flat folded package. Detailed flight instructions warned against windy launches. Two persons were instructed to hold the balloon upright while the third poured methyl alcohol on a cotton wool pad affixed to the wire former at the open end. For safety, excess alcohol was squeezed out of the pad before lighting. The balloon was to be released after it "pulled well". No mention was made of a payload for these small sizes; colored tissue gores enhanced daylight visibility.

As suitable flying sites diminish throughout the world, the writer feels that fire balloons are unlikely to be sold to the general public again.

*The Montgolfier brothers were French papermakers who demonstrated in 1783 the first successful human flight. They flew together in a wood-fueled paper balloon. Fireworkers caught on and imitation abounded, but in smaller sizes. JB

[Daniel Beard's classic fire balloon how-to article was republished bv Klofkorn in his 1994 *Bonfires & Illuminations.* An earlier treatment of the Beard classic was done by Vander Horck in his *American Pyrotechnist* and reprinted by AFN in Best of AP.]

Picture: "The Glorious Fourth - Sending Up a Fire Balloon", the cover of *Harper's Weekly,* July 8, 1871. JB

WHEN AMERICAN HELICOPTERS RULED

by Joe Barkley

The small one-driver tourbillion often named "helicopter" became a popular over-the-counter fireworks device in post-WWII years. Never mentioned in Weingart's classic text, it was described to Weingart by Orville Carlisle in written 1940's communication between the two, upon which Weingart seemed to think the device was impractical. Three or more domestic manufacturers supplied these goods before the great influx from China in the 1970s.

Helicopters under various guises and names are now plentiful in retail fireworks outlets nationwide, however, mostly with Chinese labels. One Texas manufacturer dedicated a single facility to helicopter (Buzz-Bomb, UFO) production. L.L. Buckley, the Plant Manager, Operations, showed how a two-man operation could compete with foreign competition and turn out superior products at a fair price.

Their manufacture of the UFO involved press-filling cases from the tube manufacturer with a single plug of clay, followed by a modified blackpowder propellant. Critical to a successful product was propellant composition and moisture. Meal powder (ICI at the time) was blended with charcoal in a cement mixer, or made from blackpowder components at the plantsite. The charged case with one end open could be finished with small star material or flashpowder, depending upon the end use. This case was closed with a paper plug, lightly glued. Stars were made in a cement mixer using standard commercial formulas. Overall design is so common that most pyros not familiar can find examples at most fireworks outlets nowadays.

Quality control: These production constants promoted repeatable performance:

t Ends on drifts for ramming clay plugs were rounded for concavity at the fuse hole, stopping premature case burnout (longer airtime).

• Fuse holes were drilled through the filled case in a closed (safe) environment. A jig designed for 45° fuse hole/wing angle assured repeatability. Cases were fed automatically to the drill jig and collected downside a fire barrier.

• A plastic wing in a locking groove was attached with an elastic band (compare shoddy imports using paper wings that are invariably bent out of shape).

• Repeated testing finished product onsite by observation (actual firing). Height, 200-300 feet, ending in a horizontal sweeping circle before burnout.

Principal production headaches: Purchased meal powder was inconsistent in composition and moisture, forcing constant adjustment of blend ratios with charcoal. Seasonal moisture variations in all ingredients compounded the problem. Reasonable storage (relatively constant ambient humidity) of items after manufacture retained quality. JB

TIP OF THE MONTH

BAMBOO FOR GIRANDOLAS

I've been rather disappointed in the bamboo I've been able to get now. It is MUCH thicker than the stuff I got back when I wrote the book (*The Incomplete Book of Girandolas*), and I've had to run it through a planer to get it thin and light enough. Alas, this process weakens the bamboo at the "knots". So I take the thinned pieces, bend them around to a little tighter radius than I intend to use them at, and tie them in that position. Then I leave them for several days and use those that have not broken. Be sure to put them where they cant cause damage when they break and suddenly spring back out straight!!

Tom Dimock

SHAPING BAMBOO

A neat trick taught to me by Bill Kimbrough: After bending your bamboo into a ring and holding it in place (clamps, small brads, etc.) heat it with a torch until it just starts to blacken a little. It will hold its shape amazingly well. John Vico

CHRYSANTHEMUM STARS

by Charley Wilson

A curious page of formulae, with attributions, is to be found in *Best of AFN II.* Page 65 contains many very good compositions for stars, but as in many cases, other documentation for the correct use of the compositions is poor or lacking completely.

One of the compositions listed is for "TITANIUM/CHARCOAL COMET which could be an excellent starting point for a simple chrysanthemum star. The formula as given in *Best II* is peculiar in that it contains an abnormally high percentage of dextrin. I have made slight changes to it and here present a version given in percentages by weight.

Potassium nitrate	50
Sulfur	9
Charcoal, fine powder	23
Antimony sulfide	6
Titanium, 30 mesh	7
Dextrin	5

The composition is made up with water/alcohol and pumped into 3/4" or larger stars, and can be used in 4" or larger cylinder shells or 5" or larger round shells.

The effect is a white star (comet) with a huge bright white tail of sparks.

The stars light easily and do not need priming.

Another interesting concept that might be applied to a chrysanthemum star is the use of some of the older materials of pyrotechnics. This includes zinc powder, lead nitrate with steel or iron powder, and arsenic compounds. Given their hazardous nature, the use of such material is best left to the experts. CW

TIP OF THE MONTH

I found that "STP" (oil absorbing) Sweeping Compound in a 10 lb. box appears to be bentonite! Hey, it works great for nozzles! And it was cheap at the Dollar Store. I got 10 lbs. for a buck! Bill Schleef

CATTAILS & ECO COPS

[Way! Gibbs' story, *The Willow Wood Caper* has sparked comment from readers who experienced similar episodes. Here's a representative one from a PGI founding member.]

by Joel Baechle

In the winter of 1977 I was driving nearly 40 miles to work and back, and as a result I passed a state hunting preserve/wildlife refuge twice a day. This was in a swampy area, where the poorest people who decided to move to the country from Cleveland, ended up. It had occurred to me that some of the cattails growing there looked like they would make mighty fine rocket sticks, so I decided to find out. Knowing full well that there were signs posted about trespassing and hunting, I took my cocker spaniel along.

I stopped along the road, let the dog out, and started looking for cattails, to see how mechanically stable they were. True to my paranoia, *within a few minutes* an Ohio Eco-cop showed up to make sure that I wasn't taking any cattails!

I explained that I had let the dog out, and was waiting for the pup to finish. And that I would be happily on my way the moment the dog returned. That was sufficient for the time being.

Of course, I ventured back at a less obvious moment to test my hypothesis. Turned out that they were a little too flimsy - they just barely worked. And that is how the Great State of Ohio avoided having a cattail extinction as a result of their exploitation by zealous rocketeers! JB

TIP OF THE MONTH

I came across this by accident. For tough cleanup of a star rolling bowl or machine or other tools when using comps that contain Red gum or other hard to remove substances like fire clay, just take a damp sponge and put a small amount of hand cleaner with pumice (Goop or Gojo work really well) on it and in a few seconds and with a little bit of scrubbing, your tools or bowl are clean.

Mike Mioduszewski

THE WILLOW WOOD CAPER

by Wayt Gibbs

In my never-ending quest for better BP, I have been scouring the city and countryside for willow trees to make faster charcoal. My wife noted that outside the Dept. of Corrections a nice stream ran, on whose banks many fine willow trees grew, so off I went to get some branches. Being a law-abiding sort, and not wanting to alarm the locals, I went to the administration building, noting the metal detectors and armed corrections officers in abundance around the grounds.

The warden was gone, but the nice secretary promised to ask the assistant warden. She didn't hold out much hope. "They are afraid someone driving by would see you and think you were trying to help someone escape." She said. "But its outside the prison," I said. "And all I want to do is pick up some dead limbs." "Doesn't matter," she said. I envisioned a little old lady driving by the prison, and upon seeing an elderly man picking up dead branches from under a tree within sight of a prison, immediately conclude that he's an escaped convict, who decided to tidy up the place before leaving. The warden's phone would naturally be ringing off the hook immediately thereafter.

Finally, she gets the assistant warden. "I have a gentleman who wants to pick up some dead branches from underneath the willows," she asks. It's the first time anyone has described me as a gentleman in a long time, and I'm not sure if I should take umbrage or not. "No, he may not," he replied. "Someone might think he's helping a convict escape."

Defeated, I turned to leave, but the pretty secretary, (Angel was her name), said "There are several willows in the median strip at exit 213A off the interstate. You could get some of them." "By the way, what do you want willow branches for?" she asked. I thought about telling her the truth, but decided I might end up on the wrong side of the wall we were facing. "It's for a science project. I'm investigating the energy in different types of wood." "Oh," she said, "Sounds interesting," she lied.

Thanking her profusely, I left and drove the 10 miles down to the exit she had indicated. Sure enough, there were three willows nestled between the on and exit ramps. I celebrated my good fortune by parking along the berm and walking with my saw and lopers to the first tree. Then I saw them. Big guys, wearing orange and blue vests, carrying shotguns. Oh, no, not again! It was a road maintenance crew of convicts from the Dept. of Corrections. A crew of 10 was cleaning up the right-of-way under the watchful eyes of several guards.

I contemplated asking permission from the guards to pick up dead branches from under the trees, but was sure they would have to call the warden, who would deny the request on the grounds that passing motorists would think I was trying to help convicts escape. Instead, keeping the tree between me and the crew, I went about my business.

I arrived home an hour later with a goodly assortment of willow, which made some nice charcoal, thanks to help from Crackerjack Rich Weaver and others. I'm still waiting for a DOC car to come ask why I was hanging around a bunch of convicts on the interstate, but maybe I'm just a tad paranoid. I sure hope this willow charcoal is worth it! WWG

MORE ON DEXTRIN MAKING

By Randy Peck

The July issue of AFN had a tip about making your own dextrin. I've made some this way and I had a huge problem with the starch melting and sticking and burning fast to the tin foil lining my tray during baking.

The solution was to set my oven on BROIL so that the starch was cooked from above and therefore not burn in the pan. There was a lot less waste as well, meaning more dextrin! RP

PAULOWNIA COAL - WHAT IS IT?

By Richard Ogden

[In his classic text *Fireworks, The Art, Science & Technique,* Dr. Shimizu mentions charcoal made from the Paulownia tree, and later lists formulations that call for "Paulownia coal". Recently a question was asked on the pyrotechnic Mail List about what this really means. The short answer is that when some pyro writers mention "coal" they actually mean "charcoal". Here Richard Ogden discusses the Paulownia tree, which Dr. Shimizu reports makes the best charcoal for fireworks.]

Paulownia is a genus of trees comprising a number of species all native to China, some of which are also grown for lumber there and in Japan, among other places. The genus is in the botanical family Bignoniaceae (though it is sometimes listed in older references as a member of the Scrophulariaceae or Figwort family), which also includes a large number of genera including species of trees, shrubs, woody vines and a very few herbs (non-woody plants, in this context).

The species P. tomentosa is best known of these, and known by the common names Empress Tree, Princess Tree or Karri Tree (though the latter name also refers to wood from a species of Eucalyptus), and is planted for use as cabinet wood, for making furniture, among other things. The wood is described as "being a pleasant silvery color and very resistant to the damp climate [of Japan]". The wood swells in high humidity. It is also a traditional ornamental in the U.S., planted for it's large tropical-looking leaves and large purplish fragrant flowers. When grown as an ornamental, regular annual pruning is used to maintain shape (a bonus for BP makers!). The tree grows very easily in a variety of soils, and very rapidly if given good care (capable of 8-10 feet per year), and is hardy to 15°F (-9°C). Specimens grown in the North will sometimes die back in winter, only to sprout up again from the roots on the return of warm weather, providing wood perhaps unsuited to cabinet-making but fine for charcoal production.

The trees are amenable to pollarding, meaning they can be cut back quite hard and will send up new growth readily from the stump or even roots, so with extra care the same trees can be harvested again and again (though this will interfere with flowering). Trees that are allowed to grow undisturbed to maturity command high market prices. It grows best in moist, rich soils but has been known to grow in the cracks of sidewalks and even in mine spoil. It is propagated by seeds and root cuttings, and has been successfully tissue-cultured - the latter two means of propagation can be used to duplicate exceptional specimens. The wood is used for charcoal extensively (probably originally because trimmings from working the wood were readily available) and is said to make one of the fastest black powders.

While the literature all deals with the tomentosa species, because of its wide adaptation and history of use, it is likely the other members of the genus would be similarly useful for charcoal production. P. fargesii and P fortunei are similar in appearance, bloom and growth habit, and will stand lower temperatures. A thorough coverage of the non-pyro properties of this genus can be found at

www.idrc.ca/library/document/071235/

There are a number of other genera of interest in the same family, most notably the closely allied genus Catalpa. These include popular ornamental trees native to China and to the Southern and Southwestern US which closely resemble the Paulownias, and which should be considered candidates for charcoal making.

References: Hortus III; The International Book of Wood (Simon and Schuster); Fireworks. The Art Science and Technique (Shimizu); The Southern Living Garden Book (Oxmoor House); Carolina Landscape Plants (Sparks Press); Flowering Plants in the Landscape (Univ. of Ca. Press); The Reference Manual of Woody Plant Propagation (Varsity Press, Inc.). RO

SENSITIVITY FINDINGS

by Charley Wilson

I had noticed that a blue star composition that produces a beautiful color in static tests seemed to go 'high order' when shot from mines. It uses ammonium perchlorate oxidizer and sulfur as the fuel with only 5% copper oxide colorant. I decided that some testing of sensitivity was needed.

Here is the data that I collected over Memorial Day weekend at the Kosanke's lab in Whitewater, Colorado.

Ken has a device which uses a drop hammer that can be set up for .5, 1 or 2 kilogram weights for various heights on small samples of pyrotechnic compositions. For my trials I used 1 kilo.

We used the Bruceton method to iteratively find the 50% fire point height. For comparison, we chose the Lancaster blue box star. Impact sensitivity data for ammonium perchlorate compositions is one area that is severely lacking. However, many superior colors can be made with it and used when the limitations are understood.

	Wilson	Lancaster
Ammonium Perchlorate	65	29
Potassium Perchlorate	-	39
Sulfur	26	-
Red Gum	-	14
Cupric Oxide	5	-
Basic Copper Carbonate	-	14
Dextrin	4	4

Results in inches (Bruceton):

Wilson blue - 11.1 (!)
Lancaster blue - 22.0

Compare to potassium chlorate and sulfur 50/50: - 8.2 inches.

My conclusion is that copper catalyzed ammonium perchlorate with sulfur fuel is much too impact sensitive for practical use.

Another area of misinformation over the years is the sensitivity of other chlorates in comparison to potassium chlorate. While copper and ammonium chlorates have documented nasty properties, the sodium and barium salts have been decried without much evidence.

Indeed, the oxygen generation business consumes tons of sodium chlorate each year without incident. Barium chlorate has probably received a bad name because of impurities such as arsenic and antimony in shellac fuel more so than because of barium.

To test the chlorates we started with a 70/30 mix of potassium chlorate and red gum. For comparison, we kept the molar percentages of chlorate ion the same. Thus, barium chlorate/red gum 87/13, and sodium chlorate/red gum 61/39 were used.

The results:

Potassium chlorate - 10.96
Barium chlorate - 12.25
Sodium chlorate - 15.25

No doubt that I will receive criticism from some quarters. I welcome your comments and suggestions.

My sincerest thanks to Ken and also to Brett Floyd for his patient help with the Bruceton trials. CW

SALTPETER & "LONG-DISTANCE COMMERCE"

by Stewart Tick

When reading about the early history of pyrotechnics, I've often been struck by how quickly the knowledge of black powder spread from Asia to Europe for the time (13th century). I was recently reading an article in an entirely unrelated field, and realized that I had inadvertently come across the answer to this question.

According to the well-known medical author Dr. Andrew Weil and Wade Davis (of the New York Botanical Garden), "it is an axiom of long-distance commerce that the ideal trade item is one that is highly esteemed, easy to transport, durable, readily available at the source, and difficult or impossible to find at the point of exchange". Saltpeter fits all requirements, doesn't it? ST

MAKING POLYSTYRENE-XYLENE GLUE

by Charley Wilson

At my last Rocky Mountain Pyrotechnics Guild seminar I mentioned the use of xylene as a solvent for styrene plastic. It is really quite easy to make, as pointed out by Bill Ofca in his "Technique in Fire" series. But unlike Bill's technique, I find it unnecessary to dissolve plastic shell halves. This is impractical for most people; gathering bits and pieces of used casings could be tedious.

Instead, I use any polystyrene scrap material that can easily be found. Easy sources include the polystyrene packing "peanuts", the foam backing plates which meat vendors use, and foam plastic cups. Also, most of the disposable plasticware that is available is made from styrene. Various colors are available, allowing for different colors of glue to be made as well. Look for the number 6 in the recycling symbol and the letters PS below it.

This glue can be used in the assembly of the polystyrene plastic shell halves, but it also works well as a glue for spollettes or time fuse in traditional shell end cap assembly.

The two benefits of the glue in plastic shell construction are its lower toxicity (than methylene chloride), and the higher strength of the joint that it creates when fully dry. But it does take longer to dry.

Toluene and xylene are very similar solvents, differing in that xylene has two methyl groups attached to a benzene ring, as opposed to one. Xylene may also be called dimethyl benzene or xylol. Xylene can be purchased in most hardware stores.

The glue should be made and stored in a glass jar with a firm screw-on lid. I start with a small amount of solvent and simply add pieces of polystyrene until the consistency is thicker than honey. The glue can be applied with a polyethylene glue syringe. CW

GLUING PLASTIC BALL SHELLS

by Matt Romey

What I use to glue my plastic ball shells is polystyrene mixed with methylene chloride. That is pretty common, but I put in a little red plastic like the plastic you find on a fishing bobber. I do this to give it a little color so you can see that you have completely covered the area needed.

The way that I apply it is kind of unique. I place this concoction in an old Elmer's School Glue bottle; that way I can squeeze out just the right amount where I exactly want it and very little fumes are being released into the air. MR

AVOIDING SERIOUS ACCIDENTS

by Lloyd Scott Oglesby

I was about 10 years old when I began working in my parent's garage and in a few years my rockets were making 3,000 feet. In high school our science-oriented group had several competing pyros having great fun and finding much to be explored, and at last giving us fast enough rockets, large enough explosions, bright enough lights, and the pretty colors. Life was grand.

Then the explosion occurred that changed my life; the months in the hospital, the summers of plastic surgery, and from then on being treated as a cripple in society. Always remember, the larger and more serious the accident, the worse and more enduring will be the results. Store your material in several places, never all together. Don't use strong containers. Keep as much distance as possible between you and your materials. Store things out of reach; remote storage is better. Remote grinding and mixing are excellent safety measures, and don't forget to limit quantities. Separate your work area from your storage area. At least once a week, perhaps as you clean up, ask yourself about your storage. Too many of us create the Too-Much-Stuff-In-One-Place monster. I need all my friends in good shape! LSO

FLYING-FISH VISCO SHELL

By Wayt Gibbs

Recently a new item called "fish-visco" or flying fish came on the pyro market, and was available for a short time at Kellners. It is available, if not sold out, from Skylighter. This item looks like thin green, red or silver visco, and comes in various colors in a bundle of about 100 strands where each strand is six feet long. I bought a bundle of some silver, and noticed that the diameter of the bundles was just under 1 1/2".

Several years ago I was enraptured with film cannister shells, as I can shoot them here in the city without attracting much attention. Consequently, I have a bunch of 1 1/2" i.d. PVC mortars, the kind that you load with your lift charge, add a film cannister shell, and fire from a piece of visco stuck in a hole in the bottom. These seemed good for shooting flying fish shells.

The trick in using the fish-visco properly is getting it into the air, lit and dispersed properly, without working your tail off.

I made a flying fish shell this way: I take the whole bundle and wrap a six-foot long piece of Kraft paper (I use 30#) around it. A 9 1/2" wide piece goes around twice. The long edge is glued so the bundle is tightly wrapped all around the bundle. Next, I mark off 1 1/2" from the end and using some stout twine or waxed linen string, tie the bundles between the marks. This keeps the short bundles, obtained in the next step, from falling apart.

Now, with a sharp, non-serrated knife, I cut the bundles on the marks into as many as needed, then cut the bottom 1/8" off a SOLO drink cup, (which has a 1.4" diameter,) and hot glue it to a film lid, broad side up. A hole is punched in the combined cup/lid and a short piece of light blackmatch is strung through it. I use a double piece of the gray match that comes off the Happy Bees candles, but any thin blackmatch will work.

Finally, I sprinkle a couple grams of 3Fg into the cup of the fused cup/lid and tape the short bundle of fish into it. This fits perfectly into the mortar. I put 15 grams 2FA in the mortar, fuse it, then drop the fish bundle in. Then it's just Light and Get Away!

The 2Fa blows the cannister, lights the fuse, fires the FFFg and lights the fish visco on both ends all at once. Spectacular. To enhance the affect, I wired three of these mortars together to fire three bundles of fish simultaneously. The effect is awesome. WG

HOT MELT GLUE

By John J. Vico, MD

Hot melt and glue guns can be used effectively and safely for certain pyro applications. Hot-melt gluing end discs to a loaded salute is not on my list. Nor is attaching rocket sticks, although many do this proficiently. Whenever hot melt is substituted for traditional construction it is important to consider: will it serve the same function as well or better, and will the associated heat cause any potential problem? Better yet, when the associated heat ignites something unexpectedly, will it be a limited event?

The best use I know for hot melt is sealing around time fuses in plastic or on cardboard end discs prior to shell assembly. A nice bead of glue inside and out can be accomplished. Together with a good pasting job this further assures against a gas leak and premature ignition at lift. The same can be accomplished with wood glue but it takes longer to dry. JJV

SUBSTITUTE FOR HEXACHLOROBENZENE

by Harry Gilliam, Skylighter, Inc.

Hexachlorobenzene, a chlorine donor, was an ingredient in many older formulas. Its production was banned some years ago, so it has pretty much disappeared. While other chlorine donors (saran, pvc, parlon, etc.) may be substituted in some proportion for hexachlorobenzene, dechlor-ane can be used in many formulas as a 1:1 substitute. We certainly cannot vouch for the efficacy of dechlorane in any formula, but you may want to try it. Keep in mind that it is toxic, so follow the directions on the MSDS. HG

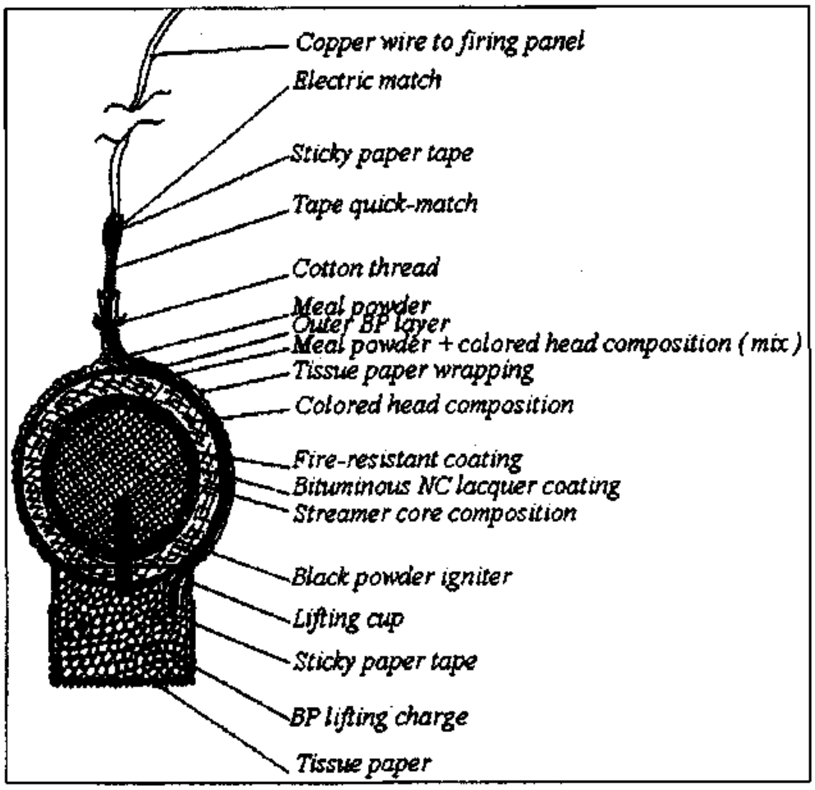
2" ROUND CRIMSON METEORS WITH GOLDEN STREAMER TAILS

By Serguei Postoliako

Introduction

The idea for these devices came to me several years ago after I saw similar interesting effects during a good display.

I was very impressed by the beautiful big round colored stars which were leaving dense glitter tails behind. At that time I had no access to any information about the world of fireworks, modern construction, pyrotechnic compositions and so forth. I had no opportunity to obtain the chemicals which were necessary to make the many fireworks devices. I had only some little fragments of pyrotechnic information from the Internet. Therefore, I decided to make my own version of those devices using those materials I did have.



Assuredly, a lot of what I am about to describe will be absolutely apparent to most pyros, so I want to apologize beforehand. I will describe only my own method which was successful enough for me, taking into consideration some corrections which I was able to make to the present time, having gotten some wonderful books on fireworks from my American friends.

I will be describing my process using those materials and chemicals which I had to use, not being able to get access to something more modern. Therefore, I won't give exact recommendations concerning amount of mixtures, types of chemicals and sieves, and any other special information because it would be little different from generally accepted techniques; someone will be able to make the necessary corrections and changes and produce any desired number of devices, as well as use more suitable chemicals, tools and materials, guided by his own intentions and possibilities. However, I would advised making a considerable amount of all compositions, since some stages of the process will require time for proper manipulation. It would be reasonable to make at least 10 meteors at one time.

Furthermore, I describe here only an example of a device which had been used by me with success. Undoubtedly, someone can try the other colored and streamer compositions in different combinations. I suppose that using strobe, glitter, flitter, firefly, crackling and other formulae, as well as colored mixtures based on metal fuels and other modern compositions, will give an opportunity to obtain a big variety of very impressive effects. Unfortunately, I had to limit myself to the very simple version of these devices. It is likely that this method will be somewhat laborious and time consuming, but someone can correct it, improving some or the procedure by using more modern and professional tools, as well as chemicals.

Chemicals, Materials And Tools

Potassium nitrate
Potassium perchlorate
Strontium nitrate (anhydride)
Sulfur
Charcoal
Shellac
Modified soluble starch
Calcium carbonate (precipitated chalk)
Zinc oxide
Sodium silicate (water-glass)
Ethyl alcohol (absolute)
Bituminous NC lacquer
Black powder (small grains)
Meal black powder
Quick tape match (ref. Dan Williams [4])
Thin copper wire (0.5-0.7mm in diameter)
Cotton thread
Kraft-paper (medium density)
Poly Vinyl Acetate glue (PVA)
Sticky paper tape
Tissue paper
Glass tumblers (250 and 500ml)
Drill (5 mm in diameter)
Spray with alcohol/water solution (70/30)
Spray for shellac/alcohol solution
Thin polyethylene film
Aluminum former (30mm in diameter and length at least 100mm)
Stainless steel bowl with flat or inclined bottom
Aluminum or tin jar with pierced lid (with holes approximately 1.0-2. Oram)
Plastic lid fitting to internal diameter of big 500ml glass tumbler
Plastic palette-knife
Glass stick

Compositions

Formula # 1. ***Meteor Core Composition.***

Potassium nitrate	35
Sulfur	12
Charcoal	45
Soluble starch	8

(ref. "Willow Star", Takeo Shimlzu, p.221[1])

Formula #2. ***Core Coating Composition.***

Calcium carbonate (precipitated chalk)	2
Zinc oxide	2
Sodium silicate (waterglass)	1-1.5

(ref. "Professional Pyrotechnic Adhesive", Ralph Degn, p.114[3])

Formula #3. ***Meteor Head Composition.***

Potassium perchlorate	57
Shellac	14
Strontium nitrate	29
Charcoal	(+2)

(ref. "Crimson Pill-Box Star", Ronald Lancaster, p.213 [2])

The meteor core composition is one of the most beautiful types of Japanese chrysanthemum stars and gives an amazing long-burning golden-orange tail of pretty sparks, if carefully prepared, (ref. Shimizu, pp.67-68 [1]; pp.355-356 [2]; Bill Ofca, p. 110 [6]; David Bleser, pp.72-73, 82-83, 150-151 [5])

This meteor head composition has been used because of several advantages - it burns long enough and has good adhesion to the core's surface. However, this mixture burns with difficulty, therefore a small amount of charcoal has been added for improvement of the burning characteristics, (ref. Takeo Shimizu, pp.347-348 [2])

When the meteor is moving through the air, both of these compositions are burning simultaneously, but separately from each other, creating the head of colored flame, like a big round star, and beautiful streamer tail of charcoal sparks behind the head. It looks very nice and if a large number of meteors is being used, it creates very impressive picture in the night sky.

Making Of Meteors

In the beginning it is necessary to prepare pyrotechnic and auxiliary compositions, as well as some additional jigs and fixtures which will be used during the main process of making and the final assembly.

Matrix and additional appliances

- Cut several pieces of thin copper wire with diameter of 0.5-0.7mm and approximately 150mm length each. The amount of these pieces depends on how many meteor cores are to be made.
- Bend pieces of wire at both ends, so as to obtain small rounded hooks. These pieces will be used for making the meteor cores.
- For making the matrix from any convenient source, take a rigid hollow plastic ball (for instance, small plastic shell casings) with an internal diameter 30mm, which consists

of two separate hemispheres. If not, cut the entire hollow ball exactly on the equator to obtain two identical hemispheres.

• Join both these hemispheres together. If the ball doesn't have the mating lip like in the shell casings, then carefully fit the edges together and glue up the seam around the equator with Scotch tape, to avoid any further slips.

• Heat a little nail 1.0-1.5mm in diameter and holding it in pliers, pierce a hole in any place in the middle of joining seam. This hole is necessary for placing the wire on which the meteor will be fastened.

• Remove Scotch-tape from the ball, if you had used it before. The matrix will be used for giving an even spherical shape to the cores of the meteors, and for removing unevenness during of forming.

Streamer meteor core composition

• Weigh out the necessary amount of sulfur, charcoal and soluble starch, using formula #1.1 have used a birch charcoal, since it doesn't burn too quickly and gives good long-burning sparks. Grind the chemicals in the ball mill at least 22 - 24 hours.

• Weigh out the necessary amount of potassium nitrate and ball mill it separately for 7 - 8 hours.

• Mix the two lots and then wearing a dust mask and goggles, sieve through the fine sieve about 10 times.

• Put well mixed composition into container and begin to sprinkle it gradually with water/alcohol solution (70/30). Spray from sufficient distance in order that the mixture will be dampened with only tiny drops of solution and mix the composition from time to time, controlling the degree of dampening and being careful not to exceed the necessary level. You want a composition with the consistency of very dense dough. It should break in big pieces but not crumble and stick together. Don't over-wet the mix.

• Put the dampened composition into any glass or tin container (big glass tumbler will be just about right), press it downwards, then place onto the surface of the comp a piece of polyethylene film and on top of it. a plastic lid with diameter a little less than internal diameter of container. Finally place a weight on top of the lid. Be careful to not press too strongly. The mix should be carefully pressed to the bottom and completely isolated from the open air to prevent its drying up. Leave the mix 1 1/2 - 2 hours in this condition. This will allow the potassium nitrate to properly impregnate the charcoal particles.

• At the end of the conditioning period, carefully mix the composition once again and press it through the fine sieve with aid of wide plastic palette-knife, scattering the little grains in a thin and uniform layer onto the surface of big sheet of heavy paper. Allow to completely dry in the shade for 2 - 3 days.

• When well dried grind the grains very thoroughly in the ball mill with lead balls for 3 - 4 hours. Needless to say, it should be done at the proper distance from dwelling houses, and make sure that nobody goes near the mill during this time. Be very careful with this operation! Store the prepared mix into a closed container.

Although this procedure is very labor-intensive, it is necessary in order to obtain the best results, namely the dense and uniform tail of tiniest and very beautiful golden-orange charcoal sparks.

Colored meteor head composition

• Using formula #3, mix the carefully ground potassium perchlorate, charcoal, strontium nitrate (preferable anhydride, if possible) and shellac, having sifted all chemicals through a fine sieve about 10 times. It is necessary to obtain a very homogeneous mixture, therefore it is desirable to use as finely ground chemicals as possible, especially the shellac. Put the mixture into the separate closed container.

• Prepare the necessary amount of 5% shellac/alcohol solution. It is optimum to use an absolute ethyl alcohol (if possible), because admixture of water is undesirable in compositions containing strontium nitrate. Pour the prepared solution into the small bottle with sprayer.

Core coating fire-resistant composition

• Using formula #2, weigh out the necessary amounts of chemicals and mix them very carefully, after having sifted them through the fine sieve. Mix and sift calcium carbonate (precipitated chalk) and zinc oxide together about 10 times through the same fine sieve as above. Put prepared mixture into the closed container.

Lift cups

• Cut a sheet of 30 # Kraft paper into strips 25mm wide and 500mm long. The number of strips will depend on how many of meteors you plan to make.

• Lay the strips in a row on a flat, even surface and smear thoroughly with a sponge moistened in PVA glue diluted to the consistence like sour cream. Roll out the strips onto the aluminum former. Allow to dry completely within 2 - 3 days. It is possible to roll out the entire sheet of Kraft paper (length 500 mm and the necessary width), and after complete drying to cut it with sharp knife into pieces 25mm wide. The prepared lift cups will be used in the following operations, at the final stage of assembling of meteors.

At this stage all preparatory operations have been completed and it is possible to begin making of meteors.

Making of meteor streamer cores

• Put meteor core mix into a container, spray it gently with water/alcohol solution (70/30) with aid of spray-bottle. You want a very dense, thick dough which will be pliant and not too sticky, about the consistency of modeling clay. It should not stick to the fingers or crumble in pieces. Alternate between thorough mixing and spraying. It is very important not to over-wet the mixture, or it will be very difficult to work with.

• Place both hemispheres of the matrix in suitable depressions in your workbench, opened sides upwards of course. Cover the hemispheres with pieces of thin polyethylene film and slightly press the film inwards with finger.

• Fill in both hemispheres with dampened mixture, pressing it with your fingers until both hemispheres are completely filled. Don't press the upper layers of mixture too hard; they should slightly go beyond over the edges of hemispheres, like in little heaps.

• Now, take one of the little copper wire hooks and place it onto one of the hemispheres, and press it into the mass.

• Join both hemispheres together thoroughly and press them tightly together, squeezing out the excess of the mass through the connecting joint. The trough of the second hemisphere should lay exactly over the first one onto the wire hook.

• Fold back the edges of polyethylene film and remove the excess with a knife.

• With a twisting motion and the aid of a sharp knife, remove the hemis, trying not to deform the obtained meteor core.

• Holding the wire of a core in one hand, remove the pieces of film with other hand. They should come off easily enough, if the mass had not been over-wetted.

• Hang prepared core with wire hook in the shade, in any convenient dry place. Hang all prepared meteor cores in one place and allow them to dry completely and very carefully for 12 - 14 days.

Coating the cores with fire-resistant composition

• To prevention of penetration of any traces of water from the fire-resistant composition inside the meteor cores, it is necessary to coat them with water-proofing composition. I have used bituminous NC lacquer for this purpose. Take one of well dried prepared cores and holding it by the wire hook, submerge it into a jar or little glass tumbler (250ml) of NC lacquer, so as it has been completely submerged. Hold the core in this position for approximately 15-20 seconds.

• Remove the core and clear off the surplus NC lacquer from the bottom of core's surface with the aid of thin glass or wooden stick,. Check that the lacquered core doesn't have any voids; if any arefound, submerge the core once again for 2-3 seconds.

• Powder the surface of wet lacquer core with a mix of fire-resistant composition (calcium carbonate + zinc oxide). This also makes a slight unevenness to the surface of the core and aids in applying of layer of fire-resistance composition.

- Hang prepared coated core in the shade and let it dry for one day. Repeat these operations for all remained cores.

- Pour the necessary amount of fire-resistant core coating composition into the big glass tumbler (500ml) and adding sodium silicate (water-glass) in little portions and constantly mixing with a glass rod; make it to the consistency of sour cream. If necessary, add more dry mixture. During submerging and subsequent extracting of a thin glass rod into and from prepared composition, it should flow down very slowly, beading on the end of the stick.

- Take the well dried core (coated with NC lacquer) and holding it by the wire hook, submerge it completely into the tumbler with fire-resistant core coating composition, so it is completely covered with mass. Then, turn the core clockwise and inversely several times, extract it from the mix, while thoroughly and slowly removing the beads of surplus of the mass with the aid of a glass rod. The composition should not flow down on the surface of the core and accumulate at the bottom, therefore don't make it very fluid. One coating should be enough, otherwise repeat it again, but more quickly; the final thickness of the fire-resistant layer should be approximately 2.5 - 3.0mm. Otherwise the core will be heavy.

- Hang all prepared coated cores for drying. Allow them to harden and dry for 1 - 2 days.

- After complete drying of the core coating composition, spray all cores with 5% solution of shellac in alcohol, so that their surfaces have been well and carefully covered with a thin layer of shellac. Allow to dry for 1 day and then the cores will be ready for applying the colored meteor head comp.

Applying of colored meteor head comp.

- The wire hooks are no longer needed so cut them off flush with the surface, and smooth the nub with a fine file.

- Take several meteor coated cores, for instance 10 pieces, and place them into the stainless steel or aluminum bowl with flat or somewhat inclined bottom, and then begin to rotate the bowl, holding it at one hand. Sprinkle the cores with 5% solution of shellac in alcohol several times, not stopping the bowl's rotation and roll them for one or two minutes, so as they are well impregnated and covered uniformly with shellac solution.

- Now, without stopping the bowl's rotation, gradually sprinkle the cores with colored head composition from a container with pierced lid . Allow the composition to stick to the cores. If excess composition sticks to the bottom of the bowl, spray it directly and continue rolling.

- Spray the meteors with shellac solution, allow them to rotate a little time, sprinkle thoroughly with the next portion of composition, allow to rotate, and so forth, alternately. Continue until the diameter of every meteor reaches 43mm.

- Continuing rotation of the meteors in the bowl, sprinkle them with the meteor head composition and meal powder in ratio (50/50) and gradually increase their diameter to 45 mm. This is necessary to improve ignition. Sprinkling should be with a solution of shellac in alcohol.

- Dry in the shade for 5 - 6 days, or a little longer if needed to ensure complete drying.

- To take fire more efficiently and quicker on the entire surface, the meteors should be covered with a final layer of meal powder without shellac. Put all dried meteors into the bowl and begin to rotate them slowly, sprinkle with alcohol and gradually sprinkle with meal powder with the addition of 2 - 3% of red gum. Apply the last ignition layer of meal powder and increase the final diameter of device to 46 mm. (I have used the home-made mortar with inside diameter 50 mm. If your mortar's dimensions will be different, correct the meteor's diameter accordingly.)

- Finally, the finished meteors should be well dried in the shade for 1 day. After that is the final assembly and firing.

Final assembly of meteors

- Doing it very carefully and slowly, with the meteor held down tightly, drill a blind hole inward to reach the core of the meteor. To obtain an even and uniform flow of sparks from the streamer composition, the hole must be drilled exactly perpendicular. The depth of penetration into the streamer core should be not less 8-10mm.

- Fill in the hole with meal powder and carefully and tightly press with aid of an aluminum or wooden stick.

- Cut five pieces of tissue paper 50mm in diameter and lay them onto each other. Take these sheets and lay them onto the lift cup at the center, then having bent their edges downwards, take it in one hand, holding the edges of paper to prevent their unfolding and fasten them tightly around the edge of lift cup with sticky paper tape. The edges of tissue paper should be well fastened and pressed to the surface of the cup.

- Cut a piece of tape match 200 - 250mm long and paste one end of it to the internal surface of the cup with a little piece of sticky tape. The open end of tape match should be approximately 5 - 7mm from the bottom of the cup (where the tissue paper is located).

- Fill in the entire cup with little grains of black powder (1.0 -1.5mm) and press a little with your finger, so as to reduce the level of grains a little lower than the upper edge of cup. Try to place the meteor onto the cup; it should lay on the edge evenly and the lift charge should be a little lower, so as not to prevent the meteor from laying on the cup's edge completely. If not, pour out a few grains of lift charge and press with meteor again, so that the lift charge has been slightly flattened and the meteor can lay onto it without resistance.

- Place the cup, filled with lift charge onto the workbench and hold it with one hand. Take the meteor in your other hand and lay it onto the cup, pressing it downwards slightly, so make a tight joint. The tape match should be bent aside beforehand. The meteor should be placed onto the cup strictly perpendicular, with its hole directed downwards. Make sure it is straight.

- Holding the meteor and the lift cup in one hand and pressing them tightly with other hand, lay the tape match onto the meteor's surface from the cup upwards and paste with a little piece of sticky paper tape. Then, holding the device in the above-mentioned position, fasten the meteor to the cup with several turns of cotton thread, winding them around, through the top of meteor and the bottom of the lift cup, trying not to displace the initial position of the parts. Fasten it tightly and wind several turns around the cup finally, to press all threads to its surface.

- Now, make a little cut on the tape match with scissors, very carefully, to reach the black powder core inside.

- Cut a strip of the tissue paper 100mm wide and 200mm long. Wrap two turns around the meteor and fasten its lower end to the lift cup tightly with sticky paper tape. Then sprinkle the meteor inside this bag with meal powder and press the tissue paper towards the meteor's surface, gradually, pressing and sprinkling. At the upper part of tissue paper covering, pour a small amount of meal powder onto the cut end of tape match and around it, and having wrapped up the excess of tissue paper around the tape match, tighten it with cotton thread in several turns, and finally cut excess of tissue.

- Insert an electric match into the open end of the tape match, and fasten it with sticky paper tape. Now the meteor is completely ready for firing. (See illustration).

Firing of meteors

The meteors are best fired at an angle of 45° to 60°. Best results can be obtained with a group of meteors fired either simultaneously or one after the other with very brief delay between shots. Shooters can use any combination of quantity and shooting technique, depending on their intentions and possibilities. I hope readers will find this device interesting, and hopefully useful, but most likely something similar to my description is already known for most more experienced pyros. Anyway, thanks for everyone who found time to read my article. SP

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THE MYSTERY BEHIND AWESOME SHELL BREAKS

By Bill Ofca

Years ago when I received a catalog from Ruggieri Fireworks Co. of France, I took particular interest in a side view drawing of their spoulette that they use for plastic cylinder shells (see fig. 1). It's no secret that they

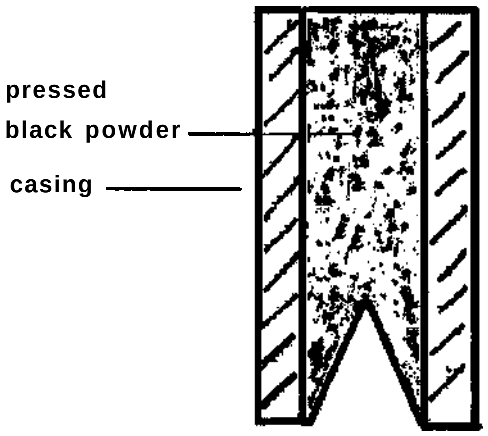


Fig.1

Ruggieri Spoulette

manufacture plastic cylinder shells that have particularly beautiful and awesome breaks. Anyone who has tried to make plastic cylinder shell knows how difficult it is to get a good break pattern, and that they usually blow out one or both ends resulting in a weak "bow tie" shaped spray of stars. My own feeble attempts at making plastic cylinder shells demonstrated also that many of the stars blow out the end "blind" or unlit. The mystery of Ruggieri's burst and ignition success became apparent after careful thought about how they machine manufactured their spoulette timer fuse.

Around the same time of my inquisitive observations, a friend was making 4" and 5" "stringless" Kraft paper cylinder shells that had rather beautiful full burst patterns. I visited him to observe how he made these shells. He assembled these shells with rolled paper casings. A gray solid cardboard disk was placed against the end of the wooden case roller and the first rolled layer of Kraft paper was glued against the disk by dabbing it with a stiff cylinder shaped bristle brush soaked in white glue. He then inserted a second disk and glued down the remaining turns of paper against this one, and retracted the case roller. After the shell bottom was dried, he filled the case with stars around a 3/4" ID copper tube that had a funnel at the top end. The copper tube was filled with a central burst of FFA black powder. The stars were packed tight with pulverone (granulated homemade black powder) filling the spaces between the stars, and the copper tube was extracted leaving behind the central burst powder of FFA. Again, the top of the casing was closed using the same method as the bottom, except he used a 3/8" OD timer fuse. The shell was pasted in with 70# Kraft paper, no string spiking. So far, everything seemed normal in the conventional Italian style assembly, except no string spiking and a peculiar way of transferring fire at the inside end of the 3/8" OD timer fuse. Imagine what a spectacular burst if spiking with twine were also used in his method!

He would split the end of the timer fuse, pack it full of a commercial Meal D slurry, dip this into a cup of 5FA commercial powder, and when dry, dip it in nitrocellulose lacquer for a heavy coating. This too, had to be the answer to the mystery of awesome breaks with a stringless paper cylinder shell.

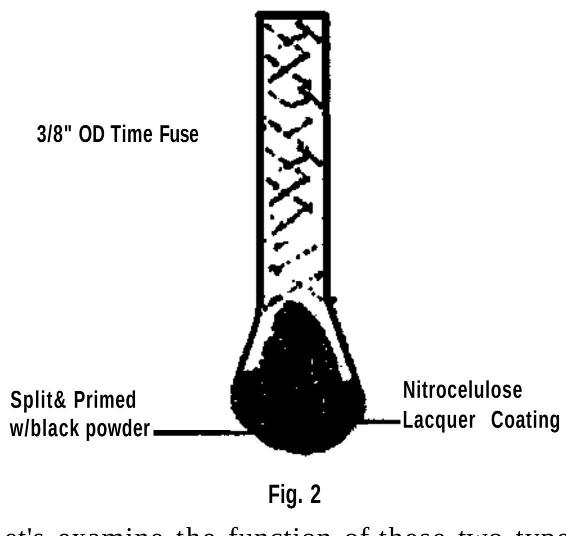


Fig. 2

Let's examine the function of these two types of timer fuses.

Both the Ruggieri method and my friend's method had two things in common: both methods delivered a sudden fast and powerful ignition flame to the central burst charge of black powder. This assures much of the burst powder grains will ignite simultaneously right out of the gate. With most of the central burst powder suddenly ignited, pressure in the shell and gas flame spread suddenly, rapidly, and evenly throughout the shell. The result is better and more complete star ignition, as well as fuller more symmetrical large burst patterns.

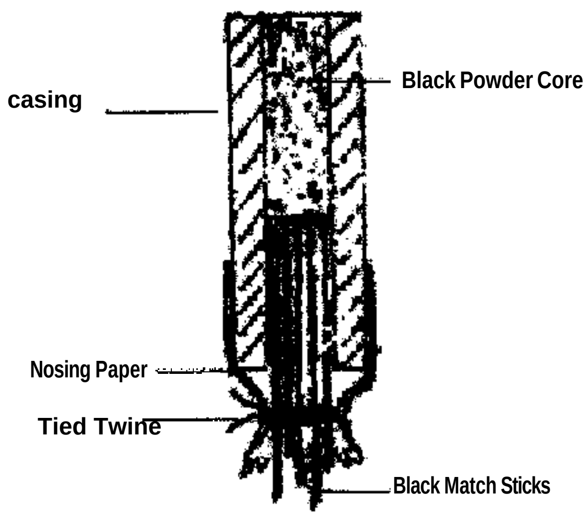
With "soft" ignitions of the burst powder that many pyros use via the common method of cross matching Japanese 1/4" OD timer fuse, the burst ignition is progressive burning from the starting end just under the canister end disk. This produces a "roman candle" effect out one end of the shell casing, or a "bow tie" effect if both ends blow out. In addition, not all the stars ignite before the pressure is sufficient to blow the end of the casing open. In addition, a good break pattern is achieved if the shell is still accelerating upward when the burst occurs. The upward thrust of the shell helps to give a wider spread to the burning stars.

A closer examination of the two types of timer fuses discussed here reveals the mechanism of their sudden delivery of a high energy flame to the burst charges. In the Ruggieri method, a cone shaped cavity is formed in the flame exit end of the spoulette when the fuse is pressed. The timer fuse burns progressively towards the point of the cone. When the flame breaks through the point of the cone, the remaining cone of powder behaves much like a rocket nozzle suddenly jetting the flame at supersonic speed into the burst powder core of the shell.

In the second method using the 3/8" OD timer fuse, the split end that was filled with a blob of commercial Meal D slurry, dipped in 5FA powder, then dried and heavily coated with nitrocellulose lacquer. The lacquer provides confinement, and thus provides a small explosion of sudden flame into the central core of FFA burst powder.

On a final note, I am reminded of the conventional method of constructing a typical Italian spoulette fuse. About half to two-thirds of the spoulette casing is rammed with screened Meal D or the finer fuse grade of commercial black powder. The starting end of this fuse has the rammed powder core flush with the end of the casing, while the internal shell burn through end has an empty cavity one-third to one-half the length of the casing. Rolling a Kraft paper "nosing" that hangs off the end of the casing finishes the cavity end. Several sticks of thin black match are then inserted all the way into the cavity until they touch the burn through end of the black powder core. About a half-inch of the black

Italian Style Spoulette



match sticks hang out past the nosing paper that is gathered and tied around the black match sticks. When the fuse burns through to ignite the black match, the parallel sticks of match behave much like quick match. The confinement of the nosing paper makes it explode. This method also produces a strong jet of flame directed toward the central burst powder of the shell, thus explaining the mystery of exceptionally beautiful and full burst patterns of these shells. WO

DETERMINING POSITIONS FOR ANGLE FIRING

by Larry Mattingly
Entertainment Fireworks, Inc.

Firing cakes, comets and mines at angles, Xs and Vs is becoming popular. The question frequently asked is, how do you decide upon the angle to place fireworks? There are many possibilities. Here are some general suggestions:

A) Measure the angles from straight up (90°).

B) All angles on all items should be the same. The exception is if you are using 2 or 3 different sizes of devices for multi-layer effects. If you do that, all like items in a layer should be the same angle. They can be angled in toward or out away from, the center of the front.

C) The smaller the item or shorter the distance of travel, the shallower the angle, and the less distance in spacing between items on the ground.

D) For symmetry, set all angles to within 1° with an "angle finder" tool.**

E) Spread the items out across the front as much as the size of the item and the distances in the venue will allow. Measure distances with a tape so the spacing is dead even.

F) Items can be set to fire in a "V" an "X" straight up or in combinations of patterns.

G) Repeat the patterns as much as you have room for or the budget allows.

H) If the firing system is capable, you can fire the items from one side to the other in a succession of angles so as to cause a "wave-like" effect.

I) Or, you can fire from the middle out, or in a "trainwreck" beginning from both sides and progressing to the middle. This can be done with items set at angles or straight up.

J) When using multi-layered angled effects, combinations of two or more patterns of the above can be really spectacular, i.e., large Roman candles straight up, with comets in "W" or "V" patterns behind. Or, small 10-ball candles with large crossette candles backed by the comets.

K) Likewise, firing different effects one after another rapid fire, or in opposing patterns and colors, can be very attractive, i.e. 1 1/2" or 2" comets in colors like red fired out, white fired in or green fired in X and purple fired in straight. Another might be six blue fired angled to the left then six gold fired angled to the right.

When setting up a cake or larger multi-shot device at angles, be sure to support the entire bottom of the device. Failure to evenly support the device can cause "blowouts" on the bottom. It may also be a good idea to stake and tie them if they are at much of an angle or they may slide downslope.

For stability, support the larger Roman candles firmly at two points along their length, to keep the angle from "wandering".

CAUTION: Pyrotechnic items set at an angle may throw burning material further then straight up. Be sure the direction of the angle does not endanger the spectators.

Other then normal safety precautions, the biggest limit you will have in these effects will be your own imagination.

Put some together and give it a try. It can be very entertaining.

** An "angle finder" tool is available at most hardware stores at from $4 to $10. It has a round face and the frame has 2 flat sides at 90 degrees. There is a "floating" needle that registers the angle. You set one of the flat sides on the item and read the angle the needle is pointing at. The better tools at around $8 to $10 have a steadier needle that doesn't float around so much and is easier to read. This tool should be in all display pyro operator's tool box. JLM

CLOSING ODDLY-FILLED SHELLS

By Lloyd E. Sponenburgh

Ever since my first one, I've enjoyed building round shells. I built my first in 1995, after over thirty years of fireworks making. I'd always only built simple canister shells. I learned my first shell construction details from a Popular Science article about the Grucci family, in 1964.

In 1995, I bought a copy of Dave Bleser's Round Stars and Shells, and my pyrotechnic life changed. *Here* was a method to build shells that was easy, fast, and very beautiful! Once I had standardized a few variables like burst and star diameter vs. shell size, it was both easy and a joy to assemble round shells. They were reliable, went together fast, and performed well. Unlike canister shells - especially multi-break Italian-style shells, the ball shells took little work and no special apparatus like spiking horses and long, wide work tables for pasting. A few strips of paper, a bit of paste, and away you go!

The "few strips of paper and paste" makes it sound too simple — saying it that way disguises a few problems. One of the difficult things about building round shells is marrying the two halves cleanly and easily without spilling contents.

Now, 'closing' is pretty simple with ordinary, small chrysanthemums, fully filled with stars. You paste a thin scrim over one or both halves, and bring them together. It involves merely pasting light paper over a hemisphere, using it to retain the contents of that half while you turn it upside-down over the other half. That method works well for small shells with light contents. Heavier contents may tend to bulge the retaining paper and shift as the hemisphere is inverted.

When the contents of a carefully-assembled peony shifts, the technician shouts, throws loose objects at walls (and the cat), and disassembles the hemisphere to re-build it (again!). To combat this possibility, builders often use the 'card' method for mating peony halves.

The card method uses a sheet of pasteboard or wood to strongly contain the contents of a hemisphere, so the contents can't shift or loosen. It requires only a thin, stiff sheet of material that is held tight to the hemisphere while it is inverted and mated to the other. After mating, the 'card' is gently withdrawn from between the shell halves to finish the joining of the pair. This method works very well for uniformly-filled shells that are perfectly symmetrical about the equator. Neither card nor scrim method works well for shells with things protruding past the equator. There are ways to build and glue into place a perforated chipboard separator that stays between the hemispheres after the shell is built. But I sought an *easy way* to join oddly-filled shells.

What's an "oddly-filled shell"? Well, to be honest, I'd never seen one until 2003: In September of 2003, my friend Renaldo Lama came to the shop to build his second annual competition entry for the Florida Pyrotechnic Arts Guild Fall Festival. The last year, he'd built a 'novice' 4" shell (and won). In 2003, he had higher aspirations. He intended to build 8" crossette shells for the competition!

Of course I warned him about how much work it would be, and how difficult - but he persisted. And worse, he kept complicating the matter by adding effects he wanted to produce. It had to have a pistle - OK. It had to have rising effects - OK. It had to have a bottom shot - Ohh... A what? A bottom shot in a round shell? A WHAT?

A bottom shot in a round shell would be a special problem if you wanted it to work right. It would have to be precisely centered in the shell to preserve the symmetry of the burst. It would need burst *around it*, rather than in the center of the shell. And (this is the big 'and') it wouldn't fit in one or the other hemisphere. It would occupy space in *both* halves of the shell! Parts protruding past the equator make for an oddly-filled shell.

His having the salute extend into both halves during assembly made me lose sleep for a few nights. How the heck were we going to assemble that thing? The scrim wouldn't work - the paper would hold the salute in place, but would allow the crossettes, pistle, and burst to fall out. The same story with the card method! We could paste in a separator, but that's not easy, and it usually shows a 'waist' when the shell breaks. In fact, Renaldo wanted to stagger the crossettes at the equator so there would be no waist. That made the idea of a separator seem not so good.

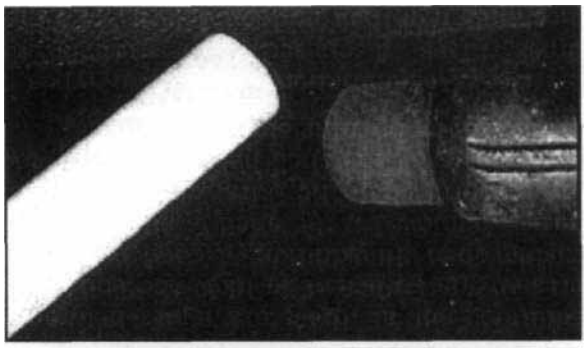
While Renaldo pressed crossettes, rolled stars, and built his 3" bottom shot, I puzzled over the problem. How could we cleanly and easily retain crossettes, burst, stars, and a hugely-protruding salute in one half of the shell while lowering it onto the other half? The idea that finally worked came from my old R/C airplane hobby.

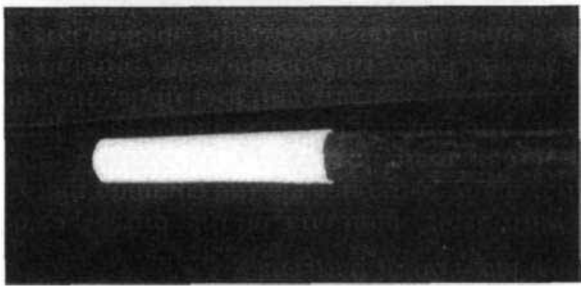
To hold oddly-shaped material together when gluing wings for models, I used *The Vacuum Bag Method.* I used it to laminate balsa wood skins to foam wings; especially 'under-cambered' wings, or wings with a hollowed-out area on the bottom surface. Vacuum-bagging involves constructing an object with glue, then surrounding it with a plastic bag, and drawing a vacuum in the bag. Atmospheric pressure provides the force to hold everything tightly together. Unlike mechanical clamping methods, vacuum-bagging provides perfectly uniform pressure across every square millimeter of surface - even around projections and in hollows!

If this method could work for under-cambered model airplane wings five feet long, it ought to work for assembling shells! I set out to build an apparatus. The first try worked like a charm.

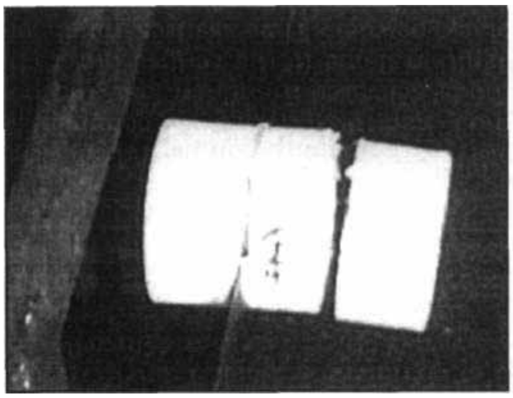
Pictures show the details. First, I built an adapter to allow a standard 1 1/4" (small) shop-vac hose to mate with my vacuum bagger. I cut a piece of thin-walled 1" PVC pipe to about eight inches long. The pipe should be long enough so that you can easily get a handful of pipe and vacuum bag.

I warmed the connecting end of the pipe with a hot air gun and pushed in the hose when the plastic was soft enough to conform. A torch would work, but be careful not to overheat the pipe. Also, be sure to twist the pipe/hose joint periodically as the pipe cools to prevent them from shrinking together tightly.



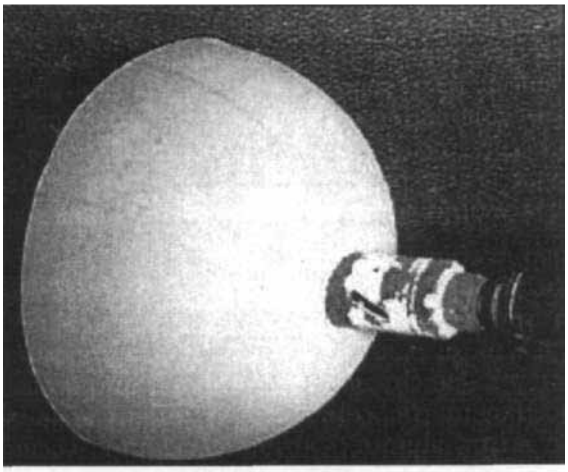


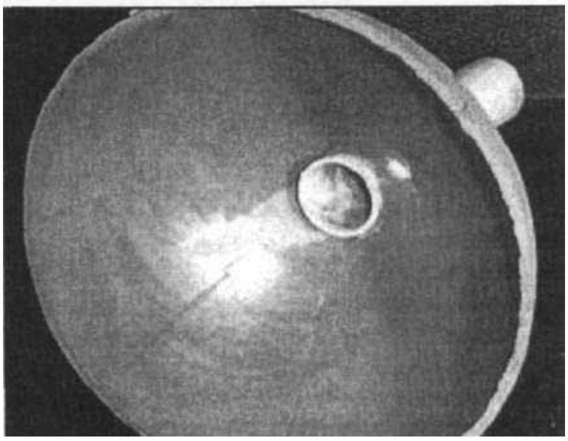
I cut a 3/8" slice off each end of a standard 1" 'slip' coupling. Now I had two couplings that would slide anywhere along the length of the adapter pipe. I glued one into position on the unformed end of the pipe, with about 1/2" of pipe extending past the coupling.



Renaldo was working with paper, so I cut a hole into the pole of an 8" paper hemisphere to accept the pipe (using a 1 1/4" hole saw, it's a tight fit).

With the pipe extending through the hole and into the cavity of the hemisphere, I glued the other piece of slip coupling onto the inner end of the pipe, and squeezed the two couplings together tightly to trap the paper hemisphere between them.

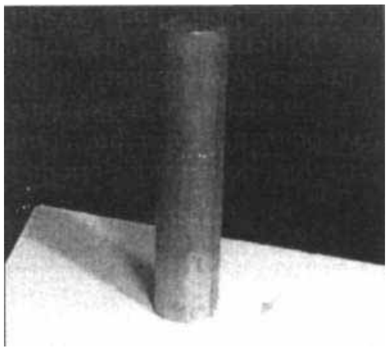




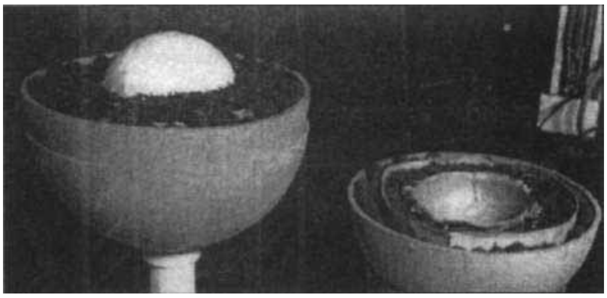
After the joints dried a while, I slathered more cement around the couplings and on the paper, both inside and outside the shell, and allowed it to dry.

The assembly was strong enough to withstand several pounds of torque and/or weight. Using the paper hemi, the clamp was complete. Paper shells work perfectly without any treatment, but plastic hemispheres are so precisely made that they'll seal at the line between clamp and work —and that line must leak. To fix this, rasp the mating edge of the clamp hemisphere. Make it only just rough enough to guarantee a poor seal. I also made a wooden base with a 1" dowel protruding vertically to convert the clamp into a work stand.

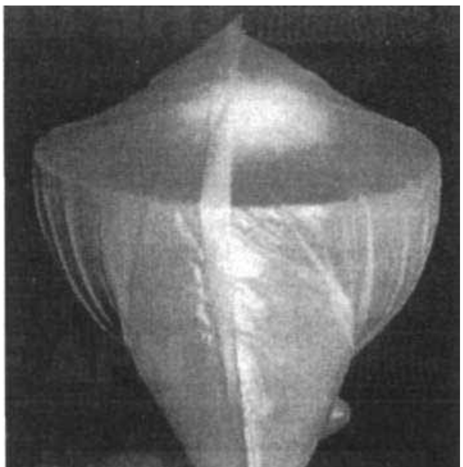
Using the vacuum clamp couldn't be easier. First, prepare the 'bottom' shell hemisphere (the time fuse half of the shell) on a cylindrical work stand. Make a thin paper 'receiver' for the salute to hold burst and stars out of that area.



Assemble the top half of the shell using the clamp as your work stand. Place the bottom shot in the middle of the shell in exactly the position you want it to remain.



Now the fun part - Cover the 'top' half with a very thin (read this as CHEAP) small kitchen trash bag. ("Ruffles" - only $1.00 for 45) Carefully center the bag over the top shell half, pulling it down around the shell until you can grab a handful of the plastic and twist it around the adapter pipe. Keep twisting until you begin to pull the plastic gently across the top of the shell; *not taut - leave it a bit loose so it will conform better.* Lift the clamp off the dowel, taking care to keep the

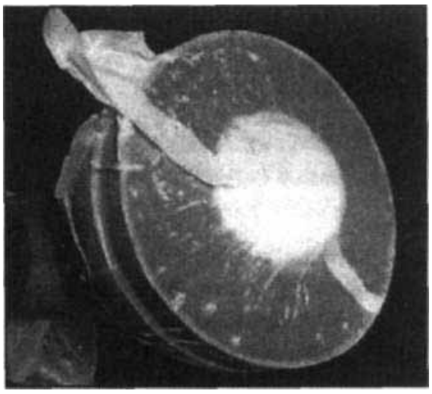


shell hemi upright and level. Plug the vacuum cleaner hose into the adapter, and turn on the vacuum.

As soon as the bag seals around the pipe, you'll see the plastic begin to suck in around the clamp and shell half, and begin to compress the shell's contents. Vacuum will leak at the line between the clamp hemi and the work hemi, sucking out the air in the plastic.

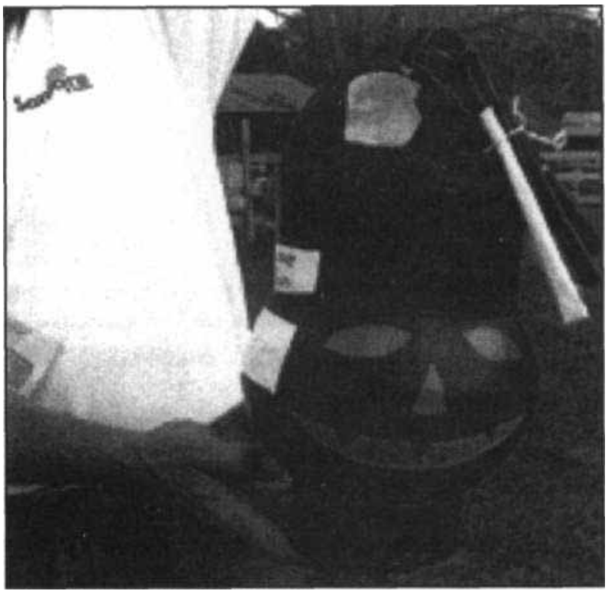
It compresses so strongly, you'll be amazed the first time you see it. Renaldo remarked, "It looks like Folger's vacuum-packed coffee!" And it did.

Every detail of the rice hulls, stars, and salute were faithfully telegraphed to the surface of the plastic. All that was left was to assemble the shell.



Maintaining the vacuum, invert the top half, and bring the parts together. Tighten, compress, and tape the joint as you would normally, cutting plastic sheeting away as necessary. The thin plastic will not interfere with fire passage between halves.

Build a clamping tool for each size shell you wish to build. Since they all have the same size adapter pipe, they'll all fit onto your dowel work stand. With an array of these, you can join any size oddly-filled shell with ease.



Renaldo built two 8" shells with bottom shots this way. The one pictured won first place in FPAG's Advanced Round Shell competition. I think this method might have other uses for clamping pyro assemblies. Enjoy! LS

TIP OF THE MONTH

POPCORN FOR CORES

I doubt that I'll ever build a 12-inch shell, but I'll bet popped popcorn would work very well as the core material for the burst charge of a 12-incher.

I would dampen the popcorn with a mist-spray bottle of water, and then sprinkle burst charge all over it. If the popcorn is too big, I'd use KP burst instead of black powder burst.

Popcorn is cheap, and that's good, but remember it has to be hot-air popped only.

Don Nelson

AERIAL SHELL BURST HEIGHT AS A FUNCTION OF MORTAR LENGTH

K. L. and B. J. Kosanke

[This article is augmented with a number of text notes, indicated using superscript letters. While it is hoped these provide useful information, they are not essential, and the reader may wish to ignore them unless further information is desired.]

From time to time over the years there has been discussion of the effect of mortar length on the burst height achieved by fireworks aerial shells. However, rarely has burst height versus mortar length data been presented, [12] even then the data has been of limited value. In one case, the results were predictions using a ballistics model where only the maximum possible height reached by aerial shells was presented, not the measured height at the time of their actual burst.[a] In the other case, only one shell was fired for each mortar length, and the method of determining the height of the shell burst was rather imprecise. The study being reported in this article is more useful in that actual burst heights were reasonably accurately measured and there were several firings from each mortar length. Unfortunately, this study only examined the effect of mortar length on 3-inch (75-mm) spherical aerial shells. While it is expected that similar results would be found for other shell types and sizes, that cannot be assured.

The test shells used in this study were Thunderbird brand, Color Peony-White (TBA-106). For consistency, all the test shells were taken from the same case of shells. The shells had an average mass of 136 g, with an average diameter of 2.72 inches (69 mm), and an average of 37 g of lift charge (apparently 4FA granulation). The mortars used in this study were high density polyethylene (HDPE) with an inside diameter of 2.93 inches (74.4 mm)[b]. Ten different mortar lengths were used, ranging from a maximum of 60 inches (1.5 m) down to just 6 inches (150 mm) (in each case, the length was measured from above the mortar plug). There were three to five test firings for each mortar length examined, for a total of 42 test firings. Approximately 10 minutes were allowed to elapse between each use of a mortar to allow time for the mortar to cool before its next firing.

The burst height of these shells was determined by measuring the amount of time elapsing between the burst of the shell (as determined optically) and the arrival of the sound of the burst.[c-d] The individual burst heights and a trend line visually fit to those data points are shown in Figure 1.[e] Further, the average burst height for each mortar length is presented in Table 1. While the measured burst heights are probably greater than many might have expected, for a number of reasons it is believed they are correct for the conditions existing for these tests.[g] However, it is the trend in burst height that is of most general interest. Accordingly, presented in the last column of Table 1 are burst heights normalized to that achieved using a 20-inch (510 mm) mortar.[h]

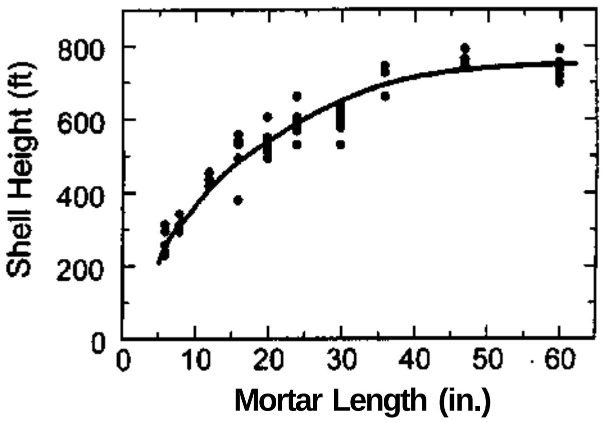


Figure 1. A graph of the burst height results as a function of mortar length for 3-inch spherical aerial shells.

Table 1. Average and Normalized 3-inch Shell Burst Height for Various Mortar Lengths.

Mortar Length (in.)	Number of Tests	Average Height (feet)[f]	Normalized Burst Height
60	5	740	1.39
47	3	760	1.36
36	3	710	1.29
30	5	590	1.20
24	5	590	1.09
20	5	530	1.00
16	5	495	0.90
12	3	430	0.76
8	3	310	0.58
6	5	260	0.48

To convert from inches to millimeters, multiply by 25.4.
To convert from feet to meters, multiply by 0.305.

It may be of interest to note that reducing the mortar length from 20 to 6 inches (510 to 150 mm) produced a reduction in the average aerial shell burst height by about 50 percent. This result was somewhat of a surprise, even though earlier calculations using the Shimizu's ballistic model had suggested that the reduction would not be overwhelming.[111] It was surprising because the top of the mortar was only about 2 inches (50 mm) above the top of the aerial shell. Even though model calculations had suggested that the aerial shell would still be propelled to a significant height, it was hard to believe, because it seemed to contradict common sense.

It was found that increasing the mortar length from 20 to 60 inches (0.51 to 1.5 m) produced an increase in burst height by about 40 percent, with the strong suggestion that further increases in mortar length cannot be expected to produce much more of an increase in burst height. That the effectiveness of ever longer mortars decreased, essentially to the point of no longer producing greater burst height, was not a surprise. This is because ballistic modeling had predicted this and it seemed quite logical.

It is hoped that this brief article provided some interesting and useful information about the effect of mortar length on aerial shell burst height.

Notes

a) For common mortar lengths, aerial shells typically burst prior to reaching what would be their maximum height. There will be a somewhat greater difference between burst height and maximum possible height for longer than normal mortars. Also, for especially short mortars the opposite will be true, where the shells burst on their way back down, after having reached their maximum height.

b) While the mortar diameter was smaller than desired, it was typical of many HDPE mortars made from commercially produced pipe. This pipe was SDR 17 (standard dimensional ratio), which is specified as having an internal diameter (ID) of 2.97 inches (74.5 mm).[3] However, manufacturers consistently produce pipe with a wall thickness greater than the minimum specification. Because.the outside diameter of the pipe is tightly controlled, the thicker walls cause the ID to be less than specified. In this case, the pipe was supplied with an ID of only 2.93 inches (74.4 mm).

c) The air temperature was approximately 68°F (17°C) at the time of the measurements. This corresponds to a speed of sound of approximately 1126 feet (343 m) per second, which was the value used in calculating the burst height of the test aerial shells.

d) If desired, see references 4 and 5 for discussions of two slightly different methods using the delay in arrival of the sound of the explosion to determine the distance to the explosion.

e) The average deviation of the individual data points from the trend line is 37 feet (11m).

f) As an expression of the statistical uncertainty in the measurements, average burst heights are only reported to the nearest 10 feet (3 m).

g) There are a number of reasons for believing the burst height results are correct: 1) the method for determining burst height is simple; 2) the data produced was internally quite consistent; 3) the testing was conducted in western Colorado at an altitude of 4600 feet (1400 m) above sea level, where the reduced air density results in lower drag forces, allowing aerial shells to reach greater heights than when fired at elevations nearer to sea level; 4) the relatively small internal mortar diameter causes the shells to exit the mortar at greater velocities and thus be propelled to greater heights; and 5) these results are reasonably consistent with previous measurements[6-7] performed at lower elevations and with nominal diameter mortars.

h) A 20 inch (510 mm) mortar length was chosen because it is thought that is the approximate length of the most commonly used mortars for 3-inch (75 mm) single break aerial shells.

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1) K. L. and B. J. Kosanke, "Shimizu Aerial Shell Ballistics Predictions, Part I", *Pyrotechnics Guild International Bulletin,* Nos. 72 and 73 (1990); also reprinted in *Selected Publications of K. L. and B. J. Kosanke, Part 2(1990 through 1992),* Journal of Pyrotechnics, 1995.

2) R. Dixon, "Shell Altitude vs. Mortar Length", *Journal of Pyrotechnics,* Issue 10 (1999).

3) Specifications published by Poly Pipe Industries, Inc., Gainesville, TX.

4) K. L. Kosanke, "Determination of Aerial Shell Burst Altitudes", *Pyrotechnics Guild International Bulletin,* No. 64 (1989).

5) K. L. and B. J. Kosanke, "Simple Measurements of Aerial Shell Performance", *American Fireworks News,* No. 181 (1996).

6) K. L. Kosanke, L. A. Schwertly, and B. J. Kosanke, "Report of Aerial Shell Burst Height Measurements", *Pyrotechnics Guild International Bulletin,* No. 68 (1990).

7) T. Shimizu, *Fireworks from a Physical Standpoint, Part III,* Pyrotechnica Publications, 1985.

WHAT DO ALL THOSE SHELL NAMES MEAN?

by John Vico

Crown: Refers to just that, a crown and thus the shape of the bursting shell. Confusion comes from the fact that all crowns are not created equal; so are we referring to the golden crown of a king with its slightly arched over pointed tips or the Tiara of a beauty queen? In fireworks I believe we should stick to the former and remember that these pointed crowns often had a jewel at their tip.

Brocade: Refers to lace. Thus a delicate star probably of glitter or similar appearance. To me lace is white but of course there can and often is golden brocade.

Diadem: Refers to jewel, usually rubies and emeralds but of course includes diamonds and I suppose could be extended to include amethyst, topaz etc. The important thing is that each respective jewel connotes a corresponding color. It would be fair to think that if someone decides to name a shell a ruby diadem, that we should expect to see some red. I believe that many have chosen this description in place of saying red tipped chrysanthemum.

Willow: Simply refers to the shape of the shell patterned after the weeping willow. To me they should be golden with a full bushy star and somewhat of a hanging branching pattern just like the tree. Note that they are not necessarily perfectly round. Also note that they are not spider-like as that term should be reserved for another shell.

Kamuro: I think refers to hair or perhaps more specifically a bowl shaped haircut. (This may depend on different dialects of Japanese or simply different barbers.)Nevertheless everyone expects to see a long-burning fine hanging star looking like an umbrella or "bowel haircut." The pattern should be more symmetric and less bushy than a willow, almost perfectly round or ovoid and may or may not reach the ground depending on your barber, err... shellmaker and fallout site.

Chrysanthemum: Refers to the flower. Thus a symmetric large white shell perhaps with colored pistils and or petals, tips etc. Of course we can and do have gold ones. For pyro purposes though, can we all agree that the main star should have a tailed appearance?

Peony: Again simply refers to the flower. They come in a variety of colors, should be round and symmetric, and in contrast to the above the stars are not tailed. JV

MORTAR EXIT TIMES FOR AERIAL SHELLS

by K.L. and B.J. Kosanke

Have you ever wondered how long it takes for an aerial shell to leave the mortar after the lift charge is ignited? We needed to determine this, as part of a study of the cause(s) of muzzle breaking aerial shells. Details of this complete study are reported elsewhere(l); however, mortar exit time data are summarized below.

Spherical aerial shells ranging in size from 3 to 8 inches were test fired from steel mortars equipped with an internal pressure sensor and a trip-wire timing system. The time taken for shells to exit the mortar, after igniting the lift charge with an electric match, was determined using both methods.

Figure 1 is a typical mortar pressure versus time curve for a shell firing. The time at which the shell leaves the mortar is seen as a sudden change in the downward slope of the pressure curve. This is caused by the propelling gases escaping behind the exiting shell. The application of current to the electric match begins the data recording process and is shown on the graph. The firing current was sufficient to cause the electric match to fire in less than 1 mSec (0.001 sec) (2)(a). There is also a slight delay in the pressure sensor noting the beginning of the more rapid pressure drop. This time delay depends on the speed of sound in the high temperature lift gases, and is also less than 1 mSec. Because these two times tend to cancel out and are both small compared to the exit time for the shells, they were ignored.

The trip-wire method used the same equipment described in an earlier article on shell

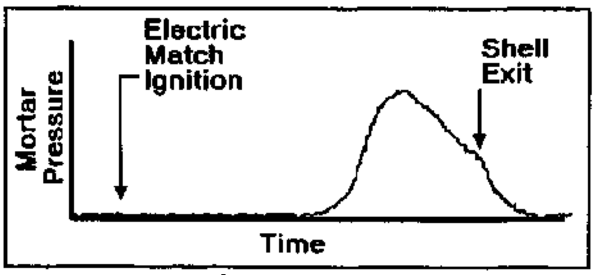

Figure 1. Typical mortar pressure versus time curve for a shell firing.

is started when power is applied to the electric match and is stopped when a trip-wire above the mouth of the mortar is broken by the exiting shell.

In the mortar exit time measurements, generally, groups of six identical inert shells were fired. When both methods worked, the exit times derived were in good agreement; however, the method based on mortar pressures was more reliable. Accordingly, that method was used for the results reported here. The average of the exit time measurements (and other relevant information) are presented in Table 1 and shown graphically in Figure 2. In the case of the 4- and 8-inch shells, there are two groups of shells fired, with differing amounts of lift powder. Thus pairs of exit times are reported.

Without having given serious thought as to how exit times would vary with shell size, it had been assumed the times would increase with shell size, particularly since larger shells are fired from longer mortars. However, this was not found to be the case. It was observed that exit times are roughly consistent or decrease slightly with increasing shell diameter. As a check on these results, rough calculations were performed using the mass and diameter of the shells, and the pressures observed during firing. The result was a confirmation that large shells should indeed exit in slightly shorter times, even from their longer mortars.

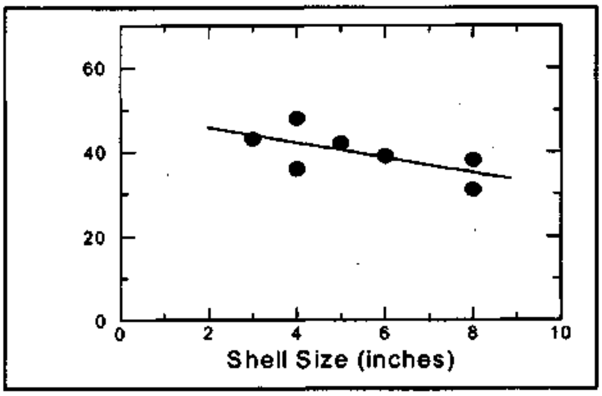

Figure 2. Graph of spherical aerial shell exit.

Table 1. Aerial Shell Exit Time Results.

Shell Size (inches)	Mortar Lengths (inches)	Exit Times (mSec)	Average Exit Times (mSec)	Remarks
Spherical Shells:				
3	20	32, 70, 34, 35, 27, 62	43	1.0 oz. Lift, 4.8 oz Shell
4	24	53, 48, 52, 34, 52, 28	48	1.0 oz. Lift, 12.7 oz. Shell
4	24	40, 28, 42, 30, 37, 37	36	1.6 oz. Lift, 11.8 oz. Shell
5	30	56, 33, 45, 46, 37, 37	42	1.8oz. Lift, 22.1 oz. Shell
6	30	34, 43, 36, 32, 47, 42	39	3.0 oz. Lift, 40.3 oz. Shell
8	36	34, 45, 36, 32, 45, 34	38	5.5 oz. Lift, 95.4 oz. Shell
8	36	32, 25, 35, 32, 32	31	7.1 oz. Lift, 95.4 oz. Shell

References:

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2)K.L. Kosanke and B.J. Kosanke, "Electric Matches and Squibs," *American Fireworks News,* No. 150, March, 1994.

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Note:

To verify the approximate firing time of the electric matches, a separate series of tests were conducted. In those tests, it was determined that small salutes, fired by an electric match, exploded in 2 to 3 mSec. Accordingly, the firing time for the electric matches used must have been less than 2 to 3 mSec. This is consistent with the reported electric match firing time of less than 1 mSec. KL&BJK

COATING PAPER MORTARS FOR LONGER LIFE

by Harry Gilliam
Skylighter, Inc.

Around The Mighty Fourth and New Year's, we always have a flurry of orders from poor slobs who are buying Class C (1.4G) festival balls by the bushel, only to belatedly discover that they only got one measly mortar tube to shoot 'em out of. We actually get feelthy rich at those times of the year selling 1 3/4" and 2" mortars to accommodate these unfortunates. We would get even feelthier if we did not pass along this tip. Cardboard tubes are notorious for unraveling after they have been used once or twice. The problem is that the potassium nitrate residue left in the tube absorbs water. The dampness causes the glue in the tube to loosen up, and your tube is now history. Their life can be extended considerably by waterproofing them.

Some thinned varnish or polyurethane is put in a shallow tray that's big enough to accommodate the tube. (I prefer varnish, even though it takes longer to dry. Varnish penetrates the cardboard; but polyurethane coats it and makes the i.d. slightly smaller.) Then the tube is dipped, completely coating it inside and out with goo. It is hung up to dry. I use straightened wire coat hangers and decorate my wife's dogwood trees with 'em for a couple of days. This is why she is divorcing me.

We don't offer plastic bases for these tubes, by the way, because they tip over. A good base can be made by getting a hole saw (adjustable or otherwise) and cutting about a 3/8" to 1/2" deep hole in a piece of lumber, then use white carpenter's (or Elmer's) glue (do NOT use hot melt!) to mount the mortar tubes to this base. Et voila! HG

FLOWERPOTS AND MUZZLE BREAKS

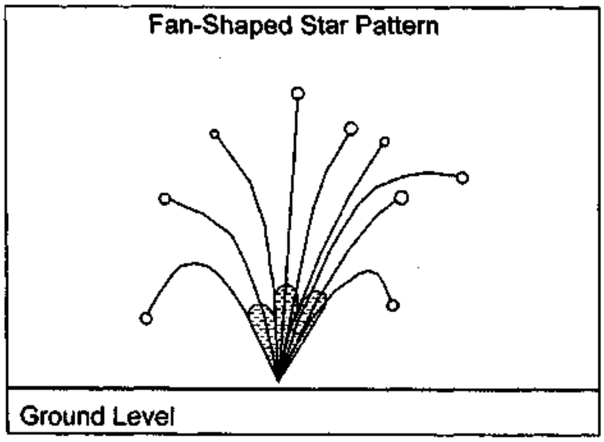
By K. L. and B. J. Kosanke

Introduction

Flowerpot and *muzzle break* are descriptive terms for two types of aerial shell malfunctions. There can be serious safety consequences from these malfunctions, especially for manually fired displays. Some commonly held beliefs as to the cause of these malfunctions are challenged by the available data. This article summarizes some of that data and then draws inferences from that data.

A common definition for a flowerpot is:

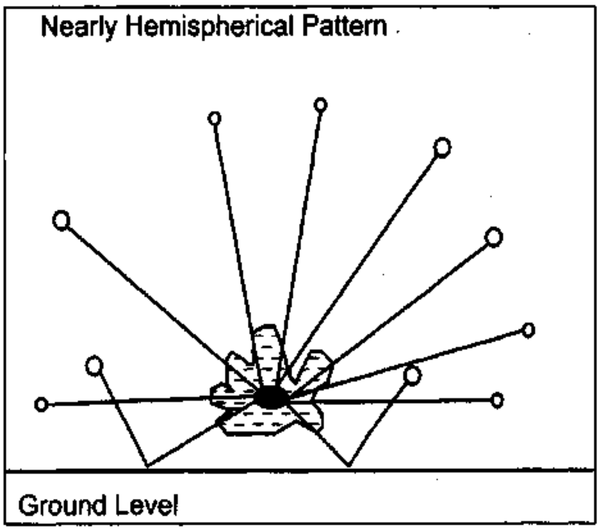
A type of aerial display shell malfunction where the shell bursts with relatively low power within a mortar. It produces an upward spray of ignited stars and other effects, as illustrated below.[1]



The odds of an aerial shell experiencing a flowerpot depend on many factors, but for typical shells and conditions it is probably in the range of 1 flowerpot in 100 shell firings to 1 flowerpot in 500 firings. It would seem that the likelihood of a shell experiencing a flowerpot is mostly independent of shell size. For the most part, since the power of the explosion is relatively low and the mortar generally remains intact, flowerpots represent a relatively minor hazard. The hazard that does result is from the potential for burning debris to fall to the ground in the area of the mortars, thus presenting a possibility for the unintentional ignition of other fireworks. This is a minor concern for an electrically fired display with no personnel present and the fireworks already loaded into mortars ready for firing. However, when personnel are present, such as for a manually fired display, especially when stores of firework shells are being reloaded, burning debris raining down is a serious safety concern.

A common definition for a muzzle break is:

A malfunctioning aerial shell which bursts just as it leaves the mortar, scattering high velocity burning stars and other material in all directions near ground level. It appears somewhat like the following illustration.[1]



The odds of an aerial shell experiencing a muzzle break also depend on many factors, but for typical shells and conditions it is probably in the range of 1 muzzle break per 500 shell firings to 1 muzzle break in 2000 firings. In addition, it seems clear that muzzle breaks are significantly more common for large shells as compared with small shells. The hazards posed by muzzle breaks are in two areas. First are hazards arising from the blast force of the exploding aerial shell. For salutes and large shells the blast force can be sufficient to cause injury to persons in the immediate area. The blast force can also be sufficient to reposition nearby mortars, such that shells fired subsequently from those mortars could proceed in dangerous directions. Second are hazards arising from the burning stars traveling at high speed. While this poses somewhat similar problems as the burning fallout from flowerpots, the hazard is more extreme. The burning components from a muzzle break will be traveling much faster, thus not allowing sufficient time to react to the threat. Another consequence of the high speed of the burning stars is that their range will be much greater.

Before a manufacturer can effectively take steps to reduce the occurrence of aerial shell malfunctions, it would be helpful to accurately understand the nature and cause of those malfunctions. While some may think they know the causes of flowerpots and muzzle breaks, for the most part this seems to be based on conjecture and intuition, rather than solid evidence.

Regarding flowerpots, it is often suggested that the cause is a fire leak into the shell through a small crack or tiny hole in the shell's casing. Another common explanation for flowerpots is that it is a result of *setback,* where a common definition for setback is:

The inertial response to the extreme acceleration of aerial display shells upon firing.[1]

The peak acceleration of an aerial shell will be approximately 1000 times the acceleration due to gravity.[2] In response to this acceleration, the contents of the shell will forcefully compress into the lower portions of the shell. It is possible that this forceful motion of internal pyrotechnic materials may on occasion produce sufficient frictional force to cause the ignition of the shell's contents, leading to the premature explosion of the aerial shell. Regarding muzzle breaks, it is often suggested that the cause is unusually fast burning (defective) time fuse. However, no published data confirm that these presumed causes for flowerpots and muzzle breaks are correct. In fact, the little published data on the subject seem to contradict these presumed causes. This article will examine the available data and suggest alternate theories more consistent with the data.

Test Data

Several years ago, in an attempt to learn more about the cause of muzzle breaks, a series of tests were conducted.[3] Subsequently, some relevant data was collected during the course of two other brief studies conducted for other purposes.[4,5] Recently some additional data were produced for use in the present study.[6] While the overall results of these studies are used in this article, a detailed presentation of those results and the methods used to produce them will not be repeated here.

A total of 32 measurements were made of the time taken for a range of typical spherical aerial star shells to explode after their being ignited internally using an electric match. The average values of these *burst delay times* ranged from approximately 30 milliseconds (ms) for 2.25-inch shells to 110 ms for 10-inch shells. (Note that, for all of the testing reported here, the conditions were such that the e-match fired in less than 1 ms.)

A total of 61 measurements were made of the time taken for a range of typical spherical aerial shells to exit their mortar after firing an electric match to ignite their lift charges. The average *mortar exit time* (the time interval between the e-match firing and when the shell exited the mortar) was approximately 40 ms. It was observed that there was relatively little if any dependence of mortar exit time on shell size (in the range from 2.25 to 8 inches) fired from mortars of typical construction.

When interpreting the mortar exit time data, it is important to recognize that, for a significant portion of the time while the lift powder is burning before the shell exits the mortar, there is no detectable increase in pressure inside the mortar, see Figure 1. (This would seem to be the time required for fire to spread through the mass of lift powder and then to have sufficiently vigorous burning so as to produce more combustion gas than can easily escape through the gap between the shell casing and mortar wall.) This is important in the context of this article, where consideration is being given to fire leaks through small cracks or tiny holes into the interior of an aerial shell as it is being fired. Until there is a significant difference between the pressure in the mortar and that inside the shell, there is no driving force to cause the entrance of the burning lift gas through any small crack or tiny hole. Similarly for setback as a possible cause of flowerpots, until there is a significant rise in the pressure under an aerial shell, it will not begin to accelerate up the mortar, and there will be no inertial forces to potentially cause the ignition of the shell's internal contents.

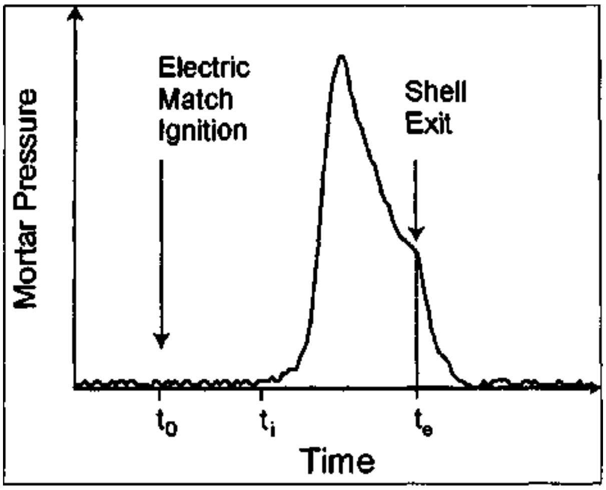


Figure 1. Mortar pressure versus time for the firing of a typical aerial shell, where the pressure impulse time equals the difference between t_j and t_e.

A total of 39 measurements were made of *pressure impulse time* (the time interval between the first detectable rise in mortar pressure, ti, and the when the shell exited the mortar, te). In effect, only during the pressure impulse time is there a pressure differential that could force burning lift gas through any small crack or tiny hole in a shell's casing. It was found that the pressure impulse time averaged 20 ms, mostly independent of shell size.

Conclusion

After an amount of fire approximately equal that provided by an electric match has entered an aerial shell, the average time taken for the shell to explode (approximately 30 to 110 ms, depending on shell size) is always longer than the average time for the shell to exit the mortar once the lift pressure under the shell starts to rise (approximately 20 ms). The inescapable conclusion for such relatively small fire leaks and setback-caused ignitions is that on average aerial shells will have left their mortars before they can explode. However, there are rather large variabilities observed in individual burst delay and pressure impulse times. Thus, if an aerial shell's pressure impulse time is longer than average, while at the same time its burst delay time is shorter than average, it is possible that some small shells will still be inside the mortar when they explode (as flowerpots). However, larger shells, with their significantly longer burst delay times, will essentially always be well clear of the mortar before they can possibly explode from such small fire leaks or from setback.

The overall results of this study are substantially inconsistent with the commonly cited causes of flowerpots. Fire leaks, approximating the fire produced by an electric match, are not expected to produce flowerpots, but rather to cause muzzle breaks. Thus one must conclude that flowerpots are rarely if ever caused by fire leaks through small cracks or tiny holes, or as a result of setback. Although not specifically investigated in the testing reported in this article, it seems certain that the time taken for an aerial shell to explode depends on the amount of fire leaking into it. To account for the observation that many more aerial shells flowerpot than muzzle break, most flowerpots must be the result of much more substantial fire leaks, up to and including the more-or-less complete failure of a the shell's casing. (Note that the substantial failure of a shell's casing as a cause of many flowerpots is consistent with the empirical observation that the explosive power for many flowerpots is substantially less than would be expected for an intact shell exploding within the added confinement of a mortar. In fact, many flowerpots seem to be no more violent events than normal shell firings.)

In considering the cause of muzzle breaks, while the data reported here does not disprove the fast burning time fuse hypothesis, it is certain that small fire leaks and setback are also viable (and probably more likely) explanations. Further, the conclusion that it is primarily the larger shells that will be well clear of the mortar before they can explode as a result of small fire leaks is consistent with common experience regarding muzzle breaks. This gives one added confidence that the cause of many (most) muzzle breaks is relatively small fire leaks.

Acknowledgment

The authors are grateful to L. Weinman and G. Hanson for reviewing and commenting on a draft of this article.

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AERIAL SHELL AUGMENTATION EFFECTS

By K. L. and B. J. Kosanke

This article provides information about a method of augmenting an aerial shell's aesthetic performance that is simple, high profit and appreciated by display sponsors. This method was discussed many years ago by the authors as part of an article on electrically fired displays.[1] In that article, these effects were described as *parasitic fireworks effects.* They were described in that way because the "parasitic" firework effects (small shells, mine stars and other small components) derived their lift energy from other "host" aerial shells. In the present article, because it is more descriptive, these same effects will be called augmentation effects.

To draw lift energy most effectively from their host shells, the augmentation effects must be loaded on top of the host shell. Based on empirical observations, when the total weight of the augmentation effects is modest in comparison with the weight of the host shell, the altitude of the host shell is not noticeably reduced, and the augmentation devices reach ample height. Table 1 presents typical weights of spherical host shells and the augmentation firework effects used with them. The weights for augmentation effects range from as much as approximately 1/2 the weight of the host for a 3-inch shell, down to approximately 1/10 the weight of the host for a 12-inch shell. In part these varying relative weights correspond to the carrying capacity of the host shell. (Because of the relatively low ratio of shell mass to projected area, 3-inch shells require disproportionately larger lift charges to reach proper altitude than is required for larger shells. Accordingly, for the shell sizes listed, 3-inch host shells have the greatest relative carrying capacity for augmentation effects.)

Table 1. Augmentation Effect Weights for Spherical Host Shells.

Host Shell (Spherical)			Augmentation Effect
Size (inches)	Approx. Weight (pounds)	Point Rating	Typical Total Weight (ounces)
3	0.3	1	3
4	0.8	2	5
5	1.5	3	8
6	2.5	4	10
8	5.5	8	16
10	11.	11	22
12	18.	14	28

Carrying capacity not withstanding, the varying relative weights for augmentation effects are primarily the result of aesthetic considerations. When a 3-inch shell is properly augmented, those effects usually weigh about three ounces. For an 8-inch shell, near optimum results can be achieved with about 16 ounces of augmentation effects. To maximize the artistic effect, augmentation effects must be properly timed and sized with respect to the host shell. In general, the lowest altitude and smallest effects should occur first, followed by higher and larger effects leading to the break of the host shell, which should be impressively greater than the augmentation effects which preceded it. To illustrate this, consider one possible 4-inch *shell set* (host shell plus augmentation effects). On firing, the shell set first produces a blue-willow mine effect extending about 150 feet in the air; this is followed shortly by a flurry of four small purple (festival ball sized) breaks at about 250 feet, followed by the break of the 4-inch bright red chrysanthemum shell at about 400 feet. The synergistic effect of the combination of effects produces a result that is far more aesthetically pleasing than might be expected (particularly when the modest added cost for the augmentation is considered). Figure 1 is an illustration of how this 4-inch shell set might appear in comparison with the 4-inch shell alone.

There are three main reasons to consider the use of augmentation effects. The first and most important reason was given above, aesthetics. Though often seriously under-utilized in displays, mines and ascending effects are attractive in their own right. They also offer variety and fill an otherwise unused portion of the sky. Another aesthetic payoff comes in the length of time the combined effects last; the use of a shell set such as the one described above produces a display that lasts at least twice as long as would be produced by the host shell alone. However, the most important aesthetic reason for using augmentation effects is that their use seems to significantly increase the perceived beauty of the host shell. This may be the result of helping to focus the audience's attention and build their sense of anticipation of the burst of the host shell, which then appears more beautiful than it would, if seen as a single unheralded event.

The second reason to consider using augmentation firework effects is increased profit. Because the augmentation effects add so much to the favorable impression of the audience and yet cost relatively little, it is acceptable to increase the gross profit on them. When the authors still performed displays, their gross profit for augmentation firework effects was approximately double that for the host shells. Yet the feedback from sponsors was very favorable. (It's a great day when you can increase your profit and still have sponsors wanting to shake your hand for the great job you did.)

The third reason for considering the use of augmentation effects is that their use allows a significant reduction in the variety of shells that must be kept in inventory. Consider the following three shell sets: blue and willow mine followed by silver glitter augmentation shells followed by large red peony; purple and gold glitter mine followed by green meteor shells followed by large red peony; green and silver comet mine followed by short-delay small artillery shells followed by large red peony. In each case the host shell was a red peony; however, even if these shell sets were fired one after the other, they would be perceived by the audience as presenting great variety. By using different combinations of only five types of mine stars (taken two types at a time), five types of augmentation shells and five types of host shells, it is possible to assemble 500 different shell sets. Obviously not all of the 500 shell sets will be artistically effective, but very many will. Thus the use of augmentation effects allows a significant reduction in the number of different types of shells needed in inventory.

Augmentation effects should be prepared in advance by loading the mine stars and small shells or other small components into plastic bags and sealing them. A few of the possible assemblages of augmentation effects are suggested in Table 2.

Table 2. Some Possible Augmentation Effects.

Points	Description[(a)]
1	2 Festival Balls plus 1 ounce of mine stars
1	4 packs (approx. 70) Firecrackers or Jumping Jacks plus 1 ounce of mine stars
2	1 - 2 1/2" Shell (may include 1 oz. of mine stars)
2	3-1" x 1 1/2" Flash Salutes
3	1 - 2 1/2" Shell plus 3 ounces of mine stars
3	1 - 3" Shell (may include 1 oz. of mine stars)
3	1 - 2" x 2" Crossette Comet
3	6 ounces of 1" x 1" Comets
4	1 - 3" Shell plus 3 oz. of mine stars

Note — all items are heavily primed.

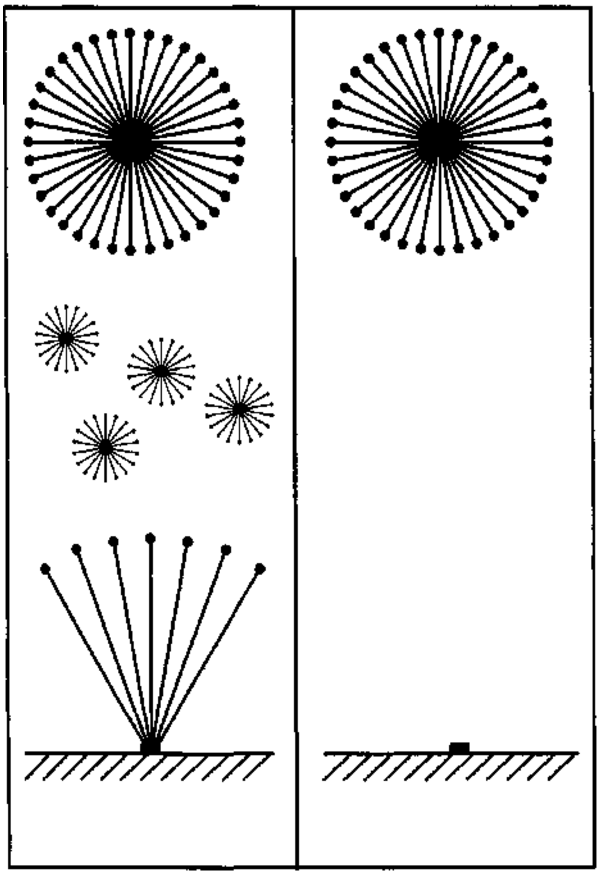

Figure 1. Illustration of the augmentation of an aerial

Large quantities of these pre-bagged items can be stored until needed during final loading before a show. Also given in the table is a point rating for each of the different assemblages. These can be used as an easy way of determining which and how many of each of the assemblages can be loaded on top of any given size host shell. (Note that Table 1 included a point rating for typical host shells.) Any number and combination of assemblages can be used as augmentation effects providing their cumulative point total does not exceed the point rating given for the host shell. For example, a 5-inch host shell has a point rating of three, thus (in addition to mine stars) six festival balls, or two festival balls plus one 2 1/2-inch shell, or one 3-inch shell are all acceptable as augmentation effects.

It is important that augmentation effects be well primed to insure their ignition by the escaping lift gases from the host shell. Probably the most reliable priming method is one that concludes with pressing the primed item into granulated commercial Black Powder while the prime is still wet. This provides many angular points on the primed surface insuring easy ignition. Small shells are usually primed by dipping the whole area of their fuse into a prime mix (usually handmade meal powder in nitrocellulose), then momentarily pressing the primed area into 3 or 4 Fg commercial Black Powder. Packs of firecrackers or jumping jacks can be primed by running a bead of prime from a catsup-like squeeze bottle down the spine of each pack, then pressing the primed area into the Black Powder. Small individual components (such as small bees) are usually primed by dipping batches of several hundred at a time into the prime mix, then gently tumbling the items in handmade meal powder. Mine stars need only be primed as they would be for use in shells. Priming is important in all cases, but especially when augmentation effects are loaded on top of canister shells, where it may be less likely than with spherical shells that each of the items will be well exposed to the burning lift gases. When augmentation items without a mine effect are used with canister shells, it is desirable to add a small charge of black powder to the plastic bags containing the augmentation effects. This will help to insure proper ignition of the effects by more completely filling the bag with fire when the host shell is launched.

Augmentation effects are loaded into mortars by simply dropping the filled plastic bags into the mortar after the host shell has been loaded. It is inappropriate and unnecessary to remove the augmentation effects from their bags. (Inappropriate because loose components or stars might jam between the host shell and the mortar wall; unnecessary because the plastic bag will melt away almost instantly when the host shell is fired.)

One word of caution, there is always the possibility that sparks from the firing of one shell will fall into other mortars and unintentionally ignite augmentation effects in those mortars. However, this is prevented by the use of protective covers. Plastic sheeting and heavy aluminum foil is generally sufficient, but polyethylene pipe covers (such as those manufactured by Cap Plugs) are probably superior. Further, it is thought that augmentation effects are best suited for electrically fired displays, or at least in preloaded manually fired displays. The use of augmentation effects in displays where mortar reloading is occurring is inappropriate for reasons of crew safety.

In the original article, which included a discussion of augmentation (parasitic) effects, a series of reasons were given as to why there is essentially no reduction in the burst height of the host shells. However, at that time no measurements had been made to confirm and quantify that empirical observation. Recently, while studying the effect of varying mortar diameter and length on the height achieved by 3-inch aerial shells, some measurements were made of the degree to which burst height of the shells was reduced when they were used as hosts for augmentation effects. In that work, it was found that under the conditions of the testing (4600 feet above sea level, 20-inch long mortars with an internal diameter of 2.93 inches) the standard test shells (3-inch Thunderbird Color Peony-White, TAB-106, with an average diameter of 2.72 inches and an average mass of 4.8 ounces) when fired alone burst at an average height of 530 feet. (Further details of the test methods can be found in two articles reporting on those studies.[2,3]) When the augmentation effects with a weight totaling 3 ounces were added on top of the test shells, the host shells' burst heights were reduced to an average of 505 feet. This corresponds to a reduction of only approximately 5 percent in burst height, which can be safely tolerated for properly performing aerial shells. While measurements were not made using larger shells, it is thought that the reduction of burst height would be proportionately no more than that found in this study. (This is because augmentation effect weights represent a smaller proportion of the host shell's weight.)

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TAPES FOR PYROS

By Big Bruce

It used to be when you went to a hardware store and asked for tape they asked you "black electrical" or "masking". Now I note tape has its own counter. There are so many kinds. Here are some of the uses I remember for the old kinds:

Masking tape is used to connect lengths of quickmatch, repair breaks in quickmatch, hold quickmatch to lances, finale racks and set pieces, etc. Gummed paper tape can be used to make small tubes for whistles, rockets and bangers. Filament strapping tape can be used to sharpen the reports of salutes (I bet they will do the same for lambettes). Silver duct tape can be used to decorate fireworks, and so on.

I wonder what pyro uses the new kinds are good for? Duct tape (or *duck* tape as one manufacturer refers to it) now comes in a multiple of colors, including a beautiful brilliant green, as well as the familiar silver. Masking tape now comes in widths up to 3", as does strapping tape.

For box sealing there is the brown plastic tape, which, I note, also comes in clear and rolls up to 4" wide. I cannot help but think this stuff has pyrotechnic use. For making shell, maybe? On a smooth surface it forms an air-tight seal.

How about this for a quickie shell? End disc with some time fuse glued in place in the usual way is taped onto the paper case using the brown box sealing tape. The shell is filled with stars and bursting charge, the end is sealed with another chipboard disc, which is tape in place. Instead of stringing, 3 or 4 turns of strapping tape are wound lengthwise and around the girth. Lastly, maybe a layer of that brown tape. The rest would be done as one would do an ordinary Kraft paper, paste & string shell. BB

THE EFFECT OF REFLECTED BLAST WAVES IN HDPE MORTARS

By K. L. Kosanke & L. T. Weinman

A recent article discussed a problem with some comet shells exploding as they were being fired, and thus seriously damaging the HDPE mortars being used.[1] Included in the article were photographs of the two mortars that had been damaged. In these photos, it was clear that, while both ends of the mortars received serious damage, the middle section of the mortars received less damage in one case and no damage in the other. This raised a question in the minds of some readers, how could a single explosion damage both ends of a mortar while leaving the middle of the mortar essentially undamaged? The purpose of this article is to address that question.

During the course of conducting initial studies of the overall suitability of HDPE pipe for use as fireworks mortars,[2-5] many explosions were caused to occur inside HDPE pipes. However, as it turned out, these explosions were all made to occur in the lower portions of the mortars and never near the top (muzzle) of the mortar. As a result, the damage was always observed to only occur in the lower portion of the test mortars. Accordingly, upon first observing a mortar damaged by a single explosion occurring near the open end, and with that damage concentrated at both its ends, it was necessary to contemplate why this would happen.

When a powerful explosion occurs near the top of a mortar, the top of the HDPE mortar will be damaged by the blast as the blast wave radiates outward. However, the blast wave must also propagate down the bore of the mortar where it will be reflected upon meeting the mortar plug (at least so long as the plug remains in place). During the time that the incident and reflected blast waves overlap in the area just above the mortar plug, their pressures will add constructively to produce a greater blast pressure. Therefore, if the incident blast wave pressure is sufficient, when it adds to the pressure of the reflected blast wave, it is possible to explode the bottom of the mortar (as well as the top) from a single explosion. This seemed simple enough, but did it really work that way in actuality? Accordingly, some testing was performed.

In the first series of tests, a starter pistol (firing blanks) was discharged into the muzzle of a 3-inch mortar, after having installed a quartz (piezoelectric) pressure sensor at various points near the bottom of the mortar. Figure 1 is a sketch of the bottom portion of the test mortar that includes the location of the lowest two positions for the pressure transducer. Pressure data was collected at four locations, 16.0, 8.0, 4.0 and 0.5 inches above the mortar plug. The data from the lowest three positions in the mortar are shown in Figure 2 (next page). For each location, the data from four separate measurements were averaged and then smoothed for presentation, using a simple running average filter.

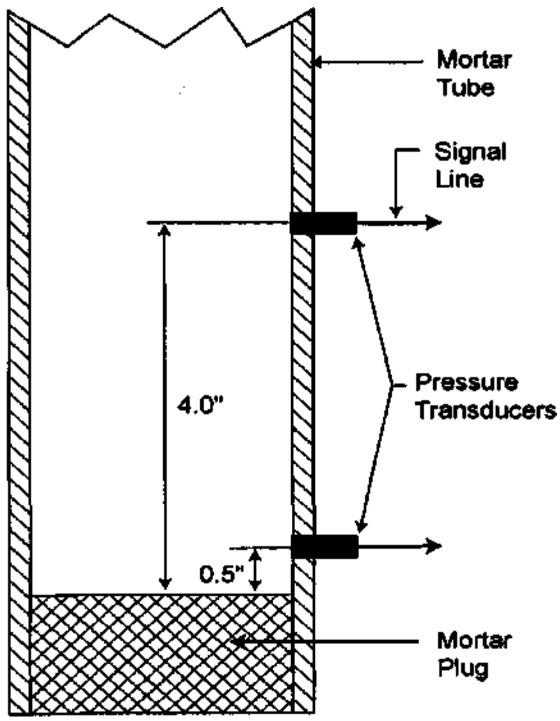

Figure 1. Sketch of the set-up for the first series of mortar tests. (Not to scale.)

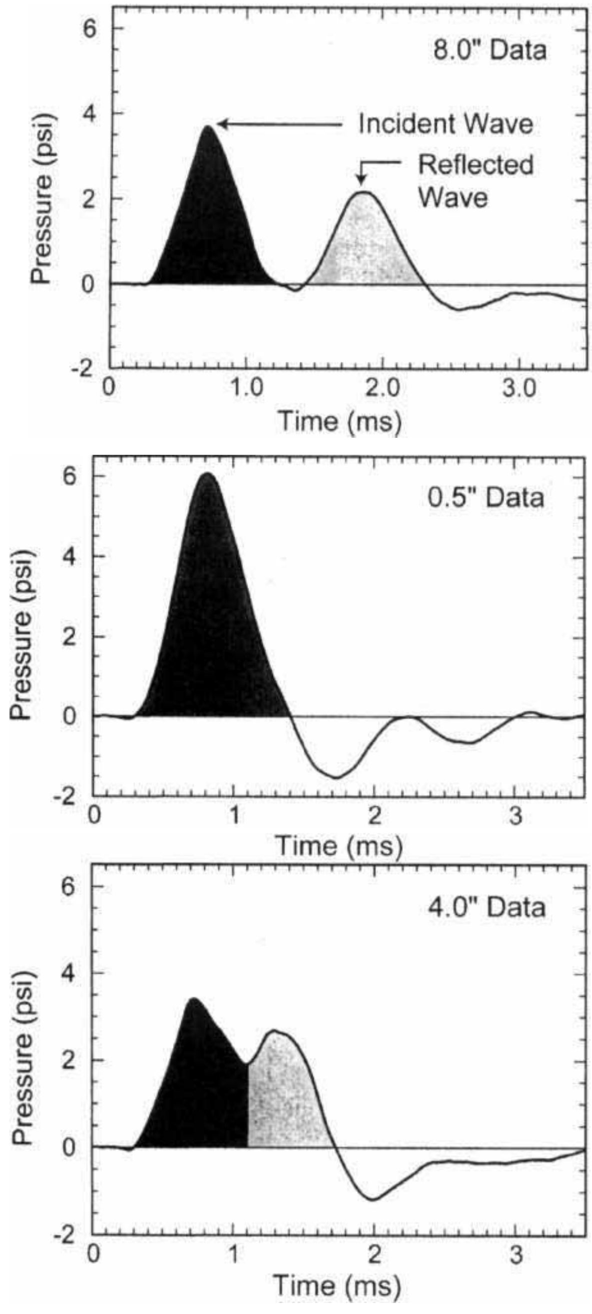

Figure 2. Internal mortar pressure data from the first series of tests.

In the data taken at 8.0 inches above the mortar plug, the incident pressure wave is shown as black and the reflected pressure wave, with its somewhat reduced magnitude, is shown as lightly shaded. The incident and reflected waves are clearly resolved and are separated by approximately 1.14 ms (milliseconds). The pressure wave needed to travel a total of 16.0 inches (8 inches down to the plug and 8 inches back up to the transducer) or 1.33 feet, during the interval between the arrival times at the transducer. At the temperature in the lab, and the initial temperature of the air in the bore of the mortar, the speed of sound would have been approximately 1130 feet per second. This computes to a time interval between incident and reflected pressure waves of slightly less than 1.18 ms, or about 3 percent longer than was measured. That the pressure wave traveled slightly faster than the speed of sound is consistent with its being a weak blast wave. (This was confirmed by examining details of the shape of the pressure event as seen in the raw, non-smoothed, data.)

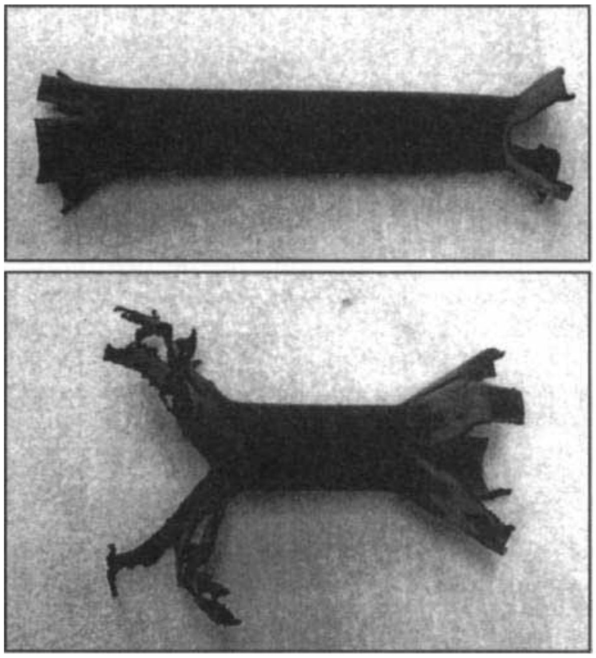

Figure 3. Photographs of the two mortars tested using small explosive charges.

In the data taken at 4.0 inches above the mortar plug, the incident and reflected pressure waves are less separated in time, and have started to merge together. In the data taken at 0.5 inches above the mortar plug, the incident and reflected pressure waves are seen to have merged into one. It can be seen that the amplitude of the combined pressure wave is approximately equal to the sum of the incident and reflected waves seen in the data taken higher in the mortar. Thus it seemed clear that theory was being borne out in practice, but how would an actual mortar react to a pressure pulse sufficiently strong to damage it?

In the next pair of tests, 2-inch HDPE mortars were subjected to explosive blasts. During the course of a fireworks display a powerful explosive blast inside a mortar might potentially originate from a premature functioning of a star shell or a salute. In these tests, the pressure events were produced using flash powder charges contained in thin-walled polyethylene bottles that were of only slightly smaller diameter than the inside diameter of the mortars. Each test charge was suspended just inside the mortar near its muzzle. The results of the two tests are shown in Figure 3. In one test a charge mass of only 25 grams of flash powder was used (upper mortar in Figure 3), and in another test a charge of 50 grams was used (lower mortar in Figure 3). With the smaller flash powder charge most of the mortar is undamaged, except for its two ends, which are damaged almost equally. In the photograph, the left end of the mortar is the muzzle of the mortar (nearest the explosive charge) and the right end is where the plug had been. With the larger explosive charge, the damage is more extreme but is still concentrated at the two ends of the mortar. Thus the reflected blast wave prediction was fully borne out in these tests.

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The authors wish to acknowledge B.J. Kosanke for preparing the figures for this article and for her editorial comments.

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NO MORE WALKING THE FINALE

Sam Bases, Delcor Industries

It does happen - the dreaded "salute blows in the gun" syndrome. Sometimes you get a bad shell, with the result that the mortar is destroyed, or worse, the rack is blown apart.

With smaller shows the finale is usually hand-fired, with the shooter following a few racks behind (or sometimes ahead) of the action, thereby distancing the shooter from a potential malfunction. However, a low break or a detonation in the mortar may still pose a significant danger, since the shooter is only a dozen or so feet away. In case of a break in the chain the shooter has to find a "safety" to re-light the finale, and there usually is very little time delay on it. There must be a better way! Of course, electrical firing to the rescue.

At the last two displays this July I used a "finale cable", which is a form of breakout cable. It's really simple, just a long cable with 5 or more connection terminal blocks spaced about 20 feet apart, and connected to a small firing panel. The first terminal block is connected to an e-match at the start of the finale, with the remainder of the terminals connected at other locations which may need to be re-lighted if the chain stops. A 100' or 200' cable extends away from the finale to the operator's position where the action can be monitored. There is no need *to run any* additional *shooting* wire *or* make any splices. At the press *of* a switch the finale is ignited, and it can be re-lighted if necessary.

The construction of the cable is a bit of a chore if it is to be rugged enough for commercial use. I used our standard firing cable, which consists of 20 gauge stranded conductors with the terminal blocks, soldered connections and re-enforcing ties protected by heavy shrink tubing. The chore part of the preparation is stripping the outer jacket, splicing a ground lead and cutting out the "window" in the outer covering. Sliding the tubing along the 50 to 100 feet of cable can result in some tangles, too.

Details on cable construction will vary with the type of cable and connectors used. A follow-up article can illustrate typical construction, if readers show interest. SMB

FACTORS AFFECTING THE PRECISION OF CHOREOGRAPHED DISPLAYS

By K.L. & B.J. Kosanke

For maximum effectiveness of tightly choreographed fireworks displays, it is important that shell bursts occur very near their intended times. For the purpose of this article, it is assumed that electrical firing employing a computer or other means of accurately applying the firing current to electric matches (e-matches) is being used. In addition, it is assumed that the choreographer has accurate information about the firing and burst characteristics of the shells being used, and that no errors are made in the design of the choreography or in the loading of the display. In that case, there are two primary sources of variation that combine to affect the overall precision of the shell burst times. First is the preciseness of the shell firings from their mortars; second is the preciseness of the time fuse burning. (In the context of this article, "preciseness" is intended to indicate consistency or reproducibility of events.)

The display company has some control over the firing precision of shells. The effectiveness of the commonly used methods of e-match installation was briefly studied and reported on in a previous article[1] and is summarized again below. The three common points of attachment for e-matches are illustrated in Figure 1 and the degree of firing precision accomplished using them are presented in the first three rows of Table 1. (For more information on test conditions and methods, see reference 1.)

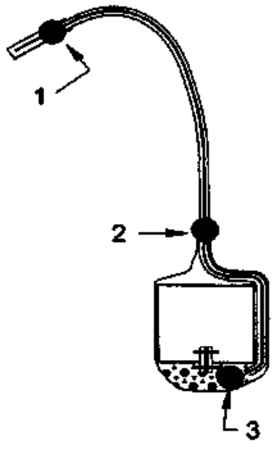

Figure 1. Illustration of the three common points of attachment of e-matches to aerial shells.

As expected, the best firing precision (lowest standard deviation) is achieved with an e-match installed directly in the shell's lift charge. However, using an e-match attachment in the shell leader just above the shell, provides a level of firing precision that is equivalent to that achieved with the e-match in the lift charge, to within the practical limits of human perception.[2]

Table 1., Firing and Burst Time Results.

Test Conditions	E. Time[a] (seconds)	Std. Dev.[b] (seconds)
Attach. Point 1 [c]	0.26	0.15
Attach. Point 2 [d]	0.11	0.025
Attach. Point 3	0.04	0.005
T. Fuse Burning [e]	3.32	0.31

a) Event time for the various e-match attachment points is the average elapsed time between applying current to the electric matches and the shells exiting from the mortars. Event time for the time fuse burning is the average elapsed time between the shells leaving the mortar and their bursting.

b)The one-sigma standard deviations of the average event times were determined using the n-1 method. This is an indication of the precision (reproducibility) of the event. Approximately 70% of the events occur within plus or minus one standard deviation of the average.

c) All using 24-inch long shell leaders with high quality quick match from a single manufacturer.

d)All using 6-inch long shell leaders with high quality quick match from a single manufacturer.

e) All shells were 3-inch Thunderbird Color Peony-White taken from the same case of shells.

Other than by purchasing high quality shells, a display company generally has little control over the burst precision provided by an aerial shell's time fuse. To gain an estimate of the precision for shells of typical quality, a series of

29 three-inch Thunderbird aerial shells were test fired while being video taped. The shells were Color Peony-White (TBA-106), taken from the same case of shells. The shells each had a pair of fairly high quality time fuses. Following the test firings, the video tape was studied frame by frame, to determine the time interval between each shell's firing from its mortar and its bursting. The results are presented as the last row in Table 1. (Based on a limited number of other testing over the years, it is thought that the burst time uncertainty reported in Table 1 is fairly typical.)

Fairly clearly the greatest source of imprecision in a tightly choreographed display is the uncertainty associated with the burning of the time fuse(s). It is possible that the use of well-made spolettes would reduce the uncertainty somewhat, but probably not by very much. Accordingly, when very precise timing of shell bursts is needed, people have turned to the use of tiny electronic timers[3,4] to replace the shells' time fuses. While these electronic units are definitely not cheap, when precise timing of bursts is required to accomplish an effect, there would seem to be no alternative at this time.

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HANDLING MISFIRES AND DUDS

by Larry Mattingly

A shell found left in the mortar after the show is generally called a *misfire. A dud* is a shell that has lifted out of the mortar and does not break. It travels all the way up and back down. If it hits the ground it is a dud by most definitions. It may burst upon hitting the ground but is still considered a dud. (If it bursts on the way down or very low around your ears it may be referred to as Aw-s*% !)

A mortar containing a misfire should be left for a few minutes and then be filled with just enough water to cover the shell, and then left to stand 20 to 30 minutes. (You have to clean up after the show anyway). If you fill the mortar with water to the top and for some reason the shell should lift, the resistance of the weight of the water may cause the mortar to burst. Care should be taken when pouring or squirting water into a misfire mortar. It is possible to drive remaining sparks down into a live part of the match or lift and cause the shell to lift right in your face. I have seen this happen several times over the years.,

Duds should be immediately located and flagged, but should be left undisturbed for 20 to 30 minutes. When recovering them it is best to pick it up with a shovel and place it in a bucket of water. We often use a plastic bag with water in it and tie the top.

Checking mortars for misfires is always a hazardous task. It should be done by the person in charge or the most experienced person present. When the last shell fires, it is prudent to wait a few minutes to let things cool down a bit before approaching the mortars. Crew members should be cautioned against rushing up to the line after the show is over.

Over the years I have heard lots of ideas for devices for looking into mortars. Personally I feel they may present more danger by giving a false sense of security. Think about what would happen if these various devices were struck by a shell. Anyone had the experience of having a fusee ripped out of your hand by a shell???

Placing a strip of tape over the mortar seems like a good tell-tale but I have seen the tape flop back over the mortar, or blow off from another shell lifting and give false readings. Even a shell with igniter attached can be hard to see. The wires sometimes fall back into the mortars... and I have seen it happen that another shell lifting catches the wires and snatches the igniter or breaks the wires. This leaves a shell in the mortar with no apparent sign.

Never fish for misfires with a stick. If you should happen to knock sparks into live material, the shell could lift right in your face, and severe damage to your body could be the result. Misfires are a tricky problem and need to be handled with the utmost care. JLM

UPLIFTING THOUGHTS

By Richard Dilg

DETERMINING LIFT CHARGE SIZE

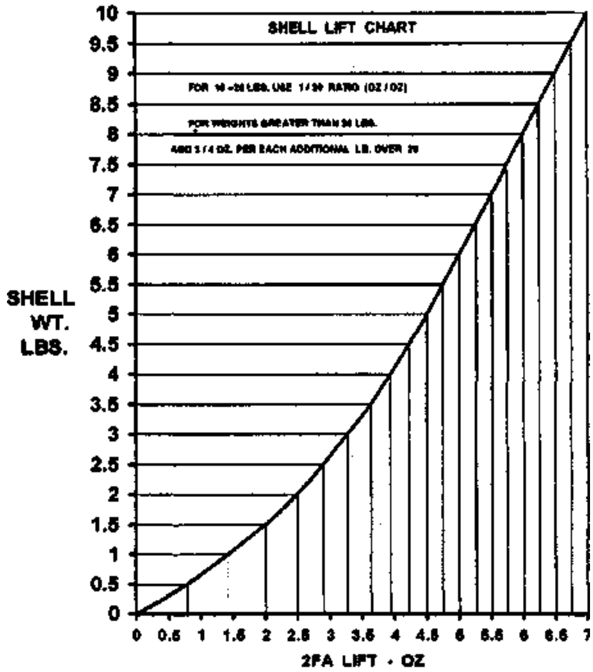
Those who endeavor to be shell builders are at some point confronted with answering the question: How much lift charge should I use for my shell? Is there a general rule? The present article will seek to answer these questions.

An historical approach will be presented. In doing so, rather than going to the classic textbook sources (Faber, Brock, Weingart, Ellern, Lancaster, Shimizu, Hardt, etc.), the ephemeral sources were perused. These included *Fireworks News, American Pyrotechnist Fireworks News, American Pyrotechnist American Fireworks News,* and the *PGII Bulletins* and spanned a time period of about 25 years beginning from 1970 to about the mid 1990's. Surprisingly, few "general" articles were found addressing the questions.

One reference (actually published in two different sources, originally as one[1] and updated in another[2]) was by the renowned pyro Chuck Tenge. The question that he answered was "What is the rule for determining the proper lift charge for shells of various sizes ?" His response was "there is no hard-and-fast rule" ! He then went on to give a "simple set" of lift charges for the "sizes of shells that the amateur shell maker is likely to be dealing with." He presented a listing for various 3", 4", 5", 6", and 8" cylinder shells and for "round" shells of the same diameters. Relevant conditions for these listings were that 2F blasting powder was the lift to be used, that the time fuse used was very specific, that the mortar lengths used were those listed in his article, and the shell type listed. He specifies shell type rather than specifying the weight of the shell in listing the amount of lift to be used. All of the relevant conditions had to be accounted for to make the lift listings valid.

Another answer to the initial question is found in an earlier PGII reference[3]. It was essentially published as a graph with minimal supporting commentary. The main relevant condition specified in the reference for the validity of information was that the lift to be used was 2FA and that, if different, other lift values would be needed. The shell size and the type of shell information were not specified ; instead, the weight of the shell was used to determine the amount of lift to be used.

Figure 1: Shell Lift Values



The graph was thoughtfully constructed and was actually designed to be used for the first of three shell weight ranges presented for determining lift charge values. The first range was for shells weighing less than 1 lb. up to those weighing up to 10 lb. The second range was for those shells weighing from 10 to 20 lb. The third range was for shells weighing more than 20 lb. The lift charge specifications for the second and third shell weight ranges were given as lined statements across the top of the graph.

Using the graph to find the amount of 2FA lift to use for shells having a weight from less than 1 lb up to 10 lb, find the weight of the shell (without any lift attached) on the vertical axis line of the graph, read across to the curved line of the graph to where the shell weight value intersects the curve, then read down from this intersection to the horizontal axis line of the graph to find the weight (in ounces) of 2FA lift to use.

Unfortunately, as published, one can observe a labeling error in the 2FA lift - oz. axis of the graph. This however, does not detract from the overall usefulness of the information provided.

The PGII bulletin does not credit the author of this curve. The author was Jon Miller, a current HPA member. According to Jon, he compiled data he had gathered from working with Illinois Fireworks in the late 1970's and from previous PGII conventions where he had discussed with other members what they were using. He plotted the gathered data and came up with a curve. That curve was the one published in PGII bulletin No. 22 in the questions and answers section. Stan Warren, a shell builder and current HPA member, has corrected the labeling glitch and has reproduced the curve. A copy of this corrected chart is included as Appendix 1 for this article. Jon also "updated" the relevant conditions[4] for using the curve by stating: "my chart was based on Goex 2F used at that time. There are other, primarily foreign made, brands of BP in the market now and [I] don't know how they compare with Goex as far as strength and burning characteristics. Also it was assumed a reasonably fitting shell in the mortar - not tight and not loose either."

Another reference published in the PGII Bulletin as a two part article[5,6] is perhaps one that should be included here to balance the "experiential" information with some " theoretical" aspects. The authors of this two part article present many factors involved with firework shell ballistics and present findings based on a theoretical basis rather than by using actual experimental firings. Their article was designed to enable a reader to come to some conceptual conclusions when one uses Shimizu's ballistic concepts to describe the performance of firework shells. Although the article does not directly answer the questions posed at the beginning of the present article, it was mentioned here to suggest to any novice shell builder to be aware of some of the concepts involved in the dynamics involved in a functioning fireworks shell of which considering the amount of shell lift is only one of many to keep in mind.

The historic approach used here to answer the leading questions posed above hopefully will give any would-be shell builder some direction. The two somewhat specific sources presented information for the kinds of lift (blasting 2F or fireworks grade 2FA) involved but go on to qualify the validity of using the lift by certain specific conditions that if not met would lessen the reliability of using any of the lift charge amounts given. The charge values given can be useful as starting approximations which might be modified as needed but hopefully without drastic variation. If other lift powder sources are to be used (home made lift for example) it would be wise to check out each such source with some tests using dummy or inexpensive shells prior to using the lift for other shells.

By now hopefully the reader has sensed or otherwise picked up from the flow of this article on the concept that commercially produced black powder (BP) of recognized quality is the preferred or highly recommended source of powder to be used to lift fireworks shells. Unfortunately, for many novice pyros the availability of commercially made BP is usually limited. This means that alternates such as homemade versions of BP would be the choice that many may have to face. This could be the topic of another article.

This author wishes to acknowledge and to thank both Jon Miller for taking the effort at compiling the 1981 PGII graph (and providing updated comments) and Stan Warren for providing the corrected version shown here, and again thanks to both for helping review this article.

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RD

USING A CARGO TRAILER FOR DISPLAY WORK

By Charles P. Weeth

I frequently use trailers for shows to haul mortar racks and other gear. I've used the standard 6' x 12' U-hauls as well as stock and custom trailers in a variety of sizes.

One basic is to have at least one side door. This way you can get stuff in and out without having to go through the back door.

I like to stack the racks so I can get at things from the side door. This way if I need a tool or something I can get at it without having to unload a bunch of racks.

Another tip is near the ceiling you'll want to have some rails that you can put up or down as needed. This is where the shovels, rakes, brooms can go so they are accessible but out of the way.

If you have long slats for the electrical firing system, these can go up here too. They are less likely to be damaged in transit than sitting on top of the racks. Tie them down because they'll bounce!

I prefer the color white because it is cooler inside when the summer sun is beating down.

On my wish list are:

A ladder rack (For ground display poles, etc.)

Exterior lights all the way around (You may need a second battery for all of these lights).

A roof vent, skylight and a couple of small windows with screens. This way when the gear is out of the trailer, it is a place to rest or work that is out of the weather, but still has natural light and air.

The doors need a latch that can be opened from the inside.

A tool box mounted on the tongue is great. Of course it would need to be well built with a good lock and hasp too.

I have a toolbox with different height and length receivers so I can handle almost any trailer. High and low receivers can be helpful if the terrain where the trailer is parked is uneven. It is one thing to park a trailer on uneven terrain, yet another to hook up.

The trailer toolbox has most of the different size and rated balls as well as various electrical connectors and adapters so almost any trailer can be pulled properly and safely. It also has fuses, electrical wire and tape to make repairs to the trailer's electrical system.

Penetrating oil is a must for any stubborn hardware that is encountered. Silicone spray helps with the connectors. It also has de-icer for dealing with any hardware that is frozen.

I carry heavy duty towing chains too. These can be used to lock the trailer up when parked. If a safety chain is too short or is broken, the towing chains can be used, but don't put too much stock in them holding a heavy trailer at highway speeds.

The trailer should have an emergency brake and connection. This is simply a wire from the emergency brake that goes over the ball. If the trailer separates from the vehicle, the wire pulls the brake on the trailer to keep it from careening too far.

The trailer toolbox also has locks with various size hasps so I can be sure to lock all the doors of the trailer.

I carry a 2 pound hammer, a large crescent wrench, a large channel lock pliers, some pry bars and a bolt cutter. Sometimes things need to be persuaded to work.

Make sure you have chocks for the wheels on both sides. Wheel chocks should be at least 4" x 4" and wider than the tires. If there is any slope to the ground, wheel chocks should be 6" x 6" or more.

One other tip. Carry a jack that is capable of lifting the trailer tongue up high enough to hitch to the truck in case the jack on the trailer has a problem. A fully loaded trailer with a broken tongue-mounted jack will surely ruin your day!

Jack stands on all four corners are good to have so the trailer can be stabilized when being loaded and unloaded. They also come in handy if the trailer jack is broken or missing.

Whether a truck or trailer is used, you'll want a heavy duty 2-wheel cart with large pneumatic tires for moving racks. Pneumatic tires work better on uneven ground than solid tires.

You'll need plenty of tie down straps and some bracer bars to secure the load. If you use rebar for stakes for the racks, you want a heavy wooden box that that will keep them from flying around.

Racks should be stacked on their sides and progressively lower to higher from back to front. They will shift less from turning and braking this way. Racks that are loaded on their bottoms bounce around like crazy. This isn't good when you're moving along at freeway speeds on a windy day!

Some fundamentals learned through experience:

#1 Don't use anything less than a heavy duty 3/4-ton pickup with a towing package. Most SUVs and 1/2-ton pickups may be able to pull it, but they don't have the frame, suspension, wheels, tires, brakes, transmission, engine and cooling systems to do so safely and efficiently,, especially when fully loaded.

#2 Use a hitch rated for the load. Just because a hitch has a 2" receiver doesn't mean it was designed for the weight being pulled. All hitches and hardware are rated and a Class IV or V hitch is what will be needed.

#3 Don't overload the truck or the trailer. If you have too much stuff, get another truck and trailer. It is very easy to overload a trailer, so have some idea what the racks weigh. Just because there is room for everything doesn't mean the truck or trailer can handle the load.

#4 Balance the load. Heavy stuff on the bottom, light stuff up top. Equal weight on both sides and front to back too.

#5 16" wheels work best both on and off road. Check the tire pressures regularly too. One tire that is lower than the rest can be devastating!

#6 If the trailer sways when empty, it will sway even more when fully loaded. Anti-sway bars can help.

#7 Maintain the trailer regularly, just like any vehicle.

Also remember trailers that are used to store mortar racks will smell like mortar racks!

Trailers are like trucks and garages: whatever size you think you'll need, always get at least the next size bigger. Don't get too big! If the truck and trailer combination are rated for more than 26,000 lbs. GVW you'll need a different class of driver's license. CPW

MORE ON CARGO TRAILERS

By Tom Dimock

I do have a few recommendations. I have a 6'x14' trailer that I use for fireworks and love it. My trailer was ordered through a Wells-Cargo dealer.

I had them add one foot to the side walls over standard. This is very important unless you enjoy trying to move heavy racks around in a hunched over posture. It also means I don't bang my head on the doors going in and out.

I had the normal plywood floor replaced with diamond plate aluminum and the wall linings upped from the standard 1/4" plywood to 3/8". The standard materials would get banged up pretty fast.

Because you'll have a lot of weight in there, you want double axles and electric brakes. You might also want to consider a ramp rear door to avoid lifting the racks in and out. Do it right and you'll love your trailer. Try to go cheap and you'll curse the day you bought it.

One other thing I did was have the trailer fitted with 12 volt fluorescent lights. GREAT for loading after a show!! TD

THE 3-LB. SUGAR ROCKET

By Stewart Tick

While growing up in the 1960s, I recall hearing about a rocket propellant that was made by melting a mixture of potassium nitrate and table sugar. When I tried this, I found that the product was quite hygroscopic, and didn't burn nearly as fast as black powder, so I quickly abandoned it. In fact, I had nearly forgotten about it when I began reading Homer Hickam's "Rocket Boys" two years ago. After reading of Hickam's successful rocket launches with the nitrate-sugar formula, I decided to try it again, and this time I too was successful.

The nitrate-sugar propellant has both advantages and disadvantages when compared to the traditional black powder mixes. On the plus side, it is theoretically about 50% more powerful than black powder (though somewhat more difficult to ignite). In addition, no special tooling is required to load it into the rocket casings.

The major drawback, of course, is the hygroscopic nature of the mixture. In the book "Pyrotechnics", Weingart wrote that "a piece of lancework made with strontium nitrate, exposed for one hour to a very damp atmosphere will hardly burn". Exactly the same observation could be made of the nitrate-sugar mixture. Consequently, the rockets must be prepared in a room where the relative humidity is 55% or less, and then immediately sealed in ziplock bags before being taken outside in the humid weather. If the air is damp, the engines need to be attached to sticks or loaded into model rocket bodies and launched as soon as possible. (If the propellant is allowed to absorb moisture, the result will be a slow-burning *smoke bomb* rather than a rocket launch.)

As long as it is kept dry, the propellant burns readily and smoothly, though somewhat slower than black powder. The thrust duration (or *burn time)* for a 3-lb. nitrate-sugar rocket containing 150 grams of propellant is about 2 seconds, compared to 1 1/2 seconds for a 3-lb. black powder engine.

Here is my procedure for making the 3-lb. sugar rocket engine:

1. A 1" piece is cut from the 3-lb. rocket casing.

2. I cut the aluminum rod in half, and one half is used as a former for the nozzle and central cavity, while the other half is used as a rammer. A piece of masking tape is wrapped around the nozzle-forming rod, 9" from the end. I coat the bottom 9" of both rods with a thin layer of WD-40.

3. Three tablespoons of Durham's Rock-Hard Water Putty is mixed with 1 tablespoon of water, to make a consistency similar to biscuit dough. This is packed into one end of the casing, using the rammer, and then allowed to harden for about an hour.

4. I weigh out 97 grams of potassium nitrate and 53 grams of powdered sugar. I break up any lumps in both ingredients with a spoon, then pour them into the Tupperware-type container and shake the container for several minutes. (The proportions are 65% KNO_3 to 35% sugar.)

5. Next I pour the mixture into the aluminum pot and heat it slowly to about 375°, while stirring constantly. While heating a mixture of nitrate and sugar may sound dangerous, the melting point is at least 300° below the ignition temperature. (Besides, most hot plates go up only to 500° F.) All the same, it is necessary to take proper precautions when performing this operation. I always wear safety goggles and a lab apron, and keep a Tupperware-type container handy that is filled with water, just in case.

After several minutes, the mixture becomes a viscous liquid with a light brown or tan color of peanut butter. The mixture should not be heated any longer than necessary; excess heating will result in excessive decomposition of the sugar *(caramelization).* The liquid should not be allowed to turn to a dark brown color. The consistency of the liquid should be a little thinner than that of honey.

6. Using the spoon, I pour the liquid into the casing. It hardens rather quickly, so it is usually necessary to reheat the final portion to get in nearly all of the propellant. It is

tamped down gently with the rammer.

7. This is the most crucial step. While the mixture is still soft, I push the nozzle-forming rod down the center of the casing to a depth of 9" (where the tape is). It is important that the rod be centered as accurately as possible. Then the rod is held in place for 3 minutes or so, to allow the propellant to harden, and then it is cooled for another 7 minutes while being held in an upright position. At this point I remove the rod by rotating it right and left while gently pulling it out of the casing (sometimes pliers are needed to get a firm grip on the rod).

8. I mix up another batch of Durham's, then coat the nozzle-forming rod again with WD-40. The rod is inserted into the central cavity in the propellant to a depth of 4" or so, and then the water putty is packed around the rod until the casing is filled. I allow the putty to harden for about 20 minutes, while keeping the casing in an upright position.

9. After 20 minutes I remove the rod and then shape the putty into a cone by carefully rotating the rod around the inside of the casing while it is being withdrawn. The finished nozzle should look like the drawing.

10. After the propellant has cooled for an hour, the now-finished engine may be placed on its side. I allow it to harden and cure completely by keeping it overnight in a room with the humidity at 55% or less, then I seal the engine in a ziplock bag from which I have expelled as much air as possible.

11. I find it necessary to prepare an igniter because the propellant does not ignite readily from visco fuse. I do this by cutting a 2" length of plastic soda straw and plugging one end with Titebond wood glue, and then filling the rest with a mixture of 7 grams potassium nitrate, 2 grams of airfloat charcoal, and 1 gram of sulfur. I insert a 5" length of visco fuse into the straw and glue it in place. This igniter I insert four inches into the engine's central cavity, and then it is ready for lighting.

MATERIALS

Rocket casing, 3-lb., 1" dia. x 12" long
Aluminum rod, 1/2" dia. x 3-ft. long.
Durham's Rock-Hard Water Putty
WD-40
Straw, soda, plastic
Glue, wood, Titebond or Elmer's
Visco fuse
Pot, aluminum, small
Hot plate
Spoon, long-handled ("iced tea")
Potassium nitrate, fine powder
Sugar, Confectioner's powdered 10X
Charcoal, airfloat
Sulfur, fine powder
Container, plastic, food, Tupperware-type
Bags, plastic freezer, ziplock-type

Note: many of the items can be found in Home Depot or similar stores.

12. Cleaning up is a simple matter. The nitrate-sugar formula does not produce the "airfloat charcoal mess" associated with black powder mixes, so I just fill the pot with water and place the rods and spoon in it. Within an hour the nitrate and melted sugar will have dissolved and everything will be clean.

The next step would be to mount a payload (or *heading)* on the rocket, but I'm sorry to say I haven't gotten that far yet. Theoretically, these rockets should be able to carry a payload about 50% larger than a 3-lb. black powder rocket, and should peak at about 50 lbs. of thrust. Of course, they will lack the long charcoal tail of black powder rockets.

I intend to add the time delay by inserting a 1/8" dia. nail (coated with WD-40) through the putty in the top end plug before it hardens. After the putty is hard, the nail could be withdrawn with pliers, and a 2" piece of 1/8" visco fuse may be glued into the hole. It would probably be a good idea if I first primed the fuse ends with a paste of black powder and water. This process should provide a delay of about 5 seconds before the heading or ejection charge ignites. ST

Afterthoughts...

After contact with several other rocket enthusiasts, I have a couple of things to add:

I've been told that electric frying skillets do have accurate temperature controls (go up to 450 to 500 degrees). I've been told these skillets are perfect for melting nitrate-sugar mixture.

To ignite the rockets electrically, if desired, by modifying the soda-straw igniter I described. Just substitute an Estes model rocket igniter for the visco fuse (and leave everything else the same). ST

TRADITIONAL BLACK POWDER ROCKETS

By Bob Svenson

"Where do I start?" is a question that all beginners in pyrotechnics ask. Till recently, I really didn't have a good answer for that question. I could tell you where I started, but that may not be the course everyone wishes to take.

However, I've recently discovered what I think is the perfect place for beginners to start - ***sky rockets!*** Here are a few reasons why I feel this way:

- Instant gratification! I can just ram one up, attach a stick and go launch the thing! No waiting for stars, paste, etc. to dry.
- The chemicals and materials are relatively cheap and easy to obtain.
- No complicated processes are used - just simple screening and ramming.
- They are (hopefully!) quiet to launch and require no cumbersome mortars.
- They can carry a decent sized heading.

They do have some drawbacks; foremost is the initial cost, which can run a few hundred dollars by the time tooling, motor casings, and chemicals are purchased.

I recommend starting with the tried and true 1 lb. (3/4" i.d.) rocket.

TOOLING: I would purchase the tooling rather than try to improvise it to get tooling that's based on a proven, reliable design. Here are a few things I would look for in tooling:

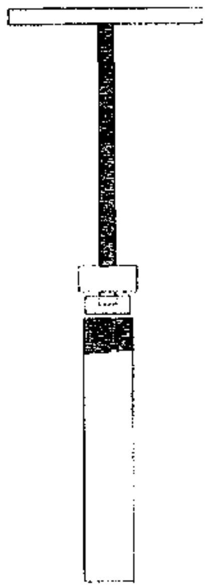
- Erosion of the spindle at the base where the operator rams the nozzle is a problem. I would opt for a stainless steel spindle (though aluminum or brass will work fine).
- Get a large (4" or so) base to provide stability while ramming.
- Have the tool maker mark the rammers - one mark to show where the rammer will bottom out on the spindle (and swear on whatever you hold sacred that you will never bottom the rammer out while ramming!), the other mark showing where to change to the next rammer.
- Have the tool maker drill holes in the ends of the rammers so if a rammer gets stuck in the case I can put a small rod or screwdriver through the hole and twist and pull to remove the rammer.

CASING SLEEVE: A casing sleeve is used to keep the motor casing from bulging during ramming. The fuel grain needs to be packed tightly, but ramming too hard can bulge and weaken the motor casing. Using a sleeve to support the motor casing prevents this from happening. Casing sleeves are not readily available, mostly because there are so many sources for the motor casings and their outside diameters vary by several thousands of an inch. I have found that the best approach is to purchase a lot of casings so they are consistent, then find a tube that's close to the size needed, but just a little smaller. In the case of a 1 lb. rocket, a piece of schedule 40 plumbing pipe will usually work fine. The nearest machine shop can ream it out until there is a nice, snug fit for the casings.

Once the composition is rammed into the motor casing it will be found that it is very difficult to remove the casing from the sleeve. To remedy this some split the sleeve and use hose clamps to tighten or loosen the sleeve. I took a different approach and did not split the sleeve. Instead I threaded one end of the sleeve, then drilled and tapped a hole in a pipe cap. I also cut a short length of 1 1/4" steel rod and had the machine shop turn it down to be a loose fit inside the sleeve. A hole is drilled about 1/4" in one end of the rod.

To remove a loaded motor from the sleeve, I place the short piece of steel rod on top of the motor (the end with the shallow hole in it is toward the outside), then I thread the pipe cap onto the pipe. Next I thread a piece of ready rod with a handle welded onto it through the tapped hole in the cap. When the ready rod is turned, it enters the short hole in the rod (this helps keep the rod centered and pushing straight down) and then pushes against the rod, which pushes the motor out. (This is essentially a very slow press.)

Since a picture is worth a thousand words I've included a sketch of the casing sleeve that I'm using.



HAMMER: I use a 4-lb. shot loaded dead blow hammer that I purchased from the local auto parts store. Since the goal is to compact the composition into one solid grain, I would choose the heaviest hammer that I could repeatedly swing accurately and solidly. Using a hydraulic press is actually the best idea, but when just to getting started, hand ramming works fine. (But don't be surprised to find yourself dreaming of presses once you're hooked on skyrockets!)

Fuel formula and chemicals: I have found that there are as many rocket fuel formulas as there are people making rockets! However, most fall close to the common "6/3/1" formula that's been around for years.

Potassium nitrate, -100 mesh	60%
Charcoal, 80 mesh	20%
Charcoal, Air Float	10%
Sulfur, -100 mesh	10%

Potassium nitrate: I've used K-Power fertilizer and Skylighter's product. Both were milled down to -100 mesh and worked fine.

Charcoal: So far all the charcoal I've used has been from Skylighter.

Sulfur: So far all the sulfur I've used has been from Skylighter. I prescreen it through a 100-mesh screen.

To mix the components, I pass the potassium nitrate and sulfur together through a 40-mesh screen until it's uniformly mixed (10 or less passes through the screen). I then add the 80 mesh charcoal and screen it in until it's also uniformly mixed. Last I add the air float charcoal and screen it in. Screening in the air float is a nasty job (there's a reason it's called "air float*'!), best done outside in a well ventilated area and wearing a mask! I'm probably going to more effort than is necessary. I've heard from several who just dump all the chemicals together and run 'em through a 40-mesh screen 3 - 4 times and call it good. They claim their rockets fly just fine and I'm sure they do. I'm just a creature of habit and my method has always worked for me.

For the nozzles and upper bulkhead plug I'm using Bentonite clay from Skylighter, mixed 50/50 by volume with a mineral called "Kyanite". The product I'm using is about -80 mesh. Kyanite is available from some pottery supply nouses (currently no pyro chemical suppliers carry it, but perhaps if enough people inquire about it they would be inclined to do so). I've heard that a material called "grog" is available from the pyro chemical suppliers and that it also makes a very durable nozzle.

MOTOR CASINGS: A 1 lb. motor casing has 3/4" i.d. and is 7 1/2" long. I've used casings with 3/16" and 1/4" thick walls and both have worked fine. Most of the pyro suppliers carry the proper casings. It is wise to get a bunch so it is unnecessary to mess around remaking the casing sleeve.

Okay, so with the tools, casings, and rocket fuel ready, what next? Here is my procedure:

- I place a motor casing over the spindle.
- Using a standard kitchen measuring set, measure out two teaspoons of clay and pour it into the casing.
- Insert the first rammer and give it 15-20 good solid blows with the dead blow hammer.
- Remove the rammer and dump out the loose clay.
- Measure out two teaspoons of rocket fuel and pour it into the casing.

• Ram the composition with 15-20 good solid blows.

• Continue in this manner, changing rammers as necessary until I reach the top of the spindle.

• Once the top of the spindle is reached, I ram in one more two-teaspoon increment of rocket fuel.

• Now I ram in a two-teaspoon increment of clay. For the beginner's first few rockets I would suggest using the flat rammer and not installing a heading. Once proficient, he can either ram a solid clay plug and carefully drill back through it into the fuel grain or use one of the "top hole" rammers the pyro tool makers sell that creates a hole in the plug as it's being made to create the heading pass-fire.

• Remove the motor from the spindle. I've heard that some have problems doing this, but so far I've had no problems. I just hold the motor in my left hand and gently twist clockwise with my right hand while slowly pulling out. Once the spindle breaks loose it should come right off, thanks to the taper on the spindle. I always twist clockwise so as to tighten the screw holding the spindle to it's base.

• Remove the motor from the sleeve.

Now the motor is completed. At this point I like to put a wrap of paper that overhangs the end of the tube an inch or so around the nozzle end of the motor. I'll discuss the reason for this shortly.

All that's left is to attach the motor to a stick and fuse it up!

STICKS: I cut my own from scrap lumber I find. I've been using 1/4" square sticks that are three to four feet long (it just depends what scrap lumber I can find).

A problem I have yet to solve is that of stick warpage during storage. The darn sticks just seem to turn into "banana boards" after a week or so. When I get a little more time I'm going to try several different types of wood and see if I can find something that will hold it's shape a little better. I also wonder if sandwiching the sticks between a couple boards during storage would help stop the warpage.

To attach the stick to the motor I've used hot glue and I've also just taped it to the stick with masking tape; both methods worked fine. Whatever attachment method the beginner chooses, he should make sure to get the motor on the stick straight! I run the stick up the side of the motor about three-quarters the length of the motor.

FUSING: I've been running a piece of black match up the entire length of the motor core, leaving a generous amount sticking out of the end of the motor. Once the match is installed I take the paper (that I installed earlier) that overhangs the end of the nozzle and gather it around the match and tie a string around it. This keeps the fuse from falling out and the paper doesn't bother anything as it just burns up as the motor fires. I also like to carefully bend the match up the side of the motor and tape it so that when lit it doesn't have a straight shot up to the motor.

I may be overdoing this also - I've talked to several people who use a piece of match or visco inserted just in the nozzle far enough to touch the fuel grain (rather than running it up the entire core) and they claim it works just fine. I've tried both ways and it seems to me that lighting the whole core gives a faster lift off, but I may be wrong. The beginner will just have to see what he prefers.

That's about as far as my experimentation has taken me thus far. I'm currently building a press. Once it's finished I'll tear back into rocketry. I'd like to try adding some various metals for different tail effects as well as trying out some of the neat heading effects I've seen - I can't wait to try a crossette or multi-break film cannister heading!

SOURCE FOR KYANITE: Kyanite appears to be turning out to be the preferred additive to nozzle clay to make the nozzles more resistant to erosion and to hold in the tube better. I surfed around the Net and found that www.axner.com has it in 100 mesh, which works fine for me. It runs about 950/lb. in 1 lb. quantities, and the price drops dramatically the more you buy. It's listed under "Raw Glaze and Body Materials", or just use their search engine to search for the word kyanite and it'll take you right to it. BS

WHISTLE ROCKETS USING STROBE ROCKET TOOLING

By Bob Svenson

Recently while watching AFN's "White Strobe Rockets" video by Steve LaDuke I noticed that he mentioned that it's possible to use the strobe tooling to make what he termed a "Long Winded Screamer". Unfortunately, Mr. LaDuke didn't go into much detail on this rocket in his video.

I posted a note on the Internet to the Pyrotechnics list hosted by EGroups. One of the subscribers sent me some notes and a handout from the PGI Convention detailing the spindle dimensions for a 2 lb. (7/8" i.d.) rocket.

The spindle detailed was slightly larger and longer than a 2 lb. strobe spindle. I figured if it flew with a larger spindle then it ought to fly with the smaller strobe spindle (though probably not as well).

I decided to try a rocket using my 1 lb. strobe tooling. I built the motor in the same manner as a strobe rocket except that for the strobe composition I substituted the following whistle mix:

Potassium perchlorate	64
Potassium benzoate	32
Red iron oxide	1
Petroleum jelly	5

This is in parts, not percentages.

Sodium benzoate was listed on the handout I received, but I only had potassium benzoate on hand so I tried - it worked fine.

The potassium perchlorate I used was the old Swedish perchlorate; if you are using any other perchlorate then the amount of petroleum jelly used may have to be adjusted (probably downward). (I would be interested in reading about other's experiences with the new "gourmet" perchlorate, if anyone would care to share their experiences with it.)

The basic difference between this and a normal benzoate whistle composition is the addition of more petroleum jelly to the mix - this slows the composition down and allows it to function with such a long spindle.

This composition is a bit more troublesome to press than a standard whistle mix - it extrudes up between the rammer and casing (and into the hole in the rammer) much easier than a standard composition, which makes it difficult to remove the rammer after the increment has been pressed.

When I fired the rocket I was most impressed! It flew fast and high, with a nice, clear, long winded scream!

If you're like me you can only afford so many tools, so I'm always happy when I find that a tool can perform a task other than that for which it was designed.

I'd like to thank Steve LaDuke for his fine seminar at the PGI convention (and the resulting AFN video). His knowledge and expertise are clearly evident and well conveyed on the tape!

If you are considering trying your hand at Strobe Rockets, or End Burning Rockets, I highly recommend Mr. LaDuke's videos - they are simply wonderful! BS

PROPER USE OF CLAY

by Harry Gilliam, Skylighter, Inc.

Folks call or write Skylighter with all sorts of questions. We hear some of them over and over again. Here's one:

Q: I am trying to make rocket nozzles with bentonite clay, but the plugs tend to shrink and fall out. I used water to moisten the clay. Is that correct? Also, they are cracking when I drill through them to insert the visco. What am I doing wrong?

A: Using water, that's what! Ram the dry clay using a hammer and an aluminum rod or anything else that is very strong and non-sparking. Make the finished clay plug at least as thick as the inside diameter of the tube. Use dry clay, not wet. Ram the plug so hard that it slightly bulges out the sides of the tube. Then gently drill your hole. HG

ARE ZINC/SULFUR ROCKETS HOT? YOU BET!

By Geny Gits

Back in the late '50s a treatise written by a former military man on zinc/sulfur rockets for young scientists, fell into my hands. Powdered zinc and flowers of sulfur were obtained from Central Scientific Co. Hieing off to my father's shop (he was an inventor and machine tool designer), I located some thin wall stainless steel tubing of various diameters, 1"- 2" dia. These were cut in various random lengths, 6" up to 2 1/2", then were mounted in a lathe with about 3 to 4 diameters extending beyond the chuck. A cone shaped live center was mounted in the tail stock and pressed against the end of the tube. A swaging tool, essentially a roller bearing assembly mounted in the tool holder, was used to reduce the diameter of the tube, forming the nozzle. The nozzle diameter was eyeballed but probably fairly close to 1/3 the diameter, as I remember it. And probably close to a De Laval configuration.

The nozzle was corked with a wooden plug, the propellant filled from the top and the unit bumped on a stump to consolidate. No drift or compacting tool was needed, the weight of the zinc being adequate. A wooden nose cone was machined and attached. Stabilizing fins were attached with sheet metal screws prior to filling.

Ignition was a problem - visco did not work. Visco plus black powder was no better. Firecracker (flash) powder was considered, but being somewhat familiar with dynamite, there was fear of it acting like a dynamite cap, and -BLOWIE!. The treatise called for hot wire ignition which I took as just a means of remote launching. A test done with a broken automobile light bulb with the filament intact, cooked off small batches of propellant, but when inserted in the butt orifice of a rocket produced much smoke and flame but nary any lift. It was there I learned the difference between atmospheric burning and burning under pressure. Going back to the treatise, it was discovered that the "burst diaphragm" had been neglected. It showed a thin copper disk fixed under the nozzle and igniter. A tight fitting wooden plug was fashioned with two holes for the copper leads for the igniter and the plug carefully tapped in.

By now I had acquired a cohort, Fred. We drove in his pickup to the bluff overlooking Lake Michigan, which we had renamed Cape Carnival, because, we said, we were just a couple of jokers. We set up the launching rail and slid on the rocket. It was 1 1/2 in diameter and 18" long. Then we attached wires, moved the truck 100-feet away, and were going to use the truck battery for igniter power. I jammed the wire ends onto the battery terminals and ... nothing. We sat down and had a barley tonic. After an appropriate wait we approached the launch pad. An ohm test snowed we had continuity through the long wire and through the igniter. What could be wrong? I opined to Fred that perhaps the 100' lead was too much resistance for six volts.

The truck was moved closer. Now the wire was 20 feet long. I jammed the leads onto the battery terminals and ... nothing. I hold the wires down, hard, till my fingers go numb ..... nothing. "Wait," says Fred, "I'll start the motor." I'm crouching down behind the truck with the truck between me and the infernal rocket, Fred slides into the truck in a prone position, from my side, keeping below the level of the window. He turns the key. He pushes the starter button. The motor chugs to life.

"Are you ready Space-King?" shouts Fred. I respond, "I am ready Space-Master," Fred presses down the accelerator with his right hand. The old Dodge engine roars. I jam the wires onto the terminals again. The fan is blowing the hot radiator air into my face. The noise of the engine is raucous. I imagine that I see a wisp of smoke at the vent end of the rocket. Before I can be sure, there is a noise like something ripped from hell - a venomous hissing, tearing, ear splitting explosion sound, and I am covered by a cloud of metallic tasting smoke. I am coughing and choking. Fred is OK. I run to the other side of the truck to assess the damage. There is none. The launching rail is still there. There are no holes in the truck. There is a burnt patch of grass with a whitish halo below the launcher which has a smoky white stain its whole length. I look to the sky, nothing. I look out to the lake, hoping to see a splash, nothing. Apparently the rocket got off, never to be seen again.

The rest of my rocket menagerie was fired off uneventfully, entirely successfully, with two 12 volt batteries in series. And viewing a rocket lift off? Just for an instant you could see it as it left the launcher and then it was gone. Once, I did see one come down, a mere speck, barely discernible miles out in the lake(or so it seemed). The others, I am sure, are circling the earth out in space, a billion year testimonial to my fleeting moment on this planet.

Did I become a Rocket Scientist? Of course not. Are you silly? GG

QUICKLY IGNITING A FLIGHT OF SMALL ROCKETS

by Bob Svenson

Flights of rockets are awesome effects seldom seen in modern fireworks displays. We discovered them years ago when a friend invited us to their annual Fourth of July picnic which featured a small Consumer Fireworks display. Our host showed us a very quick and easy way to create a very dense flight of small rockets. Before the green safety fuses became common on bottle rockets they used to have a paper firecracker fuse which was GREAT for a quick and dirty rocket flight! He just crammed as many as he could get into a coffee can and brushed by the outer ones with a torch. Once a couple lit the sparks from those rockets would light the easily ignitable firecracker fuse and voila! instant rocket flight!

Though they were fun effects we craved something bigger. We found the next size up of whistling rockets suited the bill just fine (we like to use "Screaming Rattlers"). The sound of a bunch of them taking off is awe striking, and the visual and audible effect of all of those crackling headings going off is outstanding!

A couple of my friends built a collapsible rocket stand as shown in Weingart to launch them. Unfortunately these rockets (as well as most recent bottle rockets) use the small green safety fuses which are not as readily ignitable as the paper fire cracker fuses. In our first few attempts we simply used black match and put small slits in the paper sleeve for the rocket fuses to slide into. This worked well and the safety fuses took fire without a hitch. The problem was that it was very time consuming to slit the paper sleeve and insert the fuse. One of my partners in pyro hit upon a simple solution though - he took a small copper tube he found in the garage and drilled holes in it for the rocket fuses, then he mounted the copper tube where we used to place the quick match on the rocket stand. When it comes time to launch the rockets he just pulls a length of black match out of it's paper sleeve and inserts it into the copper tube. Then we set the rockets on the stand and stick their fuses into the holes in the copper tube. All that's left is to insert a length of visco and light up the night sky!

(Note - if you don't have any black match then the "magic whip" item can also be removed from it's paper sleeve and used in place of the match but the burn rate of the whip is slower so the flight will be slower)

The match burns fairly cleanly but if the fuse holes do get plugged with debris usually just using the fuses of the next batch of rockets to push the debris out while you are reloading is all that's necessary.

Give it a shot - it's quick and easy and a very rewarding effect! BS

TIP OF THE MONTH

Recent articles in AFN by Wayt Gibbs, Joel Baechle and Bob Svenson concerning using bamboo, cattails and other untraditional materials for rocket sticks has prompted this comment from a pyro living in Spain:

Bamboo is a bad idea, I know: One Nov. 5 I had made about 20 3/4" rockets but had no sticks. My horticultural mate taped some thin garden canes to them. They flew perfectly but in the morning they were all stuck in the lawn end on like so many golf flags. I thought it was a practical joke till we tried one. The spent motor acts like the feathers on an arrow. Could easily have an eye out.

Steve Humby

WHITE STROBE ROCKET NOTES & COMMENTS

By Bob Svenson

One of the first items of amateur pyrotechny that I witnessed was a white strobe rocket. The thing was just glorious! A short screech as it raced out of the launch tube, followed by a hefty thumping similar to a Huey helicopter, then a short whistle and a silver flitter heading was deployed. I was awe struck! I could hardly believe that an amateur could produce such an impressive item!

From that moment on I was hooked! However since I was just beginning my amateur pyro career I didn't have a press, a ball mill, etc. so I concentrated on film canister shells and similar devices.

During this early stage in my career I was fortunate enough to have the opportunity to get some one-on-one training from Doc Barr. I must say this was probably the single most valuable experience I've had to date. The opportunity to work with and learn from an accomplished pyrotechnician is something that just can't be replaced with seminars, books, videos, etc.. During my time with Doc I was once again introduced to white strobe rockets and once again I was awe struck by the device! After I arrived back home I immediately ordered a set of strobe rocket tooling!

Unfortunately the tooling just sat there on the bench. Family and job issues kept eating up my pyro time. During this period I decided to try black powder rockets - they required a minimum amount of tooling, were relatively cheap to make and, most importantly of all, I could get a quick pyro fix by ramming one up and launching it with no waiting for stars, glue, etc. to dry! I became quite proficient at black powder rockets, and since I enjoyed them so much, I invested in a press. Then I found that potassium nitrate fertilizer was very cheap and worked fine for BP rockets but required milling down in a ball mill, so I had to build a ball mill.

About this time AFN started advertising their White Strobe Rocket tape. HEY! I suddenly realized that I had everything necessary to make white strobe rockets (tooling, press, ball mill). I promptly ordered a copy!

The tape was shot during Steve LaDuke's seminar at the '99 PGI convention in Fargo. Mr. LaDuke presents a great seminar! I watched the tape several times and took notes while watching; in short order I felt I was ready to attempt my first strobe rocket.

What follows are the notes I took from the video along with additional comments reflecting what I've learned while working on the rockets. These notes and comments are just highlights of the tape - I strongly encourage anyone interested in working with white strobe rockets to get a copy of the tape as there are no doubt several things that I've missed.

Whistle Mix Preparation

Potassium perchlorate	76%
Sodium salicylate	23
Iron oxide	1
Vaseline (petrolatum)	+3(additional)

- A 40 mesh screen is used to prescreen and weigh out the perchlorate and iron oxide.
- A 40 mesh screen is used to screen the potassium perchlorate and iron oxide together.
- A gravy strainer is used to prescreen and weigh out the sodium salicylate.

Ball milling is the most effective way to mix the whistle mix, but is dangerous. To mix a 1,000 gram batch the sodium salicylate and potassium perchlorate/iron oxide are dumped in a large bowl and mixed together with a fork, then about 15 lbs. of 9/16" lead balls in a rock tumbler are used to mill the mix for 10 - 15 minutes.

Without a ball mill smaller batches must be used. One could use a gravy strainer to screen the potassium perchlorate, iron oxide, and sodium salicylate together once or twice.

Note - Hand mixed whistle mix is not as powerful as ball milled whistle mix. Good mixing procedures are needed to ensure the mix is powerful enough to allow the strobe to have enough lift.

(Bob note: Per the suggestion of a couple of my partners in puro, I prescreen the perchlorate through a reusable coffee filter - these fil-

ters are designed to replace the disposable coffee filters in a coffee maker. They hove a stainless steel screen thats somewhere around 100 mesh; with the basket shape they work great for prescreening materials.

Though Mr. LaDuke recommends ball milling the whistle mix I'm just not comfortable doing that. Ball milling results in a more homogenous mix and hence a more powerful propellant, however I've been hand mixing the whistle mix and my rockets fly high and fast enough for me. Hand mixing is not without risks either - the salicylate generates static when screened which could potentially cause an accidental ignition of the material. I read in the Best of AFN IV *that wearing rubber gloves while handling static generating materials may help avoid an accidental spark, so it may be prudent to do so.*

In correspondence with Mike Carter he related that he won't screen whistle mix because he finds the risk unacceptable. He screens the oxidizer and catalyst together and then places the fuel and oxidizer/catalyst in separate piles in the mixing bowl. He then adds more lacquer thinner to the melted Vaseline than is normally used. By using the additional lacquer thinner he makes a soup which allows for easy mixing of the materials. I've yet to try this approach but he does produce some very high performance rockets, so it is on my list of things to try.

As usual, the pyrotechnist must evaluate the different methods and their risks and decide for himself what he feels is the procedure with which he is most comfortable.)

Next Vaseline is added to the whistle mix.

There are three reasons to use Vaseline:

1) It helps keep the whistle mix from absorbing moisture due to the hygroscopicity of the sodium salicylate.
2) It slows the mix down.
3) It acts as a lubricant during pressing.

There appears to be some differences between brands of Vaseline, but it all seems to work fairly consistently. If the whistle mix is too fast or slow the amount used is increased or decreased.

The Vaseline is placed in a small tin can and melted with a blowtorch.

(Bob note: I use a hot plate. I prefer to keep the amount of open flames to a minimum while engaging in my pyro activities! In previous AFN *articles Mr. LaDuke has mentioned placing his wife's iron in a vise upside down and using it to heat the Vaseline.)*

Lacquer thinner is added to the melted Vaseline - about 21 grams of lacquer thinner per 100 grams of whistle mix.

The Vaseline/lacquer thinner is added to the whistle mix and mixed together with a fork.

Next the whistle mix must be riced through a window screen. It needs to be just the right consistency to rice properly - it takes practice to know when the consistency is right.

A large wooden dowel to push the mix through the screen helps; a cheap 2" wide paint brush with the bristles cut down to make it very stiff also helps to push the mix through the screen.

Once the mix has been riced it is spread out to dry - a comb made of a piece of cardboard tube with wires ran through it helps to spread the mix out.

Strobe Mix Preparation

Ammonium Perchlorate; 90 micron*	60%
Mg/Al -200 mesh	12.5
Mg/Al -200meshQ	12.5
Barium Sulfate!	15
Potassium Dichromatet	+5 (additional)

* Any larger must be ball milled down.
¤ Ball milled 3 hours with 5/8"-3/4" ball bearings.
† As fine as possible.
‡ Ball milled for 10-12 hours until it turns banana yellow. **(Caution!** This is a very toxic material! All due precautions must be used when handling it!)

(Bob note: Although the above procedure looks kind of daunting, it is really not The toughest part of the whole procedure is deciding when to rice the material. With experience the operator will become quite proficient at knowing when the material is ready for ricing, till then it is necessary to use trial and error. If the stuff is wet and smears on the screen as it is pushed through, then it's too wet. Placing it in front of a fan for a short time will make it ready quickly. If it is too dry it won't push

through the screen. If this happens then more lacquer thinner is added and it is tried again. The margin between too wet and too dry is fairly wide so it really isn't that difficult.)

The strobe rate must be high enough to keep the rocket flying. Many things, such as chemical purity and particle distribution of the Mg/Al, affect the strobe rate. (Mr. LaDuke had problems with a low strobe rate that he later discovered were due to the barium sulfate being used.)

If the strobe rate needs to be adjusted one could try:

Ö Adjusting the particle size of the Mg/Al. Larger sizes slow the rate down, smaller sizes speed it up.
Ö Add some magnesium. In the past LaDuke has used 23 1/2% -200 mesh Mg/Al that's been ball milled and 1 1 1/2% granular Mg.
Ö One just has to make some and see what the strobe rate is, then adjust as necessary for the materials at hand.

• Everything but the barium sulfate is combined and run through a 40 mesh screen a couple of times, then the barium sulfate is added and the mixture is run through a gravy strainer several times.

• The mix is then damped with nitrocellulose (N/C) lacquer. Mr. LaDuke makes his own N/C by dissolving about 3 tablespoons of 4640 smokeless gunpowder in a glass jar filled with acetone (it takes about 3 days for the smokeless powder to dissolve).

The amount of N/C is not critical. For an 800 gram batch Mr. LaDuke uses about 1/3 of a Dixie cup of the above N/C mixed with 2/3 of a Dixie cup of acetone. Add enough N/C to get the mix pretty wet - wetter than you would for stars.

• Next rice the mix just as the whistle mix was and then set it aside to dry.

Bob note (a long one!): The strobe mix is what's caused me the most trouble so far...

• *Ammonium perchlorate - I've been using 90 mic AP from Iowa Pyro Supply. The stuff is pretty clumpy so I prescreen it through the reusable coffee filter.*

• *In my opinion the mg/al must be ball milled. Using even the smallest commercially available mg/al I haven't been able to produce an acceptable strobe rate. Others have reported success by combining -325 mg/al and a small amount of -400 mg, though I wasn't able to make that work. I didn't spend a lot of time experimenting either. When I first started with the rockets I really wanted to avoid all the variables I could and I viewed ball milling as a large variable due to the large variation in the types of mills that we use (some use gem stone tumblers, some use optimized mills based on Lloyd Sponenburgh's book, and others use mills made from whatever materials they had available to them). It turns out that I don't think the milling is as big of a variable as I thought. It seems that 3 hours is the magic number no matter what type of mill. I noted that in Lloyd's book he states that milling metals is tricky and that the large particles mill down quickly but once they reach a certain size any further gains come very slowly. I wonder if that isn't what happens here? It takes a gem stone tumbler 3 hours to reach that size, while using an optimized mill probably reaches that size quicker, but any milling beyond that point doesn't really make much of a difference as the gains come so slowly. I have yet to use any magnesium in the mix. Currently I use 25% of -275 mesh mg/al (it's cheaper than -200) that's been ball milled, and my rockets are .flying very well. The steel balls used to mill the mg/al can be salvaged from old ball bearings (a visit to the local truck or farm implement mechanic). I try to get balls that are all the same size. If unobtainable locally then: McMaster-Carr Supply Co., 1-562-692-5911 (Los Angeles branch) or on the Internet at* www.mcmaster.com. *I would think that item # 9528K26 (5/8" chrome steel balls, 50/pkg. for about $12) or item # 9528K29 (3/4" chrome steel balls, 25/pkg. for about $10) would work fine.*

• *Barium sulfate - Since Mr. LaDuke found the barium sulfate to be a large variable in his mix I opted for the pharmaceutical grade stuff available from Skylighter. Recently however I've also used some barium sulfate from Iowa Pyro Supply and I haven't noticed any difference at all in performance.*

• *Potassium dichromate - Such a small amount is needed that I originally tried to* *grind some down with a mortar & pestle - bad idea! It grinds very slowly and whert you're gloved and masked up its just no fun! I dedicated a 4" jar and media to grinding dichromate (1 lb. of dichromate is about a cup by volume so a 4", 1-quart mill jar is well suited to the task). It was recommended to mill it for 10-12 hours until it turns banana yellow. I milled mine in a Sponenmill with a 4" jar and 3/4" ceramic media. I was pressed for time so I milled mine for only about 6 hours. It is a fine powder, and is yellowish, but not banana yellow. So far my strobes have been working fine so I just haven't taken the time to remill the material to see if lean get it to banana yellow.*

• ***Remember*** *- potassium dichromate is very toxic! Every precaution must be taken when handling it!*

• *Nitrocellulose (N/C) lacquer - Though Mr. LaDuke makes his own N/C I purchased mine from Skylighter - I use the 25% stuff. I use about a 4:1 ratio of acetone to N/C (volume or weight may be used to measure in. I use volume, 20cc of acetone to 5cc of N/C per 1OOg of strobe mix). In recent discussions on the Internet's Rocketry-Black Powder (R-BP) group Doc Ban has noted that if the strobe mix is pressed above 2,000 lbs. of force that no N/C binder is necessary. In fact he suspects that its the water that's in the acetone (acetone is hygroscopic) that is responsible for the variations in performance between different batches of strobe mix. If the N/C is affecting performance and is not necessary, then it would seem obvious that the answer is to leave it out. I'm not sure I'm ready to do that - one benefit of using the N/C is that it makes the mix less dusty to handle and with that nasty dichromate in there I'd like to keep the dust down. I prefer to use fresh acetone and to store the mix in tight sealing containers with a desiccant. So far things have been working well.*

• *Steve Mqjdali and Clive Jennings-White have pointed out that Shimizu suggests using amyl acetate (banana oil) as a less hygroscopic solvent for N/C. The use of molecular sieves (available from Skylighter) to dry out the acetone prior to use has also been suggested. I plan on conducting further research in this area*

Pressing

Strobe rockets **MUST** be pressed. Both the whistle mix and strobe mix are sensitive to shock and friction - the strobe mix is especially sensitive to shock.

(Bob note: As Doc Barr said in AFN *a decade ago,* ***DON'T POUND ON WHITE STROBE MIX!*** *I know, I know, none of what we do is* safe, *but believe me, the strobe is sensitive stuff! Just to give some respect for what we're dealing with, a pinch (a small pinch!) put on a vise and hit with a hammer - will demonstrate what I mean!)*

Relatively high pressures must be used to press these rockets, and because of these high pressing pressures a sleeve must be used to keep the motor casing from being damaged.

Recommended pressing forces:

3/4" = 4,245 lbs. of force
7/8" = 5,094 - 5,660 lbs.
1" = 6,226 - 6,792 lbs.
1 1/4"= 7,924 lbs.

(Bob note: In correspondence with Doc Barr he mentioned that varying the pressing pressure will affect the characteristics of the strobing, but as the pressure goes down so does the reliability of the rocket. I haven't had time to experiment with this yet, but it does have my curiosity up so I plan on investigating this further.)

If using tubes cut to length then the tube is left slightly recessed in the sleeve. Once the first increment is pressed it will force the tube down square on the base.

Using the recommended pressing force, the motor is pressed, following the sheet that accompanies the video for the length of the whistle and strobe fuel grains.

The whistle mix likes to squish up into the hole in the rammer so it is necessary to watch this and keep the hole clean or the spindle may be bent.

The first two increments are pressed and then a small measuring scale is used to measure how far up the spindle the fuel grain is. There should be 2" of spindle left.

(Bob note: if tubes of the same length are used each time, having the tool maker mark the rammers is much handier.)

Sometimes the whistle mix will squish up around the rammer (between the rammer and the tube wall); it must be scraped down so the fuel grain is level before switching over to the strobe comp.

After the strobe composition two more increments of whistle mix (that has had a "3 finger pinch" of flake titanium added to it) is rammed.

(Bob note: Safety? Would spherical Ti be safer?)

The spindle is removed from the finished rocket by clamping the base in a vise, then placing the flat rammer in the top of the rocket. Now the top of the rocket is grabbed (which is internally supported by the flat rammer) with a pair of vise-grip pliers and twisted.

(Bob note: I leave the rocket in the casing sleeve and then clamp onto the steel casing sleeve to twist the rocket off the spindle)

Sticks

The sticks for a *Vs"* rocket (the example rocket that was pressed in the seminar) are about 32" long. The sticks need to be long enough to provide a stable flight. Any longer is OK but is just a waste of material.

Hard woods should be avoided. Pine and cedar work very well. The sticks need to be thick enough to be straight and rigid, about 3/8" for 7/8" and larger rockets and about 5/16" for 3/4" rockets.

(Bob note: I've been making 1 lb. rockets and I use the same size stick for a strobe that I use for a black powder rocket (32 to 36" about 1/4" to 5/16" square), They work fine and I don't have to keep two different sizes of sucks on hand.)

Fusing

These rockets are very sensitive to where they are fused. The fuse should not be placed up in the core as it will burn too fast and will cause the rocket to explode.

The proper method is to ignite the very bottom of the fuel grain. There are several methods used to do this; one of the most popular is to coil visco around the bottom of the fuel grain. This works but wastes visco.

Mr. LaDuke recommends using a 3" piece of visco that's had one end dipped in NC and primed with 3- 4Fg black powder.

The primed end of the fuse is installed so it just touches the fuel grain and it's secured to the stick with 3 wraps of 1/2" wide masking tape.

(Bob note: I've found that I prefer to coil the fuse around the bottom of the fuel grain. Visco is relatively cheap and I've found the fuse is less likely to get dislodged in handling.)

Conclusion

I hope this article has helped generate interest in this unique rocket, and answered some questions for those who are considering working with them or have had problems making them work in the past. The subject line from one of Doc Barr's R-BP posts pretty much sums it up "Strobe rockets - not the final word" . . . strobe rockets are a unique device and are undergoing continual refinement so none of the above is set stone. Each worker just has to see what works for him. Those who discover something new or interesting should share the information so we can all benefit.

I've received lots of help and encouragement from several people during my experimentation with these rockets and I'm sure I'll forget someone; (forgive me if I do) . . . Thanks to: Mike Carter, Joel Harmon, Bill Kimbrough, Kolin Kimbrough, Steve Majdali, Scott Myers, Lloyd Sponenburgh, John Steinberg, and Kevin Urbom, as well as the memberships of the Pyrotechnic Mailing List, Pyrotechnics, and the Rocketry-Black Powder Internet mailing lists. I feel very fortunate to have access to such talented and kind people!

Very special thanks go to Doc Barr for some of my first instruction in pyrotechnics, Steve LaDuke for his outstanding seminar, and to *AFN* for making that seminar available to everyone. BS

WHET YOUR APPETITE FOR WET WHISTLE

By **Chris Spurrell**

Three years ago I went to my first Western Pyrotechnic Association Winter Blast. It was there that I saw my first whistle rocket. With a sound that suggest the heavens themselves were being torn apart the rockets were leaping off the desert floor and streaking across the sky. I knew immediately that I had to try that. I had never rammed (or pressed) a rocket before. So I started reading. I knew from Safe and Sane fireworks that whistle mix was HOT. I have since come to believe that whistle mix sits at the very boundaries of pyro burning speed.

My initial searches of reading material and comments by generous folks yielded formulas that ranged from around 60 to 75% KC104 with 40 to 25% either potassium benzoate or sodium salicylate with 4% petroleum jelly 1% ferric oxide catalyst. The consensus was that the salicylate formulas were the fastest burning and provided the most thrust.

Being a little too cheap to buy tooling, I tried my hand at making my own so that I could adjust the length of the central core. With a router table, 1/2" straight bit, and a fence it was fairly easy to feed in and rotate some 1/2" aluminum bar stock and turn out something that looked like a nozzle former. A piece of 1/8" steel rod chucked into the drill press could then be tapered and polished and jammed through a 1/8" hole in the nozzle former. All that was needed then was a rammer with a 1/8" hole down the center and the tooling was ready.

A year later at the next Winter Blast I mixed some salicylate-based powder. Since I got a little carried away with the toluene while mixing in the Vaseline, I figured I would let the powder dry oh paper towels to speed the process. With dry powder I started pressing rockets. To my disappointment they would barely lift. Okay, the next night I would use a longer core. Now they all blew up with only 1/8" longer core. With only one night left and near despair I listened to Doc Barr's comments on making whistle fuel and the potential problems with drying wet fuel on a porous surface - all the Vaseline gets sucked from the fuel with the solvent! From there I rushed to the local pharmacy and bought some mineral oil. Adding in about 2% I now had a stable (enough) fuel. My final rocket on Sunday night roared across the desert. Pure *October Sky*.

By the fall my rockets were flying reliably. With lots of various tooling now tested, I decided to work on the fuel. Sandy Partin's article on whistle catalyst in *Pyrotechnica XVI* proved to be hugely valuable. It clearly suggested some potential catalysts to make really fast fuel. But my respect was certainly growing for just how fast the powder was - and how sensitive. My first casual test was to mix a couple of comps and check their auto-ignition temperature on a laboratory hot plate. Placing a wire thermocouple on the hot plate and a couple tenths of a gram of powder on top of it I got:

Mix	Auto-ignition temperature
Black powder	460° **F**
Catalyzed whistle	670° **F**
Whistle (no catalyst)	800° **F**
Flash 70/30	945° **F**

I didn't like the trend. Whistle burned nearly as fast as flash and the sensitivity was going the wrong (but expected) way. My tooling now included 4# rocket sizes and required a lot of comp to fill the cases. In my mind the way to reduce risk was to go back to using a lot of toluene and mix it really wet. That has become my technique using lots of anti-static spray and HDPE mixing bowls. I mix the stuff as slurry and let it dry on a piece of HDPE plastic with occasional mixing. To convince myself of the increased safety I occasionally take a small blob of the stuff and light it (far from the larger batch). As the toluene burns off it has a lazy smoky flame. When enough solvent has evaporated the comp burns like an energetic star. However, the final dry powdered material burns with astounding speed. We demonstrated that by 72/25 $KClO_4$/salicylate with 1% copper oxychloride placed an ounce or two on the hard packed desert dirt in a line about an inch wide and ten inches long. When the spit of the fuse touched it there was a flash, a very loud bang and it was gone, leaving a groove in the dirt and some fairly rattled onlookers who thought whistle mix couldn't possibly do that - explode completely unconfined. The WPA has adopted the rule that all whistle must be mixed wet. Seems like the safest thing to do. CS

PARACHUTE ROCKETS

By Dave Muckensturm

THE CASE

I have been using these on 2 lb. (7/8" i.d.) black powder rockets, but have also used them in shells. To make the casing to contain the whole assembly, I start with a 3-inch case former, i.e. 2 1/2" diameter. I cut a piece of 60# Kraft, 5 1/2" wide x 16" long. This will give two turns on the case former. I wrap the paper around the case former, leaving one inch or slightly more sticking above the case former, then put a small bead of white glue on the edge of the last turn up to the edge of the case former and secure with a piece of masking tape. Then I insert one end disc into the case and pleat or tongue fold, securing the folds with white glue, hot melt, etc. When dry, a hole is drilled in the center of the bottom, big enough to allow a piece of Thermalite (medium) to pass thru.

Now, I cut a piece of blackmatch slightly less than 2 1/2-inches, to serve as crossmatch inside the case. I cut a piece of (medium) Thermalite long enough so that it can be wrapped around the center of the piece of blackmatch a couple of times; it will pass thru the case and extend into the rocket (head) far enough for ignition. Then using needle nose pliers I insert the assembly into the case with the match laying flat across the bottom and the Thermalite extending out thru the hole. Then I secure the crossmatch assembly inside the case with hot melt glue. Construction of the case is now finished.

FLARE

For the flare I use a short section of the tubes I use for my 2# rockets. It is 7/8" i.d. with 1/4" wall by 2" long. I start by drilling a small hole (just big enough to pass Thermalite) thru (across the diameter) as close to one end as possible, then cut a piece of medium Thermalite, o.d. of tube + 1/2", and pass thru the holes so that 1/4" sticks out of both sides. With fused end down I press (CAUTION!!! MUST NOT BE RAMMED WITH HAMMER, AS STROBE MIXES ARE IMPACT SENSITIVE) one diameter, 7/8", high, and then ram the rest of the tube with clay. I believe the added weight of the clay is necessary to aid in the opening of the parachute. (A variation: after pressing in strobe mix, I could glue in an end cap with Thermalite etc., for fusing, add flash mix, then an end cap on top of the tube and *voila,* a strobe with report!)

Next, a hole is punched in the center of a 2 1/2" end disc, the diameter of the tube. The disc is slid on the tube until it almost touches the Thermalite and then is glued in place with white glue. Now I cut a 3" long piece of half-inch wide nylon strapping tape. In the center of the tape, it is twisted 360° to form a notch, which is centered on the top of the flare. Then the tape is run down the sides of the flare. This 'handle' is secured to the flare by running a couple wraps of strapping tape around the circumference at the top of the flare. The notch will serve as a handle to attach the parachute.

STROBE FORMULA

Ammonium perchlorate	60
Barium sulfate	15
Magnalium 60m	25
Magnalium 200m	5
Potassium dichromate	5*

* I used to add the dichromate, but now I coat all my magnalium and magnesium beforehand with a hot solution of dichromate and dry it. Potassium dichromate is toxic!

PARACHUTE

The paper I use for the parachute is the kind florists use to wrap flowers in. It seems to be a waxed tissue. I lucked out in getting it; the first place I went to had a solid dark green paper. Later on I went to a different florist and got a paper with a colorful print on it, but it wouldn't open and seemed stiffer than the green paper.

The paper is 24" x 36". I start by cutting 12" off one end, so that I have a piece two foot square. I then crumple it into a ball as small as I can by hand, sort of *breaking the paper.* I repeat this process by flattening it out and crumpling it again. I flatten the paper back out and cut the corners off, about 3/4", then cut four pieces of duct tape one-inch long (it is two-inches wide) and fold them over each corner of the paper to form a gusset one inch square. Using a paper punch, I punch a hole in each corner. Then I dust the parachute, both sides, with corn or potato starch.

Next I cut five pieces of string 2' long, tie one piece to each corner and then grab the four loose ends and join them to the fifth (leader) by tying the five into a knot. I cut off any excess from the knots on the corners and the leader knot. I grab the center of the paper, the tip of the chute, and pull gently on the leader. If lucky, the chute will tend to fold itself. It does take some playing around to get the untied corners to fan out radially. When satisfied, I fan-fold two of the wings, one at a time, one on top of the other and then turn the chute over and do the same with the other two. The fanfolds should be approximately two inches wide. Making the folds narrower than inch and a quarter may make the chute fail to open. Now starting at the tip of the chute, I accordion-fold about two-inches wide until about four inches are left, and then wrap the remaining four inches around the bundle. As I wrap the string around the bundle I insert a two-inch wide piece of paper (I get this from the piece that I cut off from the original piece, 2" x 2") and wrap the paper and string until there is about six-inches of leader remaining. Now I put a rubber band around the folded chute to keep it from unfolding until it is time to assemble.

The leader is tied to the flare at the notch in the strapping tape. I take the previously made case and add a couple teaspoons of meal on rice hulls and then insert the flare into the case all the way to the bottom.

I fill the void with sawdust to the top of flare, lightly tamping in the sawdust as I fill. Then I remove the rubber band. THIS IS IMPORTANT! Then I wrap the loose string around the bundled chute and place on top of flare. Almost finished, I fill the void to the top of the chute with sawdust and cover with a 2 1/2" disc. I secure the disc with three evenly spaced beads of hot melt glue, about 1/4" long. DM

Reference:

Mitch Piatt, "PARACHUTE ROCKETS", AFN No. 169, Oct. '95

TIP OF THE MONTH

by Dave Stoddard

NOISELESS FLASH - I ran into something a couple of years ago that seemed to do this well. I mixed 3 parts standard 70/30 perc/al flash with 1 part Skylighter wood meal. It dramatically slowed the flash down. When put into a 1 1/2" diameter, 2 1/2" long convolute tube, end capped and side-fused, these things would create a giant ball of light (approximately 4 feet in diameter) without any boom. They are perfect if you live in the suburbs of a large metropolitan area. By top fusing them, they also make excellent silent rocket headers.

BURPING ROCKETS

By Bill Schleef

I've seen formulas for rockets that make peculiar noises, and I have one too. I don't know if other pyros use this formulation. All I know is that it worked for me.

I have not done any drop or friction tests on this comp. so I can't vouch for its safety. I ram it using wooden tooling and an aluminum mallet I designed, in tubes with a 1/2" bore, 3/4" o.d. and 2" to 2 1/2" long. The nozzle is 7/64".

Potassium perchlorate	75 grams
Charcoal, willow, airfloat	10 grams
Red gum	15 grams

I never make more than 100 grams at a time. For mesh sizes, I like the perc to be 100 mesh, and the Red gum to be about 150-200 mesh. I use the hand mix and screen method, then wet with 95% ethanol or grain alcohol and pass through a window screen to granulate, then dry and store until used.

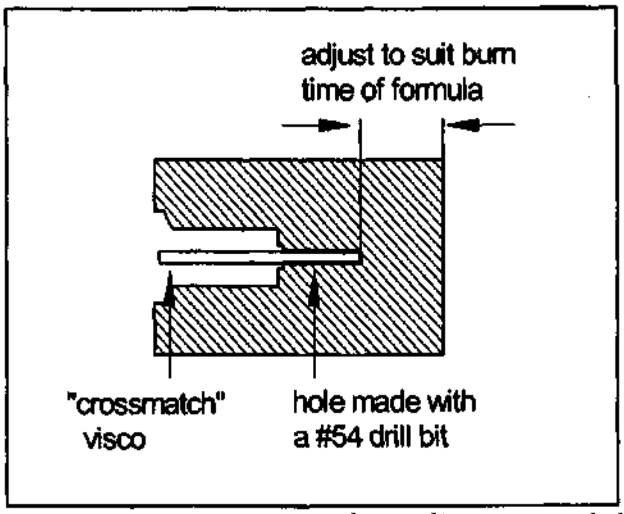
The rockets burp, fart or chuff (depending on your attitude) at a regular rate. WS

FUSING CROSSETTE COMETS

By Bob Svenson

Recently I've been working with crossette comets for use in rocket headings (for those interested in crossette rocket headings I heartily recommend AFN's video V8o "Building Crossette Rockets").

I did some research on crossettes prior to starting on them and one problem seemed to stand out - that of getting the comet to break properly. This problem results from a lack of containment for the flash powder break charge. In its simplest form a crossette burns progressively from the bottom towards the cavity with the flash charge in it. The problem is that the bottom of the cavity has to burn away to ignite the flash charge and with the bottom gone there's little containment which often results in just a bright flash of light out of the cavity and the comet not fragmenting.



Rich Wolter and other tool makers have addressed this problem by adding a small pin to the end of the pump which makes a small hole extending from the bottom of the cavity into the comet. As the fire burns toward the cavity it encounters the small passfire hole and allows fire to get to the flash charge before the bottom of the cavity has burned away, thus providing containment for the flash charge.

The passfire hole seems to give mixed results - for some it works fine and for others it doesn't. I am in the latter category - I did not get consistent results by relying on the passfire hole alone.

Several methods to overcome this have been used. Traditionally small firecrackers have been inserted into the cavity. Others have found success by installing an actual fuse in the comet to reliably bring the fire into the cavity while there's still containment.

I considered making small firecrackers but I thought I'd try the latter method first as it's less laborious.

In my first attempts at installing an actual fuse I followed the widely used method of installing thermalite into the passfire hole. This method worked fine - the comets never failed to split and when fired en mass out of a shell or rocket heading they all fragmented at about the same time.

Though thermalite worked great it's getting hard to find, so I thought I'd try some other approaches. First I followed Dave Bleser's suggestion of drilling completely through the comet and installing a piece of visco. This method also worked, but the bottom of the comet likes to flake off as I drill through it, and when fired en mass they seemed to be a bit more staggered in their timing.

I decided I liked the thermalite approach better so I started looking for an easy way to obtain substitute for thermalite. I didn't have to look far - just about that time is when my new Skylighter catalog came and I noticed that Harry was now stocking a new thin "crossmatch" visco (Harry suggests using this visco in place of thin match or thermalite when crossmatching shell time fuses).

I ordered some of the small visco and used it in place of thermalite - it worked fine!

To fuse a crossette using the new small visco I use the following procedure:

- I cut the pin at the tip of my Rich Wolter crossette pump shorter - the pin is a larger diameter than the visco and I just need an indentation in the bottom of the cavity to guide a drill bit as I use a drill press to drill the actual hole I install the visco in.

• After the comets are pumped and dry I use a drill press and a #54 drill bit to drill the hole in the bottom of the cavity. The amount of comet material below the fuse regulates the burn time till the fire hits the fuse and the comet fragments, so by setting a stop on the drill press I am able to get very consistent timing on the comets.

CAUTION! Though I've had no problems to date, drilling into a comet is not without risk! I take every precaution and EXPECT the comet to ignite - and be ready to deal with it when it does!

• The diameter of the visco varies, but most of it will fit snugly through the hole made by a #54 drill bit. To insure the visco will fit into the hole in the comet I drill a #54 hole through a block of wood and then thread the visco through it and pull it through. If the diameter increases and the visco becomes hard to pull through I just cut off that section and keep trimming back till it threads in easily again and then continue sizing the visco.

• Once the comets are drilled and the visco sized I insert the visco into the comet, being careful to insure that it's fully seated in the hole, then I cut the visco off just below the top of the cavity. (I don't know if it's really necessary to have the visco extend the length of the cavity or not, I've just always done it that way.)

With the comet drilled and the fuse installed all that's left is to install the flash charge and finish the comet as normal. BS

UNMIXED FLASH POWDER

by Chris Spurrell

I like the nice big THUMP of a salute at the end of a whistle rocket's screech. But I get this weird feeling in the pit of my stomach when I'm mixing a batch of flash in the desert. Even though I'm wearing cotton and using anti-static spray, I still get zapped by a static spark when I slide across my car seat and touch the door frame. I've heard that those little sparks have more than enough energy to set off flash.

Well, how good would flash be if 7 parts of potassium perchlorate and 3 parts of aluminum were added separately and then mixed after the device was sealed? Imagine how humiliating it would be to have a weak THUMP. Imagine how much less rich my religious life would be without a tub of mixed flash prompting spontaneous prayer. I decided to go along a and to shake those rocket headings after they were assembled.

To help with the mixing I ball milled the potassium perchlorate with 0.5% Cabosil (fumed silica). This makes the stuff flow almost like a fluid. I had finally run out of the German Black a friend had given me about 20 years ago. It was the old fashion stuff from Westech. I found the new Indian Black was the only aluminum that equaled my old German Black in reactivity. (But I haven't tested them all either). I didn't do anything to that stuff. It seemed to mix well on it's own.

But you know how it goes at Winter Blast. I had been working all day and now it was time to clean up and I hadn't finished my rockets. Worse yet, I needed to set up the Ghost Mines demo. A buddy of mine came by and asked if I needed help. What a Godsend! He took on the task of sticking and fusing my rockets. He even carried them over to the "B" rocket line magazine for me.

After the Ghost Mines were shot. I rushed over to try some of those rockets. I love whistle rockets and mine were doing a good job of flying and thumping. After I had lit about three it dawned on me that I had never mixed the flash powder in their heading. Just the modest amount of handling had been sufficient to mix the flash. I took the next one and shook it and rolled it then shook it a little more. From that I got a slightly louder bang, but not by much.

So now I have given up all notion of mixing flash. The whistle rockets I shot at "Do-It" and all I shot at *Winter Blast this year all* had "un-mixed" flash. No more looking into that gray tub of flash. I sleep better at night. If I want to get scared, I'll go see a scary movie. CS

IMPROVED ROCKET TUBES

By Lloyd Scott Oglesby

In the most popular size range, the small pyrotechnic rocket is easily the second most popular item on the planet, so the discussion continues because it is not at all well developed yet.

There is no reason to do so, but we will probably keep the traditional shape. This is because paper tubes are easy to roll into small cylindrical shapes. Then we have things to consider about the paper and other materials used for the tube.

First, you do not need a tube at all. Second, any weight it may have must be overcome. Third, the inertia of the mass of the material must not only be moved, but it must keep moving. Fourth, it will fall from whatever altitude it achieved, so a casing that does not destruct at a safe altitude becomes a small hazard.

The greatest hazard is that the returning spent materials will be smoldering or have glow reactions. Unthinking manufacturers continue to get away with using the cheap paper tubes that were made for the textile or cordage industries. Unfortunately, such tubes have a history of long lasting, smoldering reactions in the spent tube. Of the thousands I have fired, I have seen two that burst into flames some time after landing. I've seen dozens that continued to smolder. I tracked this problem to dust (dust containing potassium nitrate was in the air as powder dust continually at the place of manufacture. Rain mist and foggy precipitation had a way of entering the tube storage facility that had no dust proofing, so the tubes had been converted to smolder devices. Poor storage conditions could do the same for poorly designed commercial rockets.

Chipboard is a very poor case material. Such cases are bulky, heavy, weak, typically poorly glued, easily converted to smolder material, and undoubtedly the worst possible choice. The higher quality card materials, like Bristol board, are not a great deal better unless special gluing is done.

This is no problem at all for the amateur. Intruding a small amount of a gelatin type or hide glue into the cardboard is cheap and easy. Just remember that it does not penetrate the fibers from cold solutions; hot water soaking works very nicely and can easily double the strength of the material when dry. But it does make dampening the dried paper necessary before rolling by hand. Ordinary papers, like bond, copier and most printing papers can be used, but often they have quite considerable swelling on wetting and must be wetted and dried to relax the strains this typically produces. Best is Kraft paper. The sort that is felt finish or machine finish on both sides is best; hot rolling and pressing operations result in the same sort of swelling problems that afflict other types of papers.

The worst sort of glue is dextrin. It is subject to microbial attack during storage, it is hygroscopic, it has considerable size change during humidity changes. They make beer and bread with the stuff so it is wonderfully cheap. It is so easy to use that people who do not even know what protein hydration is, or coloidialization by solvent dispersion have no problem at all with it.

Paper products are nearly, but not quite, sterile as they are produced, especially those produced with hot rolling and pressing with steam, but mold and mildew spores survive the processing, and in storage, paper comes equipped with just the sort of microbes that make dextrin more hygroscopic, and they will eventually consume it before finishing off the paper fibers.

Rice starch is far less hygroscopic than wheat paste but unless it is made from high protein rice, such as Siamese or Thailand rice that typically runs 7% more protein, it is almost as bad about feeding the molds and becoming a smolder material as dextrin. Wheat paste is not much better, and more hygroscopic, and requires more complex processing to get excellent handling properties that are so nicely typical of rice starch. Both benefit from boric acid treatment, both can be used with mold suppressants and smolder suppressants like borax, magnesium sulfate, the inexpensive phosphates or even bicarbonate. Eliminating after-glow in case materials takes so little and so well protects against product liability suits and helps promote the safety record of fireworks. This has been known by the fireworks industry for over a hundred years.

Fortunately the chemical industries have provided two new types of glue in the last 50 years that help eliminate glow reactions, storage problems, hygroscopicity problems and dimensional stability problems, and make far stronger tubes that can be thinner, lighter weight and therefore both less expensive and better performing, as well as far more safe for the consuming public.

The two new binders or blues are polyvinyl alcohol or PVOH and the type familiar as Elmer's in this country, polyvinyl acetate alcohol, that like the PVOH, is made from hydrolysis of polyvinyl acetate. An infinite series of products between the two are available by controlling the hydrolysis process. Steam, usually under considerable pressure, is used to hydrolyze the PVA to some sort of PVAOH and PVOH mixture. The film strength and bonding properties are easy to vary with water dilution, alcohol dilution, and other solvents can be used. Paper tubes made with these are typically proof against glow reactions and paper smolder if the glue was dilute enough to penetrate the paper and leave a trace of glue on the fibers. They can also be used alone or in conjunction with other materials to treat wood and bamboo guidance sticks.

By pre-treating Kraft paper with very thin Elmer's (diluted with 20% ethyl alcohol, 80% water solution to about twice the original volume), it is easy to produce a nearly perfect material for rocket casings. This must be nearly, but not quite dry before it is rolled up with more Elmer's that has about 25% by volume water added. It takes a while to learn to judge just how dry the paper must be before it is pasted and it is rolled immediately with heavy pressure.

There are four reasons for the alcohol trick: detergency and speed of penetration of the paper; faster drying of the material; the material will be less hygroscopic with better moisture barrier; the material develops greater strength due to changes you can only observe under the microscope. Typically the paper will bend and buckle less on total dry out, and it rolls more easily. A 5/8" bore rocket takes a casing about 1/16" thick of this type material. It will weigh about half or less than other types of tubes, and have about three times the bursting strength.

If choked cases are made of this material, it is best to trim them while still damp.

It is difficult to handle cases less than about 1/32" thick, no matter how small the diameter, so the tubes will have far more strength than they need to make a functional rocket. Thus the builder can feel free to posh it up with hotter fuel. The late Orville Carlisle and I both experimented with using aircraft grade ultrafine fiberglass cloth in the last few wraps. We concluded that it did greatly increase strength but we gave it up because it was too heavy (a few wraps of paper did the same thing). Running up the pressure and fuel performance are easy with this type of case.

If a really high performance rocket is being planned, the builder will be running the fuel system at pressure just short of what reliably causes an explosion. A rocket with true snort is just a hair short of blowing up. Orv defined it as an explosion that is just slow enough to *that a'way.* LSO

TIP OF THE MONTH

John Vico taught me (or I taught him - I can't remember which) to always carry a drill bit the exact size of the nozzle i.d. Humidity makes the clay swell slightly, causing the nozzle opening to shrink, which obviously will increase the pressure in the rocket. Before shooting in any competition we always fit the drill bit into the nozzle to make sure the rocket works the way it was intended.

Doc Barr

PREPARATION OF CLAY FOR ROCKET NOZZLES

By Bob Svenson

While reading my "Best of AFN IV" I noticed something I had missed when it appeared in AFN.

In an article entitled "Rocket Nozzles" the author refers to kyanite and speculates that it's some type of clay that someone has had success with. I feel this needs clarification. Kyanite (AlAlOSiO(4)) is an aluminum silicate mineral and is used in the manufacture of spark plugs, porcelain, and other heat-resistant ceramics (sounds like good stuff to make rocket nozzles out of, doesn't it?).

I was first introduced to kyanite by one of my rocketeering mentors, who was kind enough to send me a few pounds and instruct me to mix it with bentonite clay 50/50 by volume.

That first few pounds lasted quite a while but I eventually ran out. Sometime earlier I had ordered some "grog" from one of the pyro chem suppliers, but since I was using the kyanite I never even opened the container. What a surprise when I finally did open the container! Instead of the nice 100 mesh or so powder I was used to I had a fine powder mixed in with CHUNKS! I screened the fines out and used them, which worked very well, but the fines were only about a third of the container - the other two thirds were chunks. I welded a plate on a pipe and used a large steel round to make a sort of hammer mill which I used to reduce the chunks down to something I could use. This worked fairly well but the process of milling and screening was a task I just didn't find enjoyable; my tooling was also starting to show more wear than I had noticed when using kyanite.

Well, that was enough of that! I grabbed the phone book and started calling ceramic supply houses. None in my area carried kyanite, however one said they would order it but I had to buy a 501b sack, prepay it, and that it would take a month or so as they would add it on to their stock order. I sent them a check and as promised I got a phone call a few weeks later that my kyanite was in. Oh happy day!

If you make rockets or fountains I heartily recommend trying kyanite - I'm sure you'll be as pleased with it as I am. If you can't find it locally I have found a couple companies on the Internet that carry it in both pound and sack increments. Even with shipping it's still pretty inexpensive.

Another interesting topic relating to rocket nozzles is the addition of 5% wax to the nozzle clay. It was discussed a while back on the Internet's Pyrotechnic Mailing List (PML), and more recently on the Rocketry-Black Powder List (R-BP).

The addition of wax to the clay produces a very durable nozzle that resists erosion during firing and the effects of moisture on the hygroscopic bentonite clay during storage.

I've read several different approaches for incorporating the wax into the clay, but the following method, based upon an R-BP post, is the method I recently used to produce a kilogram of nozzle clay:

- The clay and kyanite were measured out 50/50 by volume and screened it together until well mixed.
- 950 grams of the clay/kyanite mixture was weighed out.
- 50 grams of wax was weighed out into a metal can. The wax used is from an unusual source - it's from the gasket used to seal a toilet to the sewer pipe! No kidding, just go to the local hardware store or plumbing supply shop and ask for a wax toilet bowl gasket! (apparently most of the wax gaskets are made of pretty much the same thing - as far as I am aware there is no one particular brand that's more suited than another)
- The can was placed on an electric hot plate and heated until the wax melted.
- 275 grams of lacquer thinner was then added. (Note: I used lacquer thinner because I had some on hand. Some people use the fuel that's used in Coleman camp stoves and lanterns (naphtha) which is usually available from discount or sporting goods stores - the Coleman fuel is also usually cheaper.) The

amount of solvent added is not critical, just enough to thoroughly wet the clay.

• The wax/lacquer thinner mixture was heated just briefly to insure a homogenous mixture.

• The wax/lacquer thinner mixture was then added to the clay/kyanite and mixed in.

• The mixture was just a bit wet so I spread the mixture out on a cookie sheet in front of a fan. It took a little longer than I expected to dry out to a more doughy consistency, but once it did I riced it through a 16 mesh aluminum window screen onto a cookie sheet, then placed it out in the sun to dry.

The resulting material is less dusty to handle and produces nozzles that are very shiny and hard - they are really good looking nozzles!

Is all of this really necessary? Well, yes and no. You certainly can use just clay to ram a rocket nozzle and it will probably work just fine. In my own experiences I've found that I would occasionally have a CATO and when I later inspected the recovered rocket I found that the nozzle had blown out - no matter how hard I hammered or pressed in the nozzle I would occasionally have a nozzle problem. Once I started using kyanite mixed in with the clay this problem ceased. Now if I have a CATO I find the tube failed, not the nozzle. I have to admit that I've never had a problem I could attribute to the effects of moisture on the clay, but then again I don't normally store things for very long.

Adding wax to the clay is a simple and easy thing to do and it's not had any adverse effects on my nozzles staying in or on my nozzles' resistance to erosion, so if it helps offset the effects of moisture during storage, it's worth the little extra effort. BS

GEL CAP ROCKETS REVISITED

By Sara Gomez and Doug Biedenweg

I am always in search of simple entertaining chemistry projects for my students to work on. A year ago I read an article by Deane Williams on gel capsule rockets in the PGI Bulletin. I tried building several of these following his instructions, and they were fun (especially when I added dragon eggs), but they never went very far (or often, anywhere at all). Because of this I decided to assign this as a class project to my chemistry students. The goal was to discover an improved method of construction so that these little rockets would fly reliably and far and high enough to be entertaining. Below is the method developed by one of my Chemistry students - Sara Gomez.

Materials-

- Small Paper Ketchup Cups - 2
- 00 gel caps (available at many health food/vitamin stores)
- Blue Dot Smokeless Powder
- Winchester 296 Smokeless Powder
- Scotch tape
- A geometry compass - the cheap kind works great
- Spaghetti noodles (actually I use Vermicelli (a thinner form of spaghetti))
- Aluminum foil
- Fuse (we are using 1mm micro-visco; I think it is the same as GN1010 from Skylighter); if you don't have this cut off fuse from regular firecrackers
- Optional - pin vise with needle insert - ideal for punching small holes
- Optional - dragon eggs taken from Consumer Fireworks items

Constructing the rockets -

1) Pick up one of the 00 gel caps and pull it apart; it will separate into a long and short section. Carefully drill a hole in the end of the long section, using the compass needle. The hole should just be large enough to barely allow the fuse to enter.

2) Cut a square of aluminum foil about 3" by 4". Center this on the top of the compass (the knob that you hold onto when tracing out an arc) and gently wrap the aluminum foil down over this knob forming a lining for the large section of the gel cap.

3) Remove the aluminum foil from the top of the compass and using scissors, cut off

the excess foil (this temporarily closes the opening to this aluminum foil chamber). To reopen it use the tip of the compass needle and gently pry it open.

4) Place this piece of aluminum foil back on the compass knob to re-shape it. After pulling the piece off check it carefully for any small rips or tears (in my experience these happen a lot more frequently than one would expect; you do not want rips or tears because the hot gases will escape through them and burn up the gel cap).

5) Now insert this piece of aluminum foil inside the long piece of the gel-cap. If you have done this correctly it should form a nearly perfect lining for this half of the gel cap. The easiest way to get the foil lining all the way into the cap is to use the knob on the compass to firmly push it in.

6) Using the compass needle, make a hole in this lining that lines up with the hole already in the end of the gel cap. Make sure both holes are just barely big enough to allow the fuse to pass through.

7) Stick the fuse through the gel cap wall and the aluminum foil so that its end is one-third up the gel cap.

8) Place some Blue Dot powder into one of the small ketchup cups. Carefully pour the powder so it fills up about two-thirds of the space in the aluminum lining and arranges itself around the fuse.

9) Put a small layer of 296 powder on top of the Blue Dot.

10) Put a small layer of Blue Dot next.

11) Nearly fill the rest of the capsule space with 296 powder.

12) Pick up the short side of the gel cap.

13) Fill it with a layer of Blue Dot, then one of 296, then Blue Dot, then 296

14) Push the two sides of the capsule together.

15) Neatly wrap Scotch tape around the seam, sealing the gel cap.

16) Tape the gel cap onto the end of a five-inch piece of vermicelli spaghetti noodle.

To launch these rockets I place them in an empty baby food jar and carefully light the fuse (you actually do have to be careful lighting the fuse because if you're not you will melt the noodle and the rocket will flop over). If you build these carefully and launch them vertically they fly very reliably to a height of 35 to 40 feet. When they are launched at an angle of 45 degrees, they can easily travel 50 feet. Do not launch them near dry brush as they can start a fire. Finally I would like to thank Deane Williams for the original idea and for giving me many helpful hints when I was getting started.

References:

Williams, Deane 1993. *Micro-Rockets.* PGI Bulletin 85, June 1993.

TIP OF THE MONTH

4 OZ. ROCKETS

by Stewart Tick

I have never actually tried to duplicate an Estes engine (which are end burners) because I thought that the meal powder was too risky for my students to handle. However, I have had great success with my students flying Estes models using regular 4 oz. core-burning engines. (I used Rich Wolter's tools and a composition of about 65 % potassium nitrate; 25% airfloat charcoal; 10% sulfur.)

The 4 oz. engines are a little heavier than the Estes engines, so it is sometimes necessary to weight down the nose cone with a little copper shot or modeling clay.

For an ejection charge, I found that a 50/50 mixture (by volume, not weight)of FFFg Goex black powder and Pyrodex RS worked best. (FFF powder by itself is too fast, and often blows the parachute completely out of the body tube.) ST

PARLOR ROCKETS

By Joe Barkley

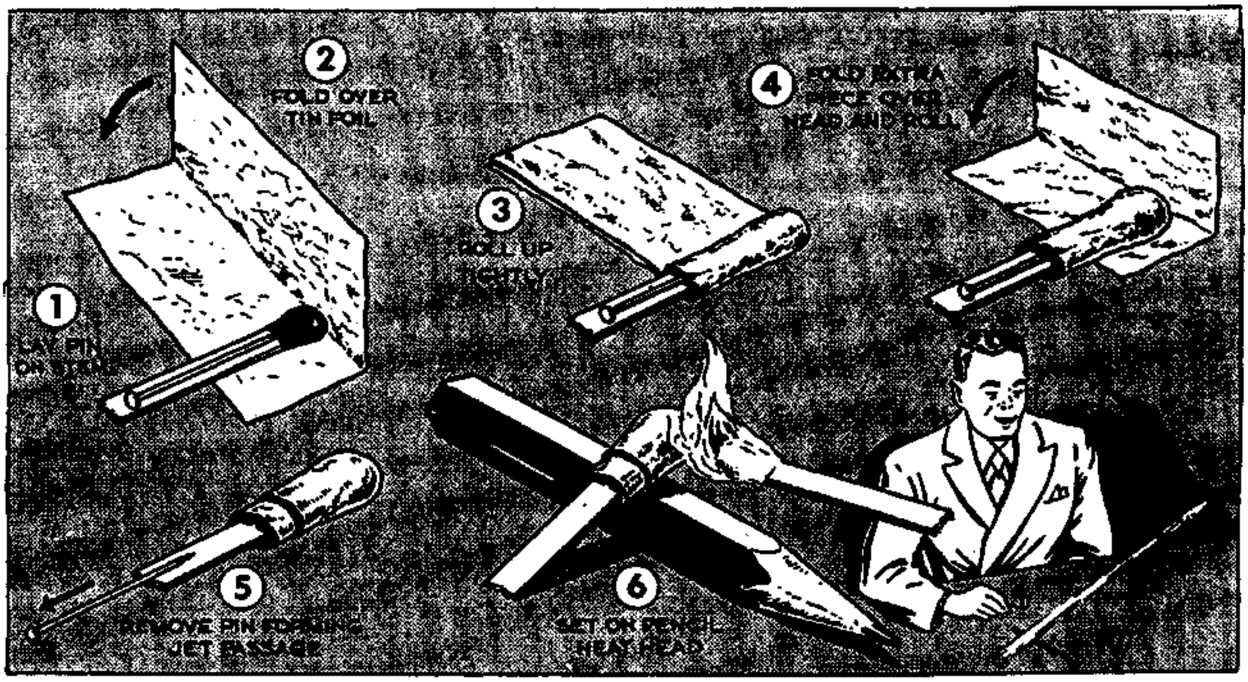
World War II caught many kids without fireworks for the "duration". Christmas/New Years 1941 was the last time the mail order houses (Spencer, for example) could sell without a Federal Explosives License tendered from the buyer. By July 1942 the local stands were SOLD OUT. We often wondered what was meant by "duration". By 1944 consumer fireworks were a fond memory for just about all.

A popular magazine presented a one page note to allay the thirst of readers who still remembered earlier days. The title caught attention and refired enthusiasm, even if briefly. Ingredients were readily available. Some AFN readers may remember:

A common bookmatch is removed from the pack and the head is laid alongside a straight pin with the pinhead away from the match head. A square of aluminum foil (from a cigarette pack back then) is wrapped tightly around the upper half of the match with the pin still in place. The pin is pulled out carefully, forming a vent for the burning match head. Effectiveness depends on preserving a very small vent which acts as a nozzle. The little rocket stands head-up (against a low ash try, maybe) and the flame from another match is played on the foil cover. On ignition the parlor rocket goes up in a swish, range depending on tightness of the aluminum cover (leak prevention) and preservation of the small vent formed by the pin.

The writer, on trying these again after some fifty years, was disappointed. Performance was not as spectacular as remembered. Maybe matches are not as good now; maybe patience in constructing the little imps and experimenting to get the best performance has declined. Years ago mine would zip across the room.

This historical note invites the AFN reader to view the situation a few years back were the smallest imitation of the fireworks we loved and could no longer get cheered us and made us hope for the "duration" to end. JB



(Thanks to Donald J. Haarmann for providing the graphic)

INSTANT READING OF RAM FORCE DURING ROCKET ENGINE CONSTRUCTION

By Harold D. Bentley

One of the operations performed during the construction of a rocket motor, driver, spoulette, or many other pyrotechnic devices is the pressing of the granulated or powdered fuel into a solid grain inside of a cardboard tube or casing. In the case of a rocket motor, the actual fuel grain must be one which must not have any fissures or voids in it. The presence of a fissure or void will cause rapid fluctuations in surface burn area which may cause sufficient variations in internal pressures to cause rocket engine malfunction (or CATO). To make the process of fuel grain pressing more consistent and reliable it is desirable to know the actual force being applied to a particular ram. In the past, ports have been drilled into the bases of hydraulic jacks, so as to allow gauge reading of the hydraulic pressure on the fluid within the jack cylinder. This porting process is complicated and time consuming, but does give a consistent hydraulic pressure per square inch which can be converted to actual force by the following formula:

F=PSI x A

Force is equal to the hydraulic pressure in PSI multiplied by the Area of the piston in the jack.

Example: If a jack with a 1.5" diameter cylinder shows a pressure of 2250 PSI. following is the mathematics process for obtaining the force:

First, $A = 7Pr^2$, so 3.1417 x .75 x .75
which computes to A - 1.7672 sq. in.

Now, Force = 2250 x 1.7672,
which equals 3976.2 pounds of force.

In this situation the jack is pressing the ram down upon the rocket fuel with the same force as if there were about seven small block Chevrolet engines sitting upon the top of the ram.

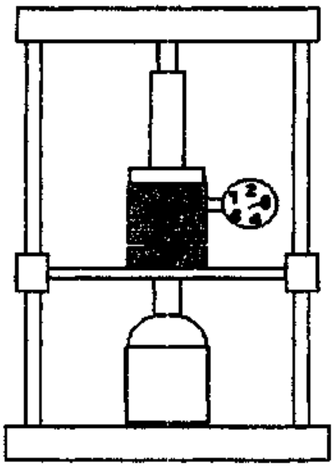
The drawbacks to this scenario are numerous and range from the complexity of computations for various rocket sizes and fuels, to the situation of changing from one press to another.

During my rocketry construction experiences I found that consistency in fuel formulation was critical to engine performance. I also discovered that variations in pressing forces caused several problems. Let us say that the nozzle is pressed clay at 2500 lbs. F, and the following increments of fuel were pressed at 1200, 1180, 1160, 1190 and 1150 pounds of force and in that order. This will cause the 1190 pound increment to further compress the 1180 and 1160 pound increments. The problem here is that they have already force-bonded to the cardboard casing, and further compression of these increments may cause a collapsing condition to occur in the casing. The casing may be compressed together and this is dangerous. It is dangerous since over time the casing will try to relax itself and decompress. If it does this, it will carry with it portions of the fuel grain which may cause a crack or fissure to form inside the grain. When the burn plane hits this fissure it may dislodge a chunk of burning fuel, which might lodge or restrict the orifice of the nozzle. A CATO is likely. I decided that I wanted a reliable method of determining the force on the ram each and every time I pressed, that was representative of the actual force on the ram regardless of whether I used a hydraulic jack, an arbor press, a woodworker's vise, or a small block Chevy engine. I designed and built a little device I call my pressure to force converter. I use P2F for short.

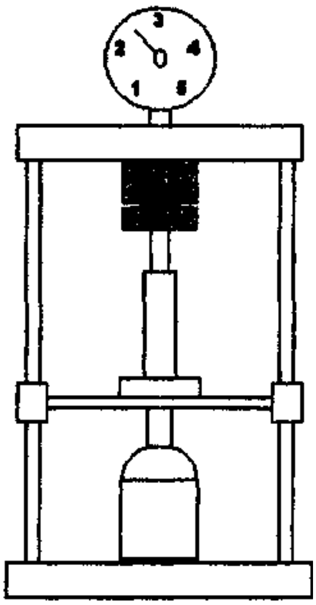
I'll explain what the P2F converter is here. Basically, it is an enclosed hydraulic cell wherein the piston portion of the unit has exactly 1 square inch of surface area on it. The cell cylinder is filled with a fluid. When the two ends of the cell are pressed together with a given force, the psi hydraulic on the fluid within the cell is directly proportional at a 1:1 ratio to that force. With the installation of a hydraulic gauge reading in psi, you can simply read the psi as Pounds Force on the gauge's scale, with no conversion math. The unit is made with parallel faces so that it can be placed between any two parallel surfaces and will indicate the force with which they are closing.

I placed one of these units on the top bar of my press, with the gauge protruding above the top bar. I simply drilled a hole in the top bar and connected the gauge to the cell with a 1/8" pipe. This allows very easy observation of the exact upward force of the jack since the ram pushes upwards on the face of the converter which, in turn, applies a 1:1 hydraulic pressure to the gauge. This makes the gauge's reading relevant in pounds of force. Many convention attendees were able to view my unit in operation at the PGI convention in Fargo.

My personal gauge goes from 0 to 5000 lbs. The accuracy below 200 lbs. is poor, but above that it is very good, with excellent repeatability.



SIDE PORT



TOP PORT

The sketches indicate how the unit is situated depending upon whether it is permanently installed on a press (top port) or portable from one press to another (side port). HDB

TAP A JACK FOR A ROCKET PRESS AND OTHER PYRO JOBS

by Nick Speraneo

I added a pressure gauge to a Walmart hydraulic jack and it really wasn't a horrible job. I used a hand drill and a tap set, and all supplies except the gauge came from the local hardware store. The gauge came from a tractor repair shop and it cost twice what the jack did.

Mine was not tapped in the bottom and they really do not need to be if you do it correctly. The first step was to take the jack apart. The rubber plug on the side is a hole to add oil to the jack. The reservoir is the thin sleeve around the outside of the jack and is under little or no pressure and might even be under negative pressure as the jack is raised. Take out the plug and drain the oil. Then using a large pipe wrench, remove the large nut that sits atop the jack which holds the sleeve on. Now the pressure tube can be removed. Unscrew it with the large pipe wrench and all you have left is the base unit. Mine had a copper gasket underneath the pressure tube, which I removed.

On my jack one side has the pump and the next side has the release valve. The next side was bare and that is the side I tapped into for the gauge. The base on my jack is 3/8" thick so drilled a small pilot (1/16") hole 3/16" from the bottom. My outer sleeve is 2 3/8" in diameter and the edge is 1/4" from the edge of the base, so I drilled in 1 1/4" with my pilot drill. Then from the top of the base I drilled down into the pilot hole and I did this by just eyeballing about where the first hole should be. Back at the outside of the pilot hole I enlarged the first hole to 5/16" and went in about 1/2". I tapped this hole to accept 3/8" threads.

I flushed all the metal shavings away and cleaned the base. I threaded in a 3/8" elbow joint with the end pointing up, attached a 2 1/2" extension to that. On top of that I attached a reducer from 3/8" to 1/2" and threaded my gauge into that. I reassembled the pressure tube, then took it apart when I found this large copper gasket. I put the gasket in and assembled the pump in the reverse order of teardown and ended up filling the reservoir with Ford transmission fluid.

Sorry to bore you pyros with an article like this but it can be done in under an hour even by the mechanically challenged. NS

WOODEN ROCKET PRESS CONSTRUCTION

By Chip Atkinson

With this article I hope to provide the instructions to create a functional rocket press made of commonly available lumber, capable of putting over 2000 lbs. of force on the ram, which will produce a pressure of over 7500 psi on a 5/8" ram and 2900 psi on a 1" ram.

There are no dimensions that are crucial for success, but the user should consider your weight and the strength of your materials. When I built the presses, I weighed about 165 pounds and figured about a 14:1 leverage ratio. If you weigh significantly more or less than that, you should adjust your dimensions or materials accordingly. My weight would stress the press nearly to its limit, and occasionally a bit further.

Approx. dimensions for my 8 oz. press are:

Part	Qty.	Material	Size
A	1	2x6	86"
B	1	4x4	96"
C	2	2x4	37"
D	2	2x4	32"
E	1	2x4 scrap	8"
F	2	2x6	32"
G	1	Maple	4"
H	2	2x6 scrap	12"
J	1	3/4" ply	18"

Parts and Tools:

- Hand saw
- Drill
- Hammer or some pounding implement such as a rock :-)

The materials needed:

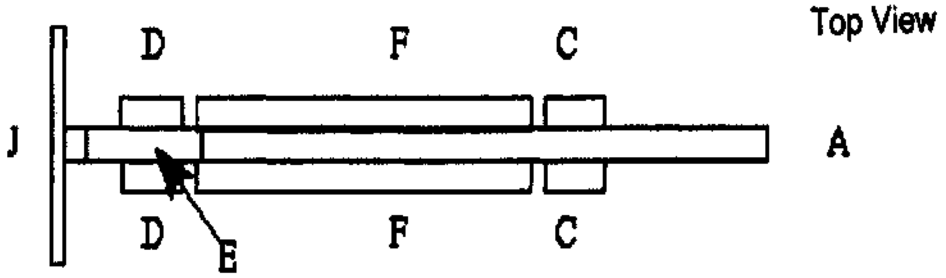
Qty	Material	Dimensions
2	2x4 Fir	8"
2	2x6 Fir	8"
1	4x4 Fir	8"
1	Scrap 2x4	~4"
2	Scrap 2x6	~ 1"
1	Maple	~3/4*'x4"xl 1/2" for G
1	1/2" or 3/4" plywood	~6"x18"
5	Steel bolts	1/2"x6" bolts with nuts and washers
-	8d &16d nails	
-	Elmer's or Titebond glue	

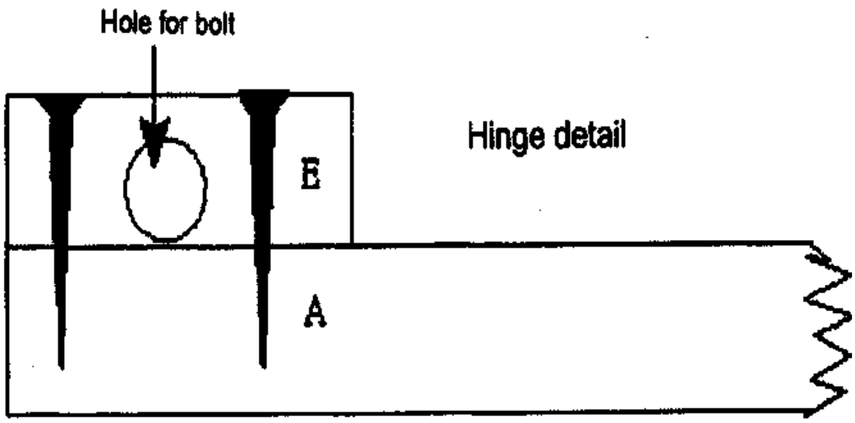
PIECE BY PIECE DESCRIPTION OF THE PARTS AND THEIR USE:

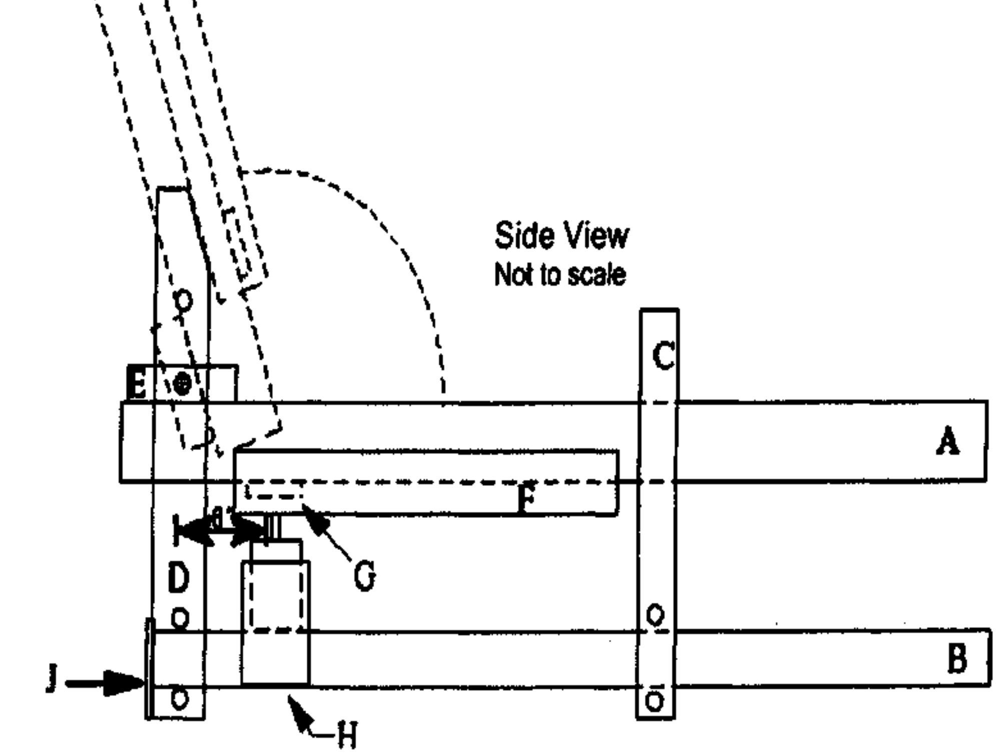
Parts A and B should be as straight and knot free as possible. If you are unable to obtain unwarped wood, it is better that they be merely bent rather than twisted. Parts A and B are the two arms of the lever system. Part B should have notches cut into the sides to hold parts D and C. The notches should be deep enough to allow about 1 3/4" of solid wood remaining between them. Notice that there are no holes drilled in A or B. It is very important that A and B's strength not be compromised by holes. This design necessity was determined experimentally. The length of B is roughly 8' while the length of A is determined by the ceiling height of the enclosure where the press is to be used. If A doesn't clear the ceiling, use a hand saw to trim off just enough to allow A to be raised.

Parts C are stabilizers. They are necessary to keep parts A and B aligned with each other. These parts were put on the press in the early refinement stages. You must use these parts or risk bending or breaking your rocket tools. Note that the holes in C are spaced so that the bolts go around B, and therefore avoid drilling holes in B. The upper ends of parts C are beveled to guide A easily between them. Parts C should be a bit longer than D, perhaps a foot or so. There is a spacer between C to keep the pieces from getting too close when the bolts are tightened. A should fit closely between parts C without binding.

Parts D provide the pivot holder for A and attach A to B. Notice in the side view that parts D extend above the pivot and are beveled. The purpose of the bevel is to allow A to tilt back past vertical so that it stays in the raised position. This allows the operator to manipulate the rocket tools without the danger of being whacked in the head by a falling part A. Notice too, that parts D extends below the bottom of part B. This is to avoid drilling holes in B and, just as importantly, to raise B off the floor. When you are putting all your


Top View
D
F
C
J
A
D
F
C
E


Hole for bolt
Hinge detail
E
A


Side View
Not to scale
E
C
A
F
G
D
B
J
H

weight on the press, B will flex. This will pose no problem with parts D lifting the end off the floor. Without it, the bowing of B will cause it to only have one contact point on the floor, allowing it to pivot about freely and present a significant danger of twisting unexpectedly and causing operator injury. (Sound like the voice of experience talking?) To size part D, measure the "average" height of your rocket tools when pressing a rocket. For example, take the ram and put it into the die with the rocket spindle in it. Measure the height of the assembly. Do the same with each ram to determine the shortest configuration and the tallest configuration. You must make sure that you can still apply pressure to the shortest configuration when you are determining the length of D too. You will probably find that the tallest and shortest configurations fall within a few inches of each other. The distance between the upper surface of B and the pivot will be this height plus the width of the 2x6 (about 5 1/2").

Part E does not necessarily have to be a 2x4. I used a piece of oak flooring. This piece is not subject to the extreme stresses that A, B, and D are. It must hold A to the pivot and prevent it from falling off when A is raised to the vertical position. Technically you don't even need E, except that you'd disassemble the press each time you lifted the lever. Do not try to save a tiny bit of trouble by skipping E and drilling a hole in A instead. Part A will crack and split. This too was determined experimentally.

Parts F serve two purposes. They create a channel to hold part G and they strengthen A. They should be glued and screwed or nailed to A. Use plenty of glue, as they are very important to the overall strength of the system. Parts F are cut to be just long enough to clear D and C.

Part G is a maple block. This block bears the brunt of all the force that is exerted by the operator on A. It will need to be replaced periodically. I tried using rubber but it was crushed into crumbs. Perhaps some hard plastic would work as well, but I haven't tried it. G prevents A from being destroyed by the rocket tools.

Parts H are used to hold the die that contains the rocket tube and spindle. I put the die in between parts H and wedge it in place with wooden shims. Parts H should be glued and screwed to B. I always use a die for my black powder rocket motors because the casings will split otherwise. I made the die out of salvaged parts of hardwood shipping pallets. I have a table saw so it was not very difficult to build. I used a drill press to drill the hole down the center. The die has two halves that are held together with bolts and T nuts (also called blind nuts.) I used to use wood screws, but after a while, the wood fibers start breaking down and the screws don't grip as well. At this point I switched to the bolts. For the bottom of the die, I got some metal inserts at the hardware store that are threaded 1/4-20.

There is no part I. The letter I looks too much like a line or a 1, and to avoid confusion it is not used.

Part J is a foot to give the press side-to-side stability. The bottom of part J should be mounted flush with the bottom of parts D so that J doesn't bear the weight of the press. I have operated the press without this piece but it is very convenient to have.

MATERIALS AND SOURCES

I got the wood for parts B, C, D, E, H, and J from construction waste heaps. You would be amazed to see what is thrown away. I got the bolts from a garage sale.

OPERATION

This press will hold all my weight at the end of part A. I could actually bounce on it, once I felt comfortable with doing so.

OTHER ITEMS OF INTEREST

When using a similar but larger and stronger press for 3 lb. rockets I put a pulley on part A, attached a rope to B in such a manner that I could slip it off quickly, and put a stirrup on the other end of the rope. This effectively doubled my weight on the beam. Needless to say, I had to make a beefier press to stand up to this force. In this case, A was a 2x6 and B was made of two 2x6s nailed and glued together. CA

NON-SPARKING MAGAZINE INTERIORS

by Carl Denninger

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 re-set 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.

In the summer, it can be very humid 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 grain. 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 run 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 drop off pieces of hardwood of a size and taper to meet your gaps. After a hot summer I found my wood shrunk considerably. Wider wedges were cut and installed. As they loosen all that's 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 your hobby! CD

STRAIGHT, LIGHT ROCKET STICKS

by Gerry Gits

Go to the lumberyard (home improvement center), pick thru the cheap 2x4 pile. Look for straight grain wood. Heft to find the lightest pieces. There is surprising difference in the density of construction wood. When you get the wood home, stack it in a warm dry location like your attic. Separate the pieces with strips of wood. Let it cook there as long as you can stand to, up to a year or more. Think of it like fine red wine that needs to age. Have piles of different vintages. When sticks are needed, rip your oldest first (FIFO).

Old or used lumber makes good sticks to. When we sold our farm in DeKalb, IL, the real estate gunky convinced me to tear down a hundred year old, falling down barn, because it was a liability. It felt like murder. The inch thick by ten, rough sawn cedar purlins made beautiful straight, light sticks.

Warping of cut sticks is caused by uneven distribution of moisture. The outside of a fresh 2x4 is dry, the inside is still damp. Cutting exposes the damp area which dries, shrinks, and causes warpage. Also there can be hidden stresses in the wood that cutting exposes, like around knots.

Cut no pine before its time. GG

BUILDING A STAR ROLLING MACHINE

By Pro Thrust

Having learned the skill of hand rolling round stars we both came to the conclusion that this method can be very time consuming and tiring when producing round stars in large quantities. We decided an easier way to make this type of star in larger quantities was required, without having to spend too much money. Thus was born the idea to make a low budget electric star rolling machine.

The basic construction consists of a plywood structure, incorporating two high quality stainless steel bearings, a drive shaft assembly, and a 12-volt electric motor with sealed bearings and a variable power supply. All are mounted on a base connected via hinges to another base which allows angular movement of the whole assembly to allow for different rolling techniques and different types of container (drum).

The suggested way to make this tool/machine is to first cut to size the following wooden parts as per the diagram/photo.

Bases (2)

side frames (2)

bottom former (1)

top former (2)

We suggest that unless the builder has access to a wood lathe necessary to cut the large pulley, he should have it made professionally, as this is a rotating part of the drive belt assembly and will not run smoothly unless it is well made. The cost to have this done professionally should be about $10, and if required, the drum backing support can be made at the same time.

The two formers are marked with positions where the bearings are to be inserted, then cut out using an appropriate sized hole cutter. Note that this hole will need to be a firm fit over the bearings!

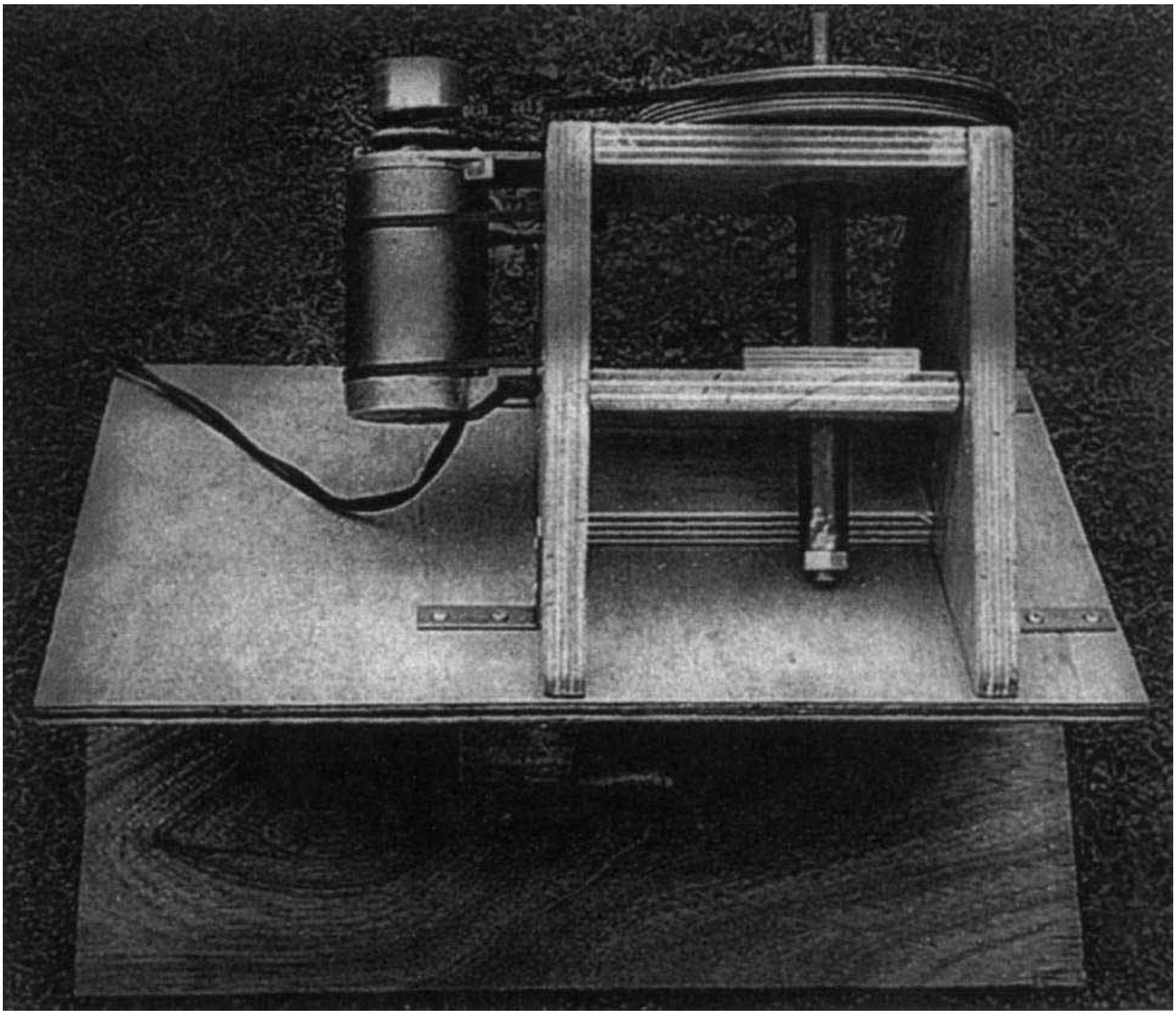
Now the wooden structure is assembled, per the diagram/photo, using white glue and wood screws. When completed it is coated with a few coats of varnish to seal the wood, which will make the wood washable when it gets dirty. At this time, the large pulley and drum backing disc are also varnished.

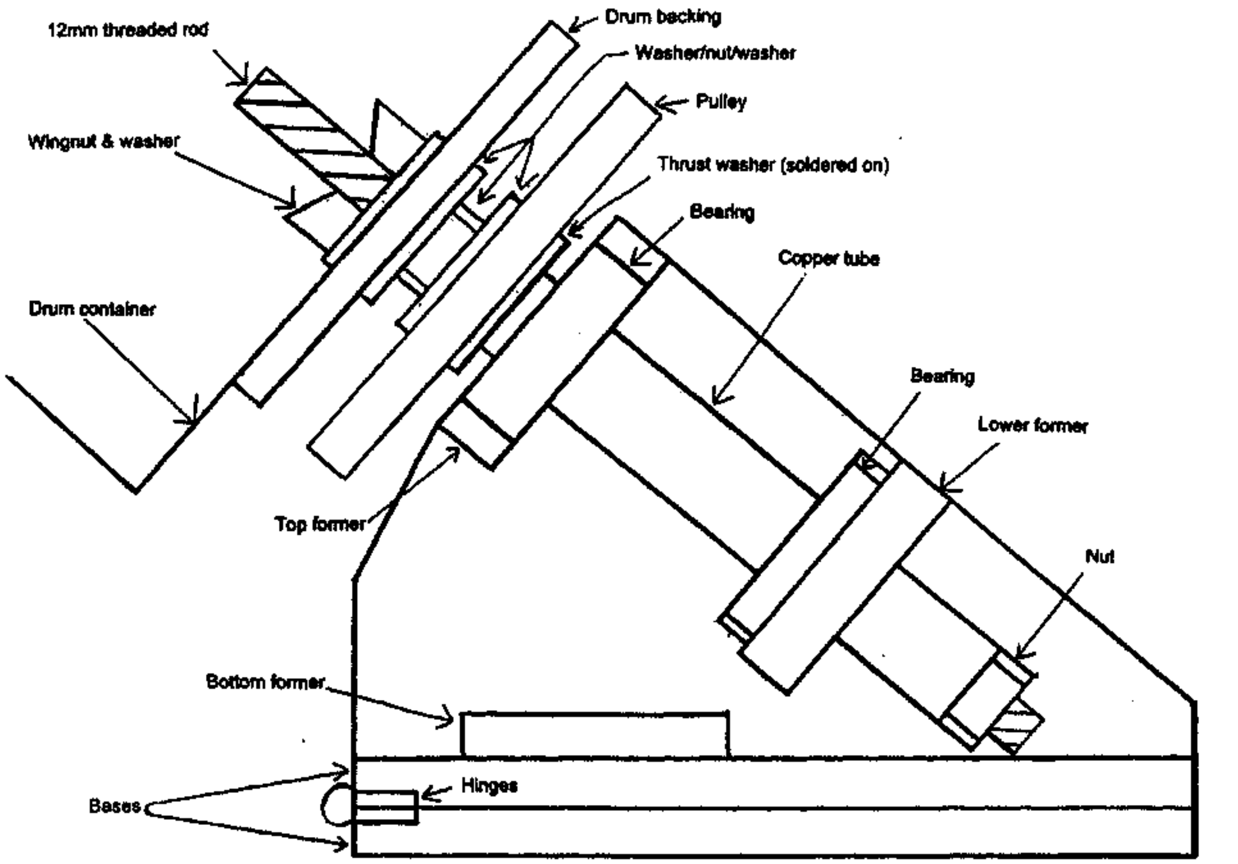
When the assembly is dry, the two bearings are inserted into the holes in the formers, then the copper drive shaft is cut to the correct length. The builder should check for the correct alignment of the bearings in the formers by sliding the tube into the two bearings and rotating slowly to check that the bearings run smoothly and so are correctly placed in the former. (Note that both planes of the bearings must be parallel with one another.)

Now the steel washer (which will act as one of two thrust washers against the bearings) is soldered to one end of the copper tube, ensuring that the 12mm hole in the washer is very accurately placed in relation to the center of the tube. Now the 12mm threaded rod is cut to length, and both ends are filed so that the nuts can be screwed on easily from both ends.

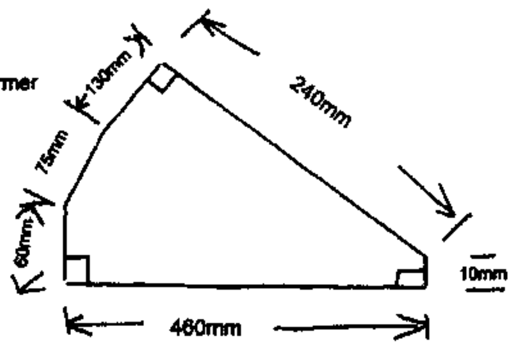
Then the threaded rod is placed into the copper tube, and the end of the tube with no washer soldered on has one nut screwed on. Note that this nut should have a small enough diameter to allow it to pass through both bearings once the drive shaft is complete (i.e., the approximate diameter of this nut will be the same size as the outside diameter of the copper tube, which will also allow for easy alignment of the threaded rod at this end of the copper tube.)

Next the large wooden pulley is placed on the threaded rod and secured firmly with a washer and nut. Then the drive shaft assembly is placed back into the bearings and checked to see that all runs smoothly and true. When all is trued up and well, a second thrust washer is placed over the copper tube and up against the lower bearing, then the position is marked where to drill a hole for the split pin, which will stop any end play of the unit. Then the hole is drilled.

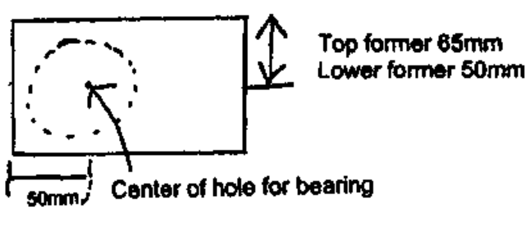




Side Former



Former (Top & Lower)



A small amount of epoxy is applied to the outer rim of the bearings to secure them in place. Note that when this machine is running, the only loads that will be felt by the bearings will be of a radical type and thus the requirement for firm fitting bearings in the wood. Now the completed assembly is placed back into the bearings and the thrust washers and split pin are fitted.

We utilized a 12-volt model engine starter for our electric motor. The advantage is that this type of motor has sealed bearings and windings, is cheap, and comes with a starter cone with a small pulley attached. Also required is a small tee belt. The belt is placed over the large pulley, then over the motor pulley. Then, per the photo/diagram, a spacer is made up to fit between the side frame and the motor casing, to give tension to the belt.

On our machine we use two strong cable ties which are wrapped around the motor casing and through holes in the side framer, which will secure the motor position.

Although this sounds very basic and simple, we have yet to have the belt slacken, the motor move, or the belt jump from the main pulley. Careful alignment of the small pulley in relation to the large pulley is all that is required.

Please remember we have tried to make the construction of this machine as simple as possible and we believe that simple works best (at least in this case!), and if it works safely, why alter it?

The power supply we use is a variable volt transformer with an output of 2 - 6 volts and a power rating of 6 amps. With this voltage the motor runs slowly enough with our gearing to give a rotation speed of the drum between low and medium revs.

The drum is fixed to the drive shaft by carefully finding the center of the drum, drilling a 12mm hold, and then place over the 12mm threaded rod and secure with a washer and wing nut. The drum we used was a 50 liter emulsion paint container which was cleaned out and the handle removed.

To adjust the angle of the rotating plane of the tumbler, all that need be done is to insert spacers between the two bases.

It quickly became apparent to us that because of the way this machine is constructed, with little effort and simply by changing the drum unit with a suitable container with a sealed lid, it is possible to turn this machine into a ball mill or mixer. We suggest that all that is necessary is to use a fibre washer on the threaded rod, next to the wing nut. This would prevent any dust from escaping from the container.

Main materials & tools

Woodscrews (approx. 50), 40mm long
Washers (4), 12mm i.d., od >22mm
Washer (1), id 22mm
Split pin (1), 2mm thick
Copper tube, 22mm o.d., 190mm long
Stainless steel bearings,
  i.d 22mm, o.d. 44mm
Hole cutter, 44mm
Threaded rod, o.d. 12mm, 280mm long
Nuts (2), (12mm rod)
Nuts (1), Wingbolt
Hinges (3) + screws
Cable ties (2)
Angle brackets (4)
Vee belt (1), circumference 620mm
Motor, 12-volt
Power supply, 2-6 volt, up to 6 amps
Drum container (1) (used 50 liter paint pot
Gas torch
Solder & flux
Varnish

Base & Frame

All constructed of 3/4" birch ply wood:

Base (1), 460mm x 290mm
Base (1), 480mm x 290mm
Bottom former (1), 130mm x 160mm
Top former (1), 130mm x 160mm
Lower former (1) 100mm x 160mm
Square bearing support, 80mm x 80mm
Wooden disc (2) 180mm diameter
Main pulley, 25mm thick
Drum backing pulley, 15mm thick.

PT

STAR TESTING DEVICE

Want a simple, reusable device to test stars in flight?

Materials needed:

1-14" length of PVC or ABS plastic pipe, ~3/4" i.d.

1-18" length of wood dowel rod (same i.d. as plastic pipe)

2 - 1 " common nails & roll of masking tape.

I cut the plastic pipe into two sections, 2" (for star sleeve) and 12" (for mortar tube). I cut the dowel rod into three sections, 4" (for star plunger), 2" (for mortar tube bottom plug), and 12" (for comet rammer). I seat the plug into one end of the mortar tube and drill two small diameter holes cleanly through both the plastic tube and the wood plug. The two holes should be an inch or so apart, and should be offset by 90° to each other. By offsetting the holes, there is less likelihood for the wood plug to crack. I insert the two nails into the mortar tube through the plug so it is held firmly in place. Next I drill a 1/8" hole through the length of the tube plug, avoiding the crossed nails. The hole should be slightly off center. This hole will accommodate a length of 2/32" visco fuse. The hole through the length of the plug should not interfere with either of the two nails. If the drilling went well, I mark the bottom of the plug and the tube to show the aligned position. If not correct, I cut another 2" plug and start over.

I cut off a 4" length of green visco fuse, tie a knot at one end, remove the plug, insert the fuse through the hole so that the knot is at the top end of the plug and there is about 1" protruding out the bottom end. I reseat the plug, pushing it up into the bottom of the mortar tube (knotted end of the fuse first). I align the plug, replace the nails, and wrap with a layer of masking tape so that the nails are held securely into the tube, thereby holding the plug in place.

I form cylindrical pumped stars by using the 2" length of plastic pipe as the sleeve and the 4" length of dowel rod as the plunger. I consolidate my stars just as I would with a more expensive, professionally made star pump.

I have also test fired round stars with this device with excellent results. When ready to test stars, I pour a very small amount of black powder (lift charge) into the tube, followed by the star. I use the 12" comet rammer to gently push the star down into the mortar so it sits directly on the black powder and the knot at the end of the fuse. I place a 2-foot length of cheap grape stake alongside the mortar, and tape it firmly to the tube. The stake is positioned flush with the top of the mortar but extends about a foot beyond its base (similar to a rocket). I push the stake into the ground, leaving the bottom end of the mortar and fuse exposed. A word of caution: hard plastic becomes a deadly frag bomb if adequate safety measures are not observed.

To reuse, I pull out the nails, replace the fuse and reload the components. Between test firings, I am always cautious to push the comet rammer completely through the entire tube in order to flush out any remaining hot dross, just in case. I have used this set-up dozens of times over before the mortar tube and plug needed to be replaced. Total cost: under two dollars.

FIELD-EXPEDIENT PAPER PLUGS

by Harry Gilliam
Skylighter, Inc.

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

DRYING STARS WITH A FOOD DEHYDRATOR

By Graham Pugh

One of the first things I noticed when I became a practicing pyro hobbyist was how long it took stars to dry. Depending on the composition of the star and other factors such as temperature and humidity, some would dry in a day or two while others took much longer. I even had experiences where, after several weeks, my stars were still damp!

I had read about professional fireworks companies using specially designed buildings for the purpose of drying stars. The design calls for hot air to be drawn into a building from a remote source, circulated around racks of drying stars and finally vented by an exhaust fan at the roof peak. Other designs use solar power. Whatever the design might be, the idea is to assist the drying process. As a hobbyist, building a "drying shed" on my property was not practical.

Several years ago I purchased a food dehydrator for the purpose of making beef jerky. If I remember correctly, I paid $29.95 at my local Wal-Mart (I have seen similar units for sale at other retail outlets). Anyway, I hadn't used it for quite a while and thought it would be perfect for drying stars.

My dehydrator is manufactured by the Waring Company and consists of a base unit, stackable trays and a lid. The base unit is equipped with electrical heating coils and a small fan. Air enters at the bottom and is drawn across the heating coils by the fan. The heated air is forced through holes in the top plate of the base unit. A large clear plastic lid fits over five stackable trays that sit on top of the base unit. The air circulates around and through the trays and is vented through small holes at the top of the lid. The unit is easily cleaned and the trays can be run through a dish washer if you like.

My very first attempt at drying stars with my dehydrator was successful. Here's how I did it: I arranged a batch of cut stars on the trays (these happened to be Spiderweb. You will be surprised at just how many stars the trays will hold!) I set the unit a considerable distance from the house, away from flammables (leaves, etc.) and other potential hazards. Power was supplied with a long extension cord. After 24 hours or so, I unplugged the extension to remove power. I decided to wait about 30 minutes before removing the stars. This would allow time for cooling. I was delighted to find that my stars were rock hard! What would have otherwise taken days was accomplished in just one! I spread the stars out on my "conventional" drying rack and left them a few days before storing.

One thing I have learned when using this method is that over-dampening your star composition must be avoided otherwise a crust will quickly form over the surface of the stars, effectively "locking in" the moisture. Your stars may never dry!

It is conceivable that some star comp could come into contact with the heating coils. For this and other reasons, caution is strongly advised. That's why I power my unit with a long extension cord and place it away from the house, out of harm's way. Stars should never be dried indoors!! Also remember that the trays and lid are made of plastic and could produce static discharge.

Please note that drying stars in this manner is a method, not a shortcut. You must decide for yourself when it is appropriate to use. I have used this method dozens of times without incident and have determined it to be relatively safe when the rules of common sense and safety are applied.

I mostly use the conventional method when drying my stars, but every now and then I call my dehydrator to duty. It serves me well and in ways the manufacturer never imagined! GP

CARE AND FEEDING OF A MORTAR AND PESTLE

by Carl Denninger

Not much is heard among pyros of the humble mortar and pestle these days. All the grinding work is being done by motor driven mills. This is fine when formulas are well tested and sure so that pounds of finished product are desired. But for the hobbyist and experimenter a mill is just over-kill. Small quantities of chemicals can be ground to a fine dust quite quickly in a mortar, allowing the experimenter to prepare formulas in the size of ounces instead of pounds. This allows for more efficient use of an experimenter's time. Small quantities of chemicals get lost in most hobbyists' mills, and there are problems with contamination from other chemicals milled and the media and the jar, as the ratio between media and machine massively exceeds the mass of the material being milled. Lead, brass and ceramic media grind against each other and show up as lead, copper, zinc and/or abrasive grains in the formerly pure dust. Also lead and brass are soft, and ceramics are porous, allowing chemicals to be imbedded in their surfaces only to show up as contamination in the next mill job. Imagine the resulting danger of sulfur contamination in chlorate, or sodium in a star mix you don't want yellow in! The mortar and pestle are easily washed with soap and water and dried with a towel. They are made of porcelain and glass, which are not very active in any chemical mixtures the average pyro might be working on. You might have to wait an hour for your mill to grind up some sulfur that got lumpy on you, and potassium perchlorate mixes so much better if it's freshly milled or ground. Small quantities are ground in minutes with a mortar and pestle.

Mortars and pestles vary in size and price depending on the source and use. Surplus chemistry suppliers are a good place to start looking. 5 to 20 dollars is a ballpark figure. Don't worry about buying used as they are easily refurbished and should be regularly maintained. The scratches in the surface do the fine grinding work. With use these sharp scratches become rounded and the grinding action slows down and the fineness' of the ground material decreases as the labor increases. Many pyros abandon their mortars soon thereafter.

Bring back that brand new fast and fine grinding action of that worn mortar and pestle with some course silicon carbide sandpaper. I'm talking about a course grade, like a 30 grit. Don't even bother with any other type of abrasive except diamond, which is pricey! The base material is far harder than aluminum oxide or flint. Tear a piece off the sheet about two inches square. Pressing as hard as you can, make horizontal scratches around the sides of the mortar until you can see the area completely covered. Replace sandpaper often as it will lose its sharp edges after just a few passes. Use a circular motion to restore the bottom. Put rotary scratches on the pestle by angling the round head and sliding it along a full sheet of sandpaper like you would scratch a match head to light it.

Never grind fuels and oxidizers together. Doing so makes left-handers out of right-handers. Do not allow cross contamination such as sulfur residue when grinding a chlorate, or chlorate with an ammonium salt, etc. Speed up your experiments and prove new recipes with small fast batches from a mortar and pestle. CD

TIP OF THE MONTH

A trick Orv Carlisle taught me is that if the rocket is blowing up, tuck a little toilet paper in the very apex and this may slow it enough to function correctly. —Doc Barr

GRINDING

By Lloyd Scott Oglesby

Learning pyrotechnics involves a lot of grinding if we want good control over the results. Understanding of grinding will overcome ignorance. Before you get your ball mills set up, you are in for a lot of work.

MORTAR & PESTLE

In the good old days you could buy a porcelain mortar and pestle that were ready to use. That the universities no longer teach the care of these is evident in any stockroom at any university. Many of the new ones on the market are not ready for use. Glass mortar & pestles never were sold ready to use. The problem is that these materials are hard and as sold, do not have the proper tooth or fit. If too rough there will be places that pack up with the stuff being ground; if too smooth they will not hold the particles for pressure and shear so as to effect efficient grinding.

The trick is simple (and is also used for cleaning when the surfaces become contaminated and ordinary cleaning is inadequate). Grit, usually either silicon carbide or the traditional emery or some other hard, abrasive material is used to grind away the surface as furnished. Normally about 200 mesh grit is used and ground until the surfaces are well ground, then a finer grit may be used, until finally 400 mesh grit leaves a good working surface. Cleaning with light grinding of abrasive cleaner is normally enough but gooey, gummy or easily packed materials may require resurfacing.

BALL MILLS

The grit treatment is particularly necessary if natural materials are to be used as the media in a ball mill, but this is no longer a common practice. Every pyro should read the section on grinding in Perry and Chiltons Chemical Engineering Handbook. It is not difficult at all and since so much industrial grinding has always been done in ball mills, there is a very good section on these. Even if you ignore the very simple equations, the common sense level of understanding that you quickly get from the book may help a great deal.

THE TILE METHOD

Pharmacy used to involve great labors of grinding, and any method that made the work go with less effort was encouraged. The mortar and pestle was not the most often used technique.

A glass or other hard material flat surface, properly conditioned with grit, was used with either a flexible spatula or a small, nearly cylindrical object used as the equivalent of a pestle. These were used to grind batches that were larger than could be easily ground in a mortar. A slab of plate glass and a small chunk of glass, perhaps 2" or 3" long and an inch or less wide provided far more surface for grinding than the usual pestle. It could be glued up on a wooden handle and shaped with wet grinding on wet or dry silicon carbide paper. It is possible to experiment with different shapes to find an efficient one for hand grinding. To surface the glass plate, the shaped grinding tool and about 400 mesh grit can be used, but it may be easier to start the process with more coarse wet or dry silicon carbide paper. The old term for this was *tile grinding* because it was done with a piece of tile. Obviously the slab and roller grinding was used for larger batch sizes.

If you read the history of grinding technology and particle size control, you will quickly understand why it is so very important. Much of pyrotechnic control is related to particle size control. For instance, if you weigh out *chunks* of chemicals, it would take about five minutes of careful heating in a test tube to get the reactions between potassium nitrate, sulfur and charcoal. But grind them all finely and you find it is not a safe thing to try to heat much quantity in a test tube!

To obtain a far better degree of control over your results, it is not necessary for you to do the tedium of fine measurements on pyrotechnic materials as would be required for fine science work, but I am very glad to see much more scientific work in our literature with the inclusion of photomicrographs. The new computer programs for particle size control will eventually improve our fireworks and our understanding of how they work. That understanding very definitely does give better control for better art. LSO

LEAD BALLS FOR MILLING

I have been collecting and melting wheel weights for bullet casting for a long time and have also cast ball milling media. Here's what I have learned.

I have been able to acquire wheel weights from garages by offering to pay for them at the going scrap metal rate (was about 6$/lb.) and by showing up regularly to get them. I always bring a 5 gal. plastic bucket with me to replace the bucket I'm taking and I also bring a handtruck and scale so that none of the shop employees have to stop their work to help me. It helps to go to shops that you patronize and if they let me have them for free I leave a large bag of M&Ms as a "thank you".

When I melt the weights I use large cast iron pots such as can be found in antique shops for $10-$20. My source of heat is a large propane torch like the road crews use to heat asphalt, or homeowners use to burn weeds. They are available in hardware stores and can be run off a 20 lb. propane (gas grill) tank. It is very important to support the pots very well as a pot about 8" in diameter and 8-10" deep can hold up to 70 lb. of melted lead. I use an auto wheel rim cut out so that the pot sits down in the middle of the rim. This serves to keep the pot stable and keep the propane flame focused on the pot. Even better is a commercial type gas deep fat fryer because it handles a large volume and allows you to pour from the bottom without having to skim off the dirt as carefully as when you are taking the molten lead off the top.

When I have a number of buckets of wheel weights to melt, I put the cleaned lead in ingots, using the old fashioned cast iron muffin pans that you see in antique shops. These make an ingot that is easy to handle and weighs about one pound.

The experts recommend adding up to 2% tin by weight to make the alloy harder. I was told that after 2%, additional tin doesn't seem to help increase the hardness. Tin, antimony, lead mixes, plumbers furnaces for melting lead and other tools marketed mainly for bullet casters are available at:

Bullet Metals
PO Box 1238
Sierra Vista, AZ 85636
602-458-5321

GAR
139 Park Lane
Wayne, NJ 07470
201-256-7641

and you may find other sources under reloading components in *Shotgun News* and *Gun List*

After you have the lead and get it melted you have to mold it. I have used bullet molds for Black Powder guns (balls) up to .50 cal. and a mold for a round ball for a 12 ga. shotgun. For larger balls I found a mold at:

Hilts Molds
1461 E. Lake Mead Drive
Henderson, NV 89015
702-565-5385.

Their molds are cast aluminum and make fishing sinkers. They designate their molds by weight of the finished product .rather than by sinker diameter. The mold that I use has 8 cavities for 2, 4, 6 & 8 oz. (2 cavities for each size) sinkers. The 2 oz. cavity is about 13/16" and the 8 oz. is about l 3/8". It is catalog item #LMCB-2468 mold, priced at $38.00. The mold is well made and has worked well.

I have found that rather than make a few balls and try to clean them to use for various mixtures, I made lots of them to have for each individual chemical or mix so that contamination isn't a factor. I have not used this media enough to declare that it works without problems and doesn't contaminate the product, however, it does seem to work well.

When I began working with the lead I was told that I was going to poison myself. My research revealed that the biggest danger of lead poisoning is by oral ingestion. I also found opinions that a lot of skin contact could also cause poisoning. Thus, I always wear gloves and am careful not to eat the lead, on purpose or accidentally. I have had my blood checked each year for lead and have never had any elevation of lead levels. However, I have learned that lead may not show up in blood but may be deposited in various tissue. It pays to be careful.

I have been told that there are lots of nasty things in the wheel weights and I am careful to wear a respirator when melting the weights. I have seen minuscule amounts of water blow lots of heavy, hot lead over 10 feet high.

If the set up for all of this seems daunting to get some cheap lead balls you might ask around in the gun shops and among the Black Powder shooters and competition pistol shooters that you know about where they get their cast bullets. You might find that you could buy the mold and get some wheel weights and have a local bullet caster do the work for you. Although the process I have described above is relatively simple and quite rewarding, it can be messy and time consuming. EDW

CASTING LEAD

I have cast lead bullets over the years and have added antimony metal to the melt to harden the alloy. Try to purchase 50-50 lead/antimony alloy, as pure antimony metal added directly to the molten lead does not readily dissolve, except at a rather high temperature.

Ading a flux to the melt is desirable, and allows skimming off the dross (and some tin, if also present). Tin is frequently added, a few percent, as it greatly improves the castabiliry. Watch out for beeswax, as it fumes and smokes like crazy, and its use must be outdoors. The smoke also can catch fire. I have used a non-smoking flux available from Brownell's, Inc., Montezuma, Iowa.

A strong word of caution about melting wheel weights and other lead sources. A tiny bit of water (as trapped under the steel clamp) can result in an explosion of molten lead. I'm not exaggerating, the lead virtually erupts from the steam produced. SMB

CANNON BALL MOLDS OFFER MILLING MEDIA

I thought that the how to build a milling machine book was so exciting that I rushed to begin the project. Alas, I was faced with the problem of finding suitable milling media.

Looking for non-sparking, round, hard objects that would work in the mill, I first examined lead fishing weights. They are available in a variety of sizes and shapes, but a larger diameter seemed better.

As was pointed out in his article, one source would be black powder round bullets which are available in many sporting goods stores. Heading for the local stores, I soon found the same problem that the author did: the largest diameter available is still too small.

Then I hit on the solution. How about cannon ball molds? They come in many sizes, and once you buy the molds you can make all the media you need, and can tailor your alloy to fit the milling problem.

Cannon ball molds, as you can imagine, are not available at the corner convenience store, but I found the manufacturer, who, he says, offers a complete catalog.

Hilts Molds
1461 E. Lake Mead Dr.
Henderson, NV 89015
(702) 565-5385

One final thing. If you do go this route, you'll find that the balls produced by these molds have the manufacturer's name in the casting. A little work with a file should soon fix that. RH

INFORMAL NOTES ON HEARING PROTECTION

By Dave Pierson

Nature gives us only one set of ears. Some activities stress them more heavily than others. Hearing damage from loud noises is cumulative; every added exposure increases the damage, and damage is more or less irreversible. By the time damage is obvious, it is too late. Soooo, some nonprofessional comments for your consideration.

The minimal protection level, and generally required by OSHA regulations in force on many crews, is foam earplugs. These come in many grades, from one-use disposables thru custom fitted "musician's plugs". These protect against sound waves arriving by air through the ear canal, however sound waves also arrive direct, thru the bony structure, and these have little effect. It was interesting to note in a recent "SEAL'S *in Training"* video on cable that foam ear plugs were in use and visible. In my own case, a low break of a major caliber aerial shell left some people near me in need of medical attention. Since I was (finally...) wearing foam plugs, I was aware that something loud had happened, but was otherwise quite functional and able to assist.

The next level above foam plugs are the simple muffs. Generally speaking, these provide improved protection, as they better cover the ears and surrounding structures. They can be a bit cumbersome, and hard to use with a hard hat, but they work well. A little shopping can turn up a hard hat designed to work with muffs; some even include the muffs and eye protection. (Eyes, like ears are vulnerable.) Commonly the muffs on such a setup flip up easily for convenience.

Any sort of passive protection, be it muffs or plugs, can affect communication. Modern electronics allow a fast switchable amplifier, of reasonable size and cost, to be built into a muff set. Such active protection gives normal sound levels and switches OFF the amplifier at the moment of **BANG** Extending this principle, 'Wolfs Ears' (as they are sometimes called), can provide enhanced hearing and still limit the extreme energy of the bangs associated with pyrotechnic operations. Many of the electronic protectors can be provided with connections to work with a radio system of choice.

Pricing runs from a few dollars for disposable plugs, up to $200 or so for one of the electronically assisted sets. $200 is a lot of money, but it is cheaper than hearing damage. The low end equipment is widely available in hardware stores, etc. Shooters' suppliers carry a wide range of more elaborate equipment, as do power equipment stores. Chain saw use imposes a fair degree of visual, aural and head injury risk. I will leave recommendations to someone more skilled than myself, except the recommendation to *Get* and *Use* some protection.

On a related note, eyeglass wearers may wish to consider getting one pair of ANSI rated eyeglasses for set up and shooting. This is distinctly more than just safety glass, as the frames must meet strength requirements. Additionally, they must be used with the side shields. Checking with the Safety Consultant for the company I shoot for, such glasses satisfy OSHA requirements if specifically purchased as safety glasses. I find them, with side shields, much better than glasses plus goggles. And I wear my steel-toed shoes on the line. Racks and pipes do get heavy and slip. DP

GROUNDING MY WORKSHOP

Garry Hanson
Precocious Pyrotechnics, Inc.

We use products made by 3M Co. and or Walter G. Legge Co.
www.leggesystems.com.

For the table tops we use a product called Legmat. It was made for the floor but works very well on table tops. This product wears good, is flexible, cleans up well, is resistant to most chemicals and solvents, and is cheaper than, and easier than covering all the tables and work areas with metal. It comes with a grounding system that has a 1 meg resistance built in, or you can buy the system with different ohm ratings for different applications.

We also use wrist, leg, and toe bands to ground the employees when needed. All containers when mixing sensitive mixes are made of conductive materials. These containers can lose their conductivity so we also place a grounding wire on them. We had a loss of conductivity one time because when mixing and moving the containers around through the process of mixing, the mixture had built up on the work surface and the container loss contact with the base surface. Keep your work area clean at all times.

When grounding, DOUBLE ground everything, just in case one of the grounds fails.

All floors are painted with static conductive or dissipating paint with a grounding system used with them. These need to be tested periodically.

Concerning grounding wire or connectors, if you use aluminum and copper together you need to protect the connecting point or connection with a electric conductive grease or paste. This is so the connection doesn't fail from aluminum and copper metal-to-metal contact. Also oxidizer in the air will get into the electrical joint and cause trouble in just a short time.

There is much written about static dissipation and should be read by all those using grounds.

WE do NOT have or use lighting rods, at least not connected to any building housing explosives. Why place a metal rod on top of a building full of explosives and tell the lightening gods to strike it and see what happens? Our military ordnance rules state IF using lightening rods they have to be tested no less than twice daily!

For shielding, we feel the safest place to store products with an electric match attached to them is all metal buildings (all walls, doors, and the roof), metal truck bodies, or shipping containers,. No science to prove this yet. GH

BLACK POWDER ORIGIN, A HOBBYIST'S PERSPECTIVE

by Carl Denninger

Because I'm a pyro hobbyist, I have a differing take on the world about me. I wish to advance my theory on the origins of BP. I have not heard this idea anywhere else but it seems to make perfect sense to me. I believe a product similar to BP could have been made regularly and unintentionally at sites which ground grain or pumped water using beasts of burden.

These animals tethered to a pole, walking in a circle about a pivot point, chasing that proverbial carrot. The ground beneath their feet must have been stone or at least very hard to keep from wearing a deep trench. Urine and other wastes no doubt covered the ground and even requiring regular removal.. The water soluble products soaking into the surface. We know animal activity equals ammonias, changing to nitrites, changing to nitrates, the major component of BP. We know how highly soluble potassium nitrate is and we've seen how our ball mills pound the nitrate into the long molecular strands of carbon in charcoal. I can imagine the animal hooves pounding their wet wastes into the ground and pushing nitrates into the carbon of the organic excrement containing large quantities of cellulose fiber.

Protein molecules contain sulfur. Muscles, hair and skin are made of protein. Waste proteins, and therefore sulfur would be contained in animal wastes. The smell of rotting flesh is hydrogen sulfide, formed as the protein chain comes apart. So there we have all the ingredients and the mechanical means to make a material that could burn rapidly and maybe even explode. Abandoned animal mills and mills during the off-season could have been highly valued by our earliest pyro forefathers, the inventors of black powder. CD

"Y" COMP MIXERS

[Mixing chemicals to make pyro composition is a mysterious process for many hobbyists. Grinding, milling, diapering, screening - who knows what to do and what is appropriate? Actually, it's not so difficult since most comps are simple mechanical mixtures and need be mixed only until the color is uniform. Many manufacturers prefer to do this mechanical mixing in a "Y" mixer, a simple device that quickly and efficiently mixes most comps. It is so simple that many people seeing it for the first time will exclaim, "Why didn't I think of that?" But some caution goes with the device. Comps falling through cardboard or plastic tubes WILL generate static electricity, so some precautions are needed when operating and unloading such devices.]

by Dick Williams

Of all the things in pyro that cause me to worry, mixing powder ranks Number 1. I'm just not comfortable with a couple of kilos of flash comp (for instance) being manipulated back and forth on a wide piece of paper. I know that should a spark occur, I'd be gone before I could realize it, but this is one of the things in the Small Comfort File. Besides, it is a very messy operation at best.

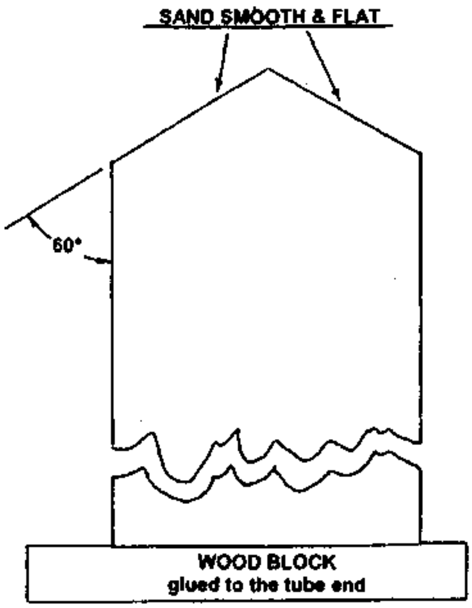
In an effort to eliminate at least the mess, I have built a mixer that does the job very well, it consists of a "Y" shaped container which pivots about an axis. Each time the mixer is rotated, the contents are divided and recombined as it drops from side to side.

I have on hand a number of cardboard (paper) tube with a diameter of 3 5/8" with a 5/16" wall. The size of the tubes in a hobbyists junk pile may well differ, so we'll just use my dimensions with the understanding that the sizes aren't that important.

I begin by sawing a tube into three segments about 1-foot long, and cut some scrap wood 4 - 5" long. The length doesn't matter but it must be exactly as wide as the diameter of the tube.

Now I glue (and allow to dry) the wood pieces to the end of each segment of tube, which will allow the pieces to be turned over with great precision.

Next I cut the tube ends to 120° by setting my miter gauge to 60°. Some saws can't make a complete cut because the blade doesn't protrude enough, so the cut can be finished with a handsaw or by eye-balling through the kerf to keep the saw lined up. Length is not important because they will be cut to length later. The 120° surface is smoothed up on a sanding disk.

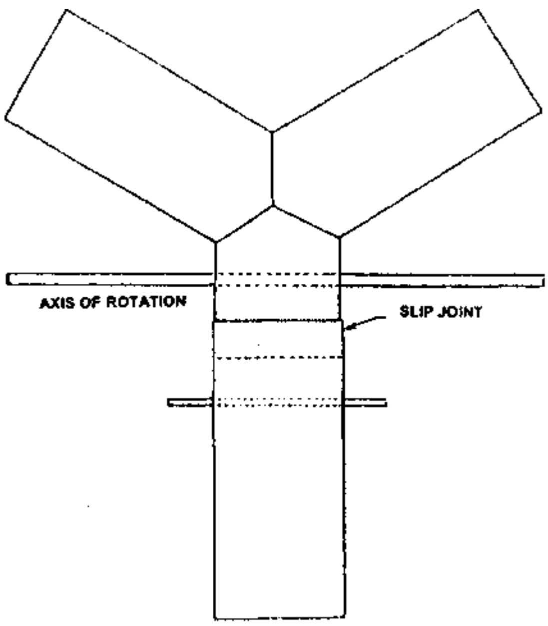


Now I cut two pieces, 4 - 6" is good, and the remaining piece to about 3". I use a sharp knife or sandpaper to eliminate any trashy spots. The two longer pieces are glued together as shown. When dry, I carefully fit the short leg, adjusting the angle, as required, on the sander. When everything is satisfactory, I glue the short leg into place. The reason for having this short leg is so I can reach into the interior to smooth the glue joints. When the assembly is dry, I use a sharp knife to correct any messy glue globs.

Next, using the cut-off of the short tube, I wrap it with light cardboard (like a cereal box) so that there is an inch or so extending beyond the end. This will give a nice fit that will slide on and off the short leg, making a removable third leg to the container. The better the fit, the cleaner will be the mixing. This is glued to the length of tube and allowed to dry.

Now this lower leg is trimmed to be 6 - 7" long. I sand the end surfaces of the tubes so they are clean and flat, and then glue appropriate discs in place. The 3 5/8" tube very conveniently fits the nominal 4" chipboard disk from the suppliers.

I use a piece of 1/2" dowel as an axle because I usually have some on hand. I don't think I'd be comfortable with anything smaller. Holes are drilled in the side of the mixer, being careful to avoid the area where the bottom leg slides on and off. The dowel is inserted and glued into place, after cleaning up the interior. I don't know if it is really necessary, but I insert a piece of dowel through the bottom leg so I can tie the bottom to the top. I suspect after a few uses, the slip joint might become loose, so this will secure the bottom.



For strength, I wrap the junction of the three tubes. At my local medical supply store I got a package of the pre-impregnated gauze used for casting broken legs and such, and cut it lengthwise into two strips. Moistened and applied to the joint as a cast, it *is* somewhat unsightly, but I haven't the patience to do a really neat job. Of course, I carefully avoid getting any plaster on the area where the bottom leg slips on.

For a frame I use any old lumber, making sure that the frame is high enough that the mixer can rotate freely. A pair of large screw-eyes at the top of the uprights will work for the axle, with a couple of short pieces of 1/4" dowel through the axle to secure it in place. A longer piece, about 3", makes a handy twister for the other end. Perhaps a motor could be used to turn it - slowly. But that adds a sparking problem.

The size of the mixer will determine how much can be mixed each time. I suppose that a 6" tube could blend 4 to 5 lbs. at a time.

Because there is always some residue left from each mixing, I made several mixers and confine each to a certain comp. They certainly are cheap enough. And I always use a puff or two of Static Guard. DW

IMPORTANCE OF FINALES

By J Larry Mattingly

Never underestimate the importance of the finale. The man that taught me over 40 years ago said that 20% of the pyrotechnic materials should be in the finale. I have followed that rule to the extent possible all these years.

The thing people remember most is the last thing they see. That's the finale. The finale is the end of the show and nothing should be fired after it. It is anti-climatic. The finale is your last chance to make or break your display. A poor finale on a great display can ruin it. A great finale on a poor or marginal display may save the day. A really exciting finale tacked on to a good display makes it great. A great finale on a great display makes it a fantastic experience.

The best way to be sure to have the very best finales is to fire electrically. By carefully choosing the ignition points you can have absolute control over what appears in the sky and when. If you don't have a firing system, use a nail board. They are simple, and fast and easy to make, and they work. JLM

VARYING THE SPEED OF A DC MOTOR

By Bob Svenson

Recently there has been some discussion on the Internet lists concerning the selection of a motor for use in a star roller, and the methods to vary the motor's speed.

This subject arises fairly regularly on the Internet lists and since I haven't seen much on the subject in the pyro publications I thought I would relate my experiences.

There are several different types of motors that can be used in star rollers - electric (ac and dc), pneumatic, hydraulic, etc. However, due to availability and ease of speed control, the most commonly used type is a direct current (dc) electric motor, so the remainder of this article will deal with the different techniques available for varying a dc motor's speed. (The author is making no recommendation on the type of motor that should be used in a star roller - electric motors can and do spark, there may be static issues with pneumatics, etc. so one has to do some research, carefully design his star roller to minimize the risks of highly flammable compositions near the motor and rotating assemblies, and decide for himself his level of risk tolerance).

There are basically three methods to vary a dc motor's speed:

1) Mechanically by the use of a gear box, belts & pulleys, etc. to vary the ratio between the motor shaft and the shaft being driven.

I felt this method would be expensive and cumbersome to implement - especially since I really wanted to have a wide range of control over the motors speed.

2) By using a rheostat (variable resistor) in series with the motor - less voltage to the motor means less speed.

The problem with this approach is that the current drawn by the motor increases as the load on the motor increases, which results in a larger voltage drop across the rheostat and thus less voltage to the motor. The motor then tries to draw more current, more voltage is dropped across the rheostat, and the end result is motor stalling.

This doesn't mean that a rheostat won't work - I know several who use this approach on their rollers and they do get some occasional stalling, but on the whole it does work for them.

3) By applying the supply voltage to the motor for a variable amount of time (this eliminates stalling under load as no voltage is being dropped across a resistor). In simple terms, the full supply voltage is turned on and off rapidly. This method seems to be the preferred one in use in industrial applications. One method for doing this is called "Pulse Width Modulation" (pwm).

After researching the different methods, I decided that pwm seemed to be the approach that looked the best to me. However while looking around for a pwm controller, I found that they are fairly expensive. Fortunately I found that Jameco Electronics sells a pwm motor speed controller in kit form that's reasonably priced. I have some experience with electronics so I found the kit was quite easy to assemble (the instructions accompanying the kit are quite clear so I'm sure that most anyone could assemble the kit without any problems).

A few tips for using the Jameco kit:

The kit can control a motor requiring up to 100 volts at 5 amps. For the smoothest speed control, I would suggest using a rudimentary dc power supply with a filter capacitor (no real need for voltage regulators, etc. but rectifying the transformer's output and smoothing the power out a bit with a capacitor is easy and inexpensive to do). Power supplies are also fairly simple to construct and I feel well within reach of the average pyro (Radio Shack sells an inexpensive book on power supply construction that's quite helpful).

The power for the pwm circuitry itself can be taken from the same power supply as the motor if the motor requires 16 volts or less, however my motor is a 40-volt motor, so I tapped off the 40 volt motor transformer and used it to feed a small regulated variable power supply. The voltage supplied to the pwm (Vcc) affects the top speed of the motor so I suggest a full 16 volt supply for it (though it will operate with 5-16 volts).

Setting the top speed of the motor: As I just mentioned, the top speed is affected by the supply voltage to the pwm board. A full 16 volts could be applied and there's a provision on the board for a resistor to adjust the top speed, but I just installed a jumper in its place and built a variable power supply for the pwm board and now can adjust its output to set the top speed.

Setting the minimum speed: The kit as provided makes no provision for a minimum speed setting. I like a nice wide span of adjustment between the upper and lower limits - if the operator never runs the machine below half speed, then half the adjustment range is wasted. This leads to the problem of "a small change in adjustment makes a large change in speed." To overcome this I installed a variable resistor (potentiometer) across the speed adjustment variable resistor. Here is a schematic of the installed resistor.

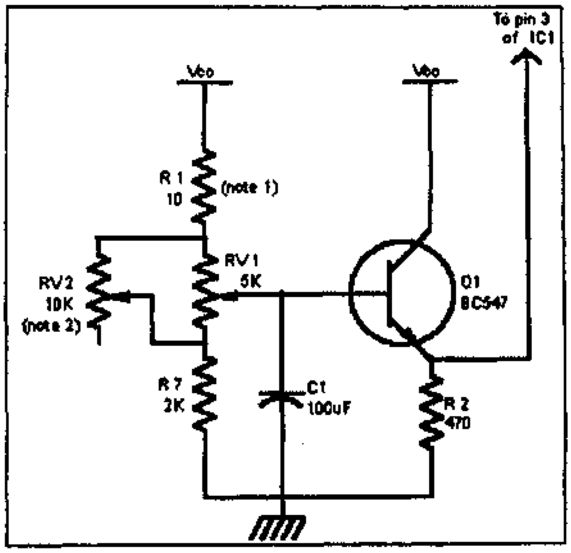
I'd like to remind the reader that this is not the only method that can be used, but it's just the method that I found worked well for me and was reasonably priced. The amateur pyro community comes from quite diverse backgrounds, so perhaps there's someone with a better or easier design?

Sources:

Jameco
1355 Shoreway Road
Belmont, CA 94002-4100
1-800-831-4242
www.jameco.com
D.C. Motor Speed Control Kit
Part # 127829, $29.95

Radio Shack (Nationwide)
Book "Building Power Supplies"
Part #62-1337, $7.99

Surplus Sales of Nebraska
1502 Jones Street, Omaha NE 68102
(402) 346-4750
surplussales.com
grinnell@surplussales.com
A great source for transformers, capacitors, etc.



Note 1: The maximum motor speed may be set by varying the value of Rl. Rl may be replaced by a link and the top speed adjusted by varying Vcc.

Note 2: RV1 is the speed adjust. RV2 is the added resistor used to adjust the span from the top speed to the minimum speed.

To set the minimum speed, set RV1 for minimum speed, then adjust RV2 to give the desired minimum speed. BS

FIREWORKS ARE IMMORTAL

By Steve Merrill

Long after we are past
They'll see the FLASH
And hear the CRASH
in someone's backyard.

What laws they passed
Which stones they cast,
they tried so-o hard!

- BOOM - bang - fz-zzz - pfft!
But none could legislate
morality, Pard'!!

BLACK POWDER & HORSE DUNG

By Donald Haarmann

Murtineddu's Powders consist of mixtures of nitrate of soda (with or without saltpeter), with sulphur and various substances as tan, coal, sawdust, &c.

The mixture, patented in England of:

Saltpeter	100 parts
Sulphur	100
Sawdust	50
Horse dung	50
Sea salt	10
Treacle	4

The object of adding the treacle is to give cohesion to the composition. It is claimed that "this composition does not cause explosion upwards as with gunpowder."

From: JP Cundill, *A Dictionary of Explosives* 2nd ed 1895

Horse dung Explosive.

W. Eberle, USP 910 365 (1909)

Potassium nitrate	12 parts
Sulphur	3
Charcoal	1
Pulverized horse dung	1

Fulop & Lackovic Explosive (Hungarian):

Fresh horse dung	60%
Potassium nitrate	26
Sulphur	10
Dye	4

Echos of Escho.

According to Molina, Explosvio Echos —

Ammonium nitrate	75%
Silicon	16
Aluminum powder	2
Dried horse dung ("Ipposino")	7

Used by the Italians for military purposes.

Praepositer (or Praposit). An explosive similar to black powder manufactured in the 1870's by the International Praeposite Co. Powder Works, Millville, NJ, until the plant exploded. The composition was potassium nitrate, sulphur, charcoal, and "Hipposine", finely pulverized dried horse dung. The same explosive was manufactured in Germany by the Deutsch Prapositwerke GmbH, Karlsruhe in Bavaria. [Hippo is Greek for horse.]

Improvised Pyrotechnic Mixtures for Guerrilla Warfare Applications, Picatinny Arsenal, 1964

Test results showed that five of the systems tested exhibited high order reaction as indicated by their capability of fragmenting the test vehicles into large pieces.

No. 3

Potassium nitrate	70%
Sulphur	18
Charcoal	6
Animal dung (chicken)	6

B Jackson, Jr. & SM Kaye

An Improved Blasting Powder

S. Fiilop and M.J. Lackovic, Budapest.

English Patent 13,822, June 4th, 1897

This powder consists of a mixture in the proportions of horse dung, 28 parts ; saltpeter, 39 parts ; fine gunpowder, 23 parts ; sulphur, 10 parts.

In:— *The Journal of the Society of Chemical Industry.* May 31, 1896. from PATR-2700.

Blasting Powder

J. Tollner, Assignor to F.G. Dokkenandle, and H.M. Grant, New York

USP 757,693, April 19, 1904

Potassium nitrate	15%
Sodium nitrate	30
Sulphur	15
Spent tan bark	20
Horse manure	20

DJH

PULVERONE-POLVERONE

by Larry Homan

Pulverone was a general term used primarily for the material used in shells. There were several other terms used for similar materials with related uses or ingredients.

At first I did not understand the idea of packing material behind components in break shells. I had used nothing for my rather long inserts (often multibreak minishells themselves). Later I used sawdust and other materials but I did not pack it very hard. I was worried about the variable ambient moisture content of sawdust. Understanding successful shell building is often a matter of understanding the characteristic interaction of water with materials. Only after instruction did I learn to pack the voids rather densely.

Again upon my introduction to pulverone, I simply packed it loosely behind the components. I made mine with 1.5 -2.5 % dextrin, then later starches or guar gum combos to control hygroscopicity. Later I learned through instruction that one was supposed to pack the material very tightly behind the components. Thus one would crush the granulated pulverone with a rod roughly the diameter of the void. This worked best with composition without binder.

The second use of the pulverone was a substitute burst. Although I have no doubt that these techniques were developed to limit the amount of commercial black powder necessary to produce fireworks, they also had other uses and origins.

The pulverone used for burst was often bound with some dextrin. Like the Maltese it was understood that the strength of the burst could be controlled somewhat by the use of dextrin. Fines were at all costs not to be included in the burst since they would result in the over breaking of the shell. Thus the pulverone burst was bound to prevent this. Those that did not, usually to preserve the peak performance, had trouble. At least it had to be carefully graded.

There were various techniques to use pulverone as burst. Sometimes a core of black powder was used, then the rest of the burst cavity filled concentrically with pulverone. Sometimes it was mixed in a ratio - often around 50/50, varying as to intent. Sometimes it was used in layers. Other more complicated arrangements were used. There are several special break techniques that use complicated placements of types of burst, mainly to ensure correct burst of components and relative orientation in space. A great deal was known at the time and very little was ever documented.

One interesting method was to use almost all pulverone as burst, even in shell-of-shells. The shell casing of these Italian-style shells used very heavy paper, maybe ninety pound today, cement bags or the like in the thirties, with very few turns, much stringing of complicated patterns, and little pasting, either one or two turns of heavy paper, one turn of light paper per inch of nominal diameter, or for special shells a combination to make them look good, light on the string, heavy then light to finish. The complications are many as one would expect from such technicians that didn't have electronic entertainment to distract them. LH

CHOKING QUICK MATCH

J Larry Mattingly

I have been putting chokes on match, particularly in finales, for over 20 years. That half-second or so delay between shells in a string makes a big difference.

We put the delay in the horizontal line of match. That is between shell leads, not on the downline /shell leader. I have found the simplest way is to pull up a fold in the match, pinch it tight and put a piece of masking tape around it. We have found that you can pinch it too tight and actually cut off the ignition train and it can cause failures. That is the match goes out. It is easy to say that wouldn't happen with quality match, but finale strings don't always have quality match.

We tried tying it off with string but I found that crew members were pulling it so tight that we did have a significant number of failures. (Even one is too many). Using a cable tie and gun seems simple enough but I would be afraid of failures and all of our crew members have a roll of tape.

It is quick and easy and we never have a failure. JLM

RELIABLE JOINTS FOR VISCO/QUICKMATCH DELAYS

By Marshall Willcy

I have been experimenting with cross matching visco and quickmatch for use with timed finale racks and have come up with a method I have not seen before. The problem I have had with cross matching these two fuses has always been the violent burn rate of the quickmatch which can cause an unreliable fire transfer between it and the visco. The solution for me has been the use of 2" metal duct tape at the junction of the two fuses. The advantages of using metal duct tape are as follows:

- The tape comes with its own backer so I can pre- crosscut 1" x 2" pieces and I can have a bag full of them ready before going to the shoot site.
- The tape holds the fuse very firmly throughout the burn, and because it does not burn itself, I am not left with bits of burning tape, buckets, or string afterwards.
- The tape seals tightly around the fuse so the burn rate of the visco does not accelerate at the joints, giving more reliable timing.
- The tight seal also prevents fire from leaking out around the joint, so nearby joints will not pre-ignite.
- The joints are quicker to make than using buckets or string.
- The tape can withstand the July 4th Kansas sun without loosening.

Note: When crossmatching quickmatch to visco, it is important to allow the flame front in the quickmatch to pass through the joint.

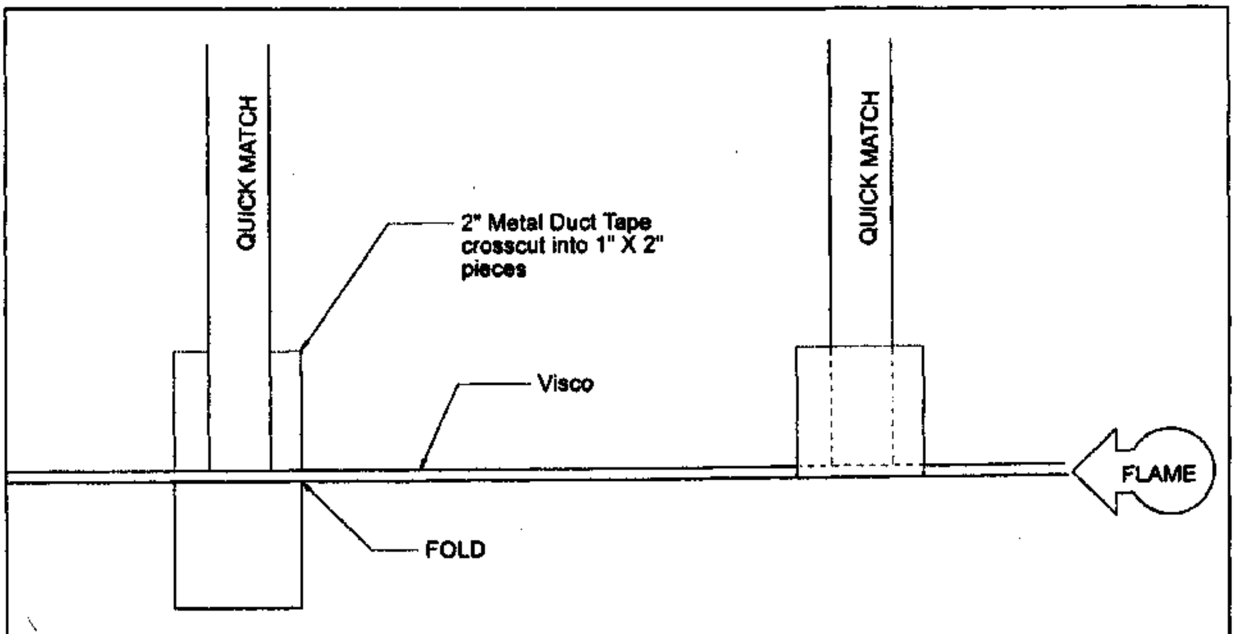
The tape was bought at a heating and air distributor and the visco is some of the new red American made visco available at Skylighter.

I have used up over 100 ft. of visco in my tests and have not had a single failure of fire transfer from visco to quickmatch or vice versa.

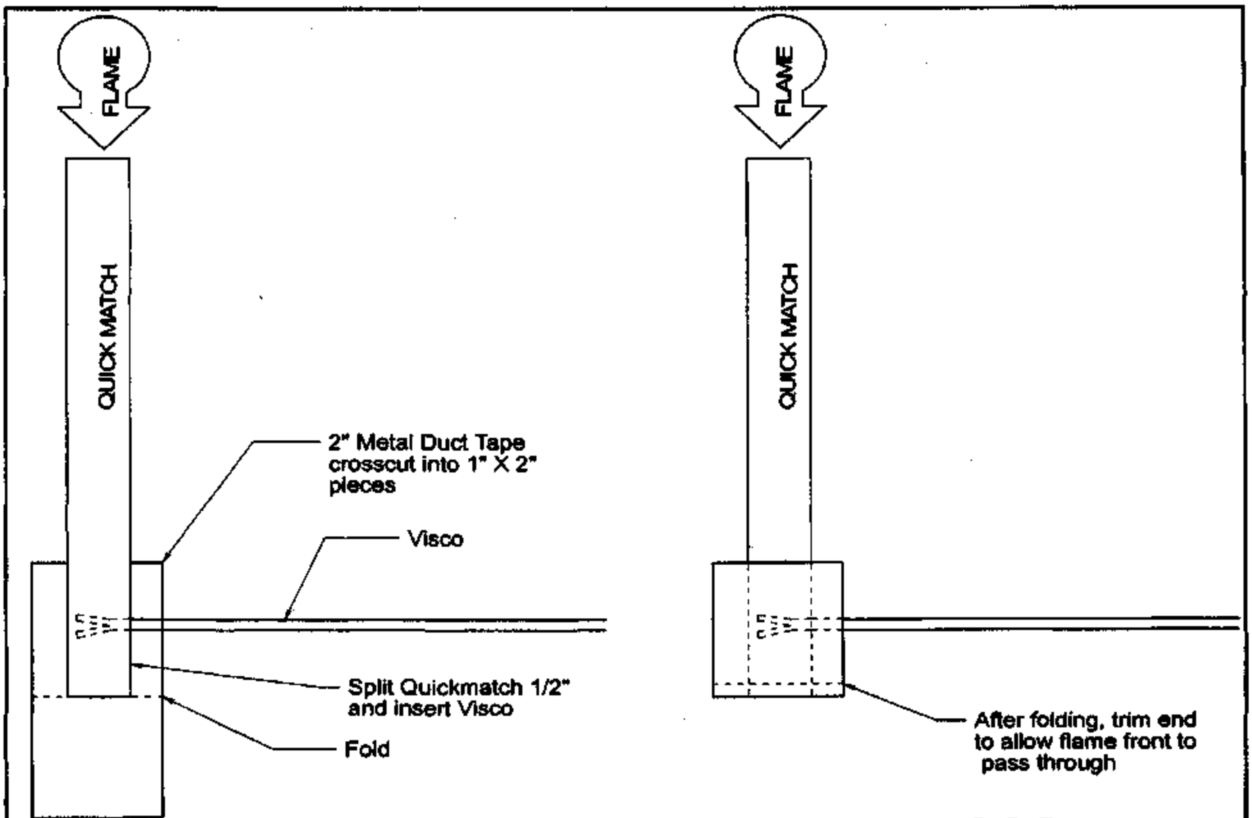
As I have not seen this method used before, any feedback would be appreciated.

mwilley@kscable. com

MW



CROSS MATCH VISCO to QUICKMATCH



CROSS MATCH QUICKMATCH to VISCO

"Y" VISCO

The most obvious reason for the title is **why** do we call 3/32" fuse *VISCO?* Cannon fuse is my choice but I suppose that name is useful mainly because it's sale and possession may be protected by the 2nd Amendment to the US Constitution. Before cannon fuse it was commonly referred to as waterproof fuse even though all knew of its poor performance in the water. (I've found wrapping it with a layer of good electrical tape solves the water problem!) The reason for the name escapes me.

The reason for this article is to address the problem I've had joining or 'Ving visco type fuse. Sometimes the time delay this fuse offers is very useful and is quite predictable. But my joints quite often failed to *pass fire* onto a fuse tied, wrapped and/or glued to a main leader. The solution for me was to split the end 1/2" or so of the fuse to be 'Ted, position one on one side of the leader fuse and the other half on the opposite side so that the powder grains inside the add-on fuse touch the lacquered surface of the leader. I then wrap this with a tight layer of heavy thread or light string. This gives a strong, positive joint that has been very dependable for me.

This technique allows me to make the *machine gun* effect of small Chinese-type firecrackers lit while in a string, out of some more substantial sized salutes. I start by making a large salute out of a cylindrical tube with a two-foot fuse on it. I make some smaller salutes, like the ones described in my August '99 article, and splice them onto the long leader as close to one another as I can. This assembly is fastened to a tree limb by a string tied to the finale main salute. When the leader burns, the small salutes will burn off and fall exploding away from the others so as not to damage them. The whole thing then ends with the big salute. So go ahead and "Y" visco?! CD

VISCO IGNITION TRANSFER

by Gerry Gits

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 Tom Wipruds 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

CHAIN FUSING VISCO

by J Larry Mattingly

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

THERMALITE SUBSTITUTE FORMULA

By Tony Petro

Here is a method for making a replacement alternative for Thermalite. It is just as effective, if not better for breaking crossettes.

It is a simple matter of making a slurry of flash mixture with dextrin and using the same procedure as for making blackmatch.

Formula 1:

Potassium chlorate	43
Dark aluminum	31
Antimony sulfide	26
Dextrin	5%±

If I can find string thin enough that will fit into the passfire hole, great. If not, what I do is take a length of string and remove two plies and then coat this with the slurry. When it is dry it should fit in the hole.

This formula seems to burn faster and hotter than Thermalite. There are other flash formulas such as nitrate ones, but you have to dust it with meal powder to get it to burn fast.

Another formula to try is:

Potassium perchlorate	50
Dark aluminum	23
Antimony sulfide	27
Dextrin	5%±

I'm sure anyone using this in place of Thermalite for breaking crossettes will be very satisfied.

Remember, use care and mix in very small quantities. TP

IGNITION MEASUREMENTS

By Lloyd Scott Oglesby

Microscopic examination of ignition failure materials is enormously educational. Leaning to guess why it did not light is the key to learning to get all the fireworks to light absolutely every time. You will quickly learn why those ignitors that looked so impressive but gave ignition failure did not work.

It is educational to compare results of tests with ordinary glass surfaces and specially prepared ground glass surfaces; that will teach you what type of surface texture is optimal for particular materials.

It is essential to realize that what you are doing is heating to reactive temperature some material, doing it with solids, liquids, gasses, and infrared and visible light. You might think a spray of burning metal particles looks impressive, obviously hot, but does it get things lit? Much depends on the physical conditions. You can look at a layer of oxidizer particles that had sparks impinged on the surface and ask, how much melting occurred?

Few ignition materials are made to the same uniform performance standards as visco safety fuse. The small jet of flame at the end should be observed in both daylight and darkness to assess the performance. Normally about a half inch is seen in daylight, and three-quarters of an inch in darkness. Microscope slides or other glass surfaces will collect spatters of molten material at those distances. If there is significant difference in the appearance under the microscope of deposited materials on slides held at various angles, careful examination allows an assessment and actual count of particles that arrived at the surface as molten materials of frozen or freezing materials. Thus we have a way of visually judging the heat content of the material.

Either the freshly prepared surface of the end of a piece of visco or a thin spread of some relatively standard material such as grain sporting powder can be used to measure the effectiveness of any ignition materials to effective ignition. The materials cool very rapidly as they move through the air, so distance from the ignition source will track as a function the loss of heat. Sometimes visco is made from powder of inferior grand or improperly stored, and it produces a few longer duration sparks that make it unsuitable for this kind of testing, so it requires careful testing of several pieces to assure that it will be suitable. Of course, video taping of each test at low magnification in a dark condition will be advisable.

Microchemical tests will furnish information about what chemicals are in the materials left on the slides. That, and the shape of the material will allow some examination as to how much of the material arrived as melt or as a slush of both liquids and solids and very hot solids. The simple observations of the residues will reveal that there are significant changes at set distances and that information can be used to help design our ignition testing. We can calibrate the distance the visco will ignite from other ignition sources and compare to the pressed flat surface of freshly ground grain powder, so we have quantitation of what works and how well.

Now you have a way of easily testing quantitatively the effectiveness of various primes as little smears on glass slides and this can be used quantitatively to assess the various surface textures and shapes, and compare one mixture with another or one material with different wetting and drying conditions, etc. This provides a nice, easy, scientific way of getting out of that depressing chemical-wasting zone of poor results, It is a lot less depressing to have ignition failure in a nice little testing than during an important fireworks event. This is invaluable information and technique when you start producing your own specialized electrical ignition materials and want to precisely tailor the device design to the item. LSO

FISH FUSE IN CAN SHELLS

By Richard Ogden

A question was asked on PML about how to incorporate fish fuse into a canister shell? Would it be necessary to coat it all except for the end that is to light?

I had a chance to examine a 3" red & green fish shell with the Lidu label a few years ago. The fuse pieces were loose in the shell, simply mixed in with the burst charge of coated rice hulls. The fuse diameters (red and green alike) varied from less than 1/16" to about *Va",* and were all roughly 1" long but not at all uniform. All the pieces were primed at one end with a layer of what appeared to be mill dust or BP fines in a binder. There was no evidence of anything at the other end being used to passivate it, but it lighted much more easily at the primed end.

Here's what has worked very well for me:

Cut the pieces of fish fuse as close to the same size as you can; 1 1/2" is generally good, depending on the size (height of burst) of the shell and the speed of the fuse. If you cut them longer to try in a bigger shell, remember how far apart they will get as they burn, and that they will simply not be very visible at high altitude. Fish fuse is definitely a low-to-mid level aerial effect.

Decide what sort of bundle size you are comfortable with, that is, bundles of the fuse pieces all lined up. I just use what will fit easily in one hand, in the circle formed by my thumb and forefinger. Smaller is fine. You might be able to devise some sort of ring of plastic or paper tubing to hold the bundle -I didn't bother.

Cut rectangles of hobby tissue paper (available at craft shops) long enough to completely wrap the fuse bundles two times around, and wide enough so you'll have a "flap" that will completely cover one end of the fuse pieces with some to spare when folded over, say the length of the bundle plus the diameter of the bundle plus an inch. (You can always cut off what you don't need.) Take the bundle in one hand and tap it fuse-end down on a flat surface to line up the cut ends of the pieces. Place the bundle at one end of the paper rectangle with the lined-up fuse ends hanging slightly off the paper, and make the first turn, rolling the fuse pieces up in the paper. You should have enough excess paper at the end opposite the lined-up fuse piece ends to fold over the other fuse piece ends. Do that, then continue rolling the bundle. At this point you should have a fairly tightly wrapped cylindrical bundle of fuse pieces with one end of the fuse exposed at the open end. The fuse pieces at the open end should have their cut surfaces lined up - if not, GENTLY take the bundle and tap it again on a flat work surface. Don't worry if the bundle seems a little loose at this point - just don't let the fuse pieces start dropping out or you'll have to start over.

Now take a piece of masking tape long enough to completely encircle the wrapped bundle and make one turn around the middle of the wrapped fuse bundle. This is where you want to get the bundle tight so that the fuse pieces can't shift on the bundle. You should be able to pick up the wrapped fuse bundle at any place and not have fuse pieces drop out or change position in the bundle.

Finally, mix some mill dust with NC lacquer to the thickness of syrup or honey in the bottom of a shallow Tupperware-type container (be sure it's PE or equivalent - don't use anything that might dissolve in acetone or amyl acetate). Dip the exposed fuse ends of the wrapped fuse bundle in the slurry so that all the fuse ends are coated, and set the bundle on it's side on a flexible cutting board or other solvent-resistant surface to dry. If you're using NC or DB dissolved in acetone, the bundle should be completely dry and ready to use within an hour or so. I trim the excess paper off before I put the bundles in a shell, but it's not essential. The bundles are placed just like you would any insert.

A couple of tips:

- Don't worry too much if all the fuse pieces aren't exactly the same length. Its enough that one end be lined up so that it can be dipped in the NC/powder slurry and get a complete, uniform coating. If you have a LOT of different lengths, though, be sure you cut the paper to cover the longest pieces AND still completely cover the bundle with enough left over to tape down to the side.

- You might want to dab a little of the NC/powder slurry on the masking tape to help ensure it burns away on shell burst.

- The bundles can also be wrapped with rubber bands, or anything else that is handy and will disintegrate, melt, or burn quickly in the heat of the break charge. I used masking tape because it was handy. The point of using tape is threefold: to hold the bundle together during the dipping process; to hold the tissue paper over one end to impede ignition; and to make a bundle that can be used as an insert.

- Depending on how hard you break your shells, you may want to substitute a hotter prime for the mill dust.

- The purpose of the paper wrap, and of the paper over one end of the fuse pieces, is to delay the burst fire reaching that end of the pieces. I'm not sure how much this contributes vs. just leaving them unprimed. I just know it has worked for me. You may find it works to simply wrap the bundle tight and dip one end in slurry and the other in a flame retardant of some sort. Just be sure whatever flame retardant you use doesn't permanently glue the fuse pieces together, or soak deep into the fuse cores and ruin them.

- The bundles can be used in cylinder shells just like any insert.

- Note that shells containing only fish are gently broken, for the same reason that Go-Getter shell breaks are not too strong: they don't need to be, and a strong burst charge can be counterproductive to the desired effect. RO

CUT, PRIME & PASSIVATE FISH FUSE

By Dan McMurray

A couple of years ago, after one of our club events, three PAT members (the Texas club) brainstormed for over two hours about hot to cut/prime/passivate fish fuse. We finally came up with these simple solutions. The best part about this process is that it works!

Elmer's white glue makes a good passivator and dries fairly fast.

Just a note for all of you out there that want to cut a lot of fuse pieces that are EXACTLY the same length.

The easy way to cut a lot of pieces of fuse is to wrap a length of fuse around a piece of PVC water pipe several times and cut the wraps with a very sharp blade. To control the blade better, I use a pocket knife skinning blade rather than a razor blade. A 12" piece of PVC pipe lets you make over 100 pieces of 3/32" fuse exactly the same length in a few minutes.

To make handling easier, stick a narrow (1" wide) piece of masking tape or duct tape to the fuse wraps along the entire length of one side of the pipe. Cut the fuse along the other side of the pipe. The fuse pieces all come off on the tape.

With the fuse pieces still stuck to the tape, the fuse ends can be primed or passivated without having to handle the individual pieces of fuse. When passivating with Elmer's white glue, separate the fuse pieces as soon as the glue sets up or you will have to cut the glue between the pieces of fuse with a knife. When priming with NC lacquer and Meal D, the fuse pieces break off easily after the prime is dry.

Note: Drilling a 1/8" hole about 1/4" from each end of the PVC pipe provides a place to hold one end of the fuse while wrapping the rest of the fuse around the pipe. Naturally, the PVC pipe size determines the length of fuse in each wrap.

Just another note: "fluffing" the end of the visco works about as well as priming AND it is a lot easier. Visco is designed to light easily. It usually does that without much help.

DMcM

CHEAP & EASY QUICKMATCH

By Bob Bov

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 consumer, 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:

1) 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, stick 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 I've 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 I've 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.

I've 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 black powder 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!

I've shown the technique to several old time pyros and their response has been: "Big deal - I've been doing that for years."

My only response is, shame on you for not sharing it with us new guys.

To put this article to bed, I would like to state that my failure with homemade quickmatch is due to my own lack of technique and knowledge, and not to any deficiencies in the current printed and accepted articles.

BB

THE VITAL *UHK...PAPER FUSE*

By Joe Barkley

This often maligned little piece of burning paper and black stuff has survived the ages alongside the firecracker from China. To be CPSC legal, today's cracker string is started with visco fuse, but the remaining fuses in the pack are braided paper, as of old. The early 1970s saw the attempt by Pyrosonic Devices company to introduce a thin plastic-coated fuse as replacement for paper fuses, but the Chinese would not buy it. Think of what a pack of plastic fuses would cost today!

The real value of paper fuses is hidden beneath the smatter of enticing color and rhetoric wrapped around the cakes, fountains, and novelty items we see across the counter. For example, the little novelty "Star Ball Contribution" seems to perform as by a miracle until we look inside and see a maze of little delays...all accomplished by paper fuses.

Imagine these ubiquitous paper fuses being declared illegal in all imported items at once. No more of what we see today...absolutely. Even the lowly ladycracker would go!

What has industrial modernization done to the paper fuse? This is a topic with a vague answer. China dies not give away much about this crucial component which is used in practically all consumer fireworks that are made there. Looking back sixty years we see an old gentleman depicted in T.L. Davis' book laboring over a sheaf of papers about to be filled with powder... a technique that would hardly meet demands today. Scientific American described fusemaking in China at the turn of the 19th century in a vague and storybook way. George Weingart tells of the importance of fusemaking and conveys information supplied by Mr. Ip Lan Chuen of Hong Kong but really says little.

In the postwar years we begin to see changes in paper fuse, suggesting some mechanization away from pure hand work. Some postwar firecracker fuses came with a central thread of blackmatch wrapped with tissue, a workable system making dirty fuses. So what do we have today? One outward difference is an increase in burning speed for braided firecrackers since we are advised to light the pack at the visco supplied to the first member. Faster speed may promote better consumption of the string (fewer duds).

Paper fuse powder needs contain little sulfur (or none at all). Examination of the table by Anticole given in March 2003 AFN shows this. Sulfur promotes "senko hanabi" or dross formation which is undesirable in paper fuse. Dross blobs fall away, taking out the fire train. A well-mixed 70/30 blend of potassium nitrate and charcoal makes good fuse powder. Charcoal promotes golden sparks which add to the visual effect.

Paper Chinese fuse should not be taken for granted. It plays a vital part in today's consumer fireworks. JB

NO MORE "BANANA BOARDS"!

by Bob Svenson

In an earlier article I mentioned that I was having problems with my rocket sticks warping and turning into "banana boards".

I was going to try several different materials to make rocket sticks but then it occurred to me that I'm not the only one who makes rockets and I'm sure others have also had this problem. Rather than "reinvent the wheel" I posted a note on the Internet's Pyrotechnics Mailing List (PML) and found that I was indeed not alone.

I was given lots of advice:

* "Use bamboo shoots." Since I don't have a local source of bamboo I skipped this.
* "Roll a small diameter tube out of Kraft paper." This looked promising, but rolling a long tube is always challenging.
* "Find someone tearing down a house and see if they'll sell you a few boards; lumber that's decades old doesn't warp at all; the lath boards from lath & plaster walls work especially well." This looked promising also, but I didn't know anyone who was tearing a house down. If I do run across someone who is, I certainly will try to get boards.

The most frequent suggestion was "use cedar" so I trotted down to the local lumber yard and bought a cedar board and proceeded to cut it up into rocket sticks. After a couple months all the sticks are still straight as an arrow! Now I can't blame any errant flights on "those darn banana boards"! BS

SAFETY TIPS OF CROSS MATCHING

[The author of this very important article is a well respected, long established fireworks manufacturer. We are very pleased to be able to offer his position on cross-matching to our readers.]

by Anon Pyro

Cross-Matching: This may be the most important thing a fireworks maker does. The reason is because it passes the fire from one means to another, i.e., quickmatch to visco fuse (safety fuse). Most people think they can just be laid along side of each other and it (the quickmatch) will light the visco fuse! Wrong! The reason is that visco fuse (safety fuse) has a nitrocellulose lacquer finish in green, red or any of many other colors. The manufacturing and CPSC (Consumer Products Safety Commission) test for this fuse is so it **docs not** light from the **SIDE!** In fact, the test is if you hold a lighted cigarette flame against the side for five seconds and the fuse lights, the fuse **FAILS** the test. Maybe this is why these fuses don't light so good at the Consumer fireworks shows? If done carefully, splitting the visco fuse, then cross-matching it with a piece of bare match that is attached to your piped quickmatch, will work.

I have seen and heard of people trying to cross-match time fuse with visco fuse. This will not work because of the outside properties of the fuse. The fuse was manufactured so it doesn't take fire from the side or transfer fire through the side at any other angle. Although there is a better chance of transferring fire from visco fuse to another source, it is best used to end-transfer the fire. When I say end, that means from the end of the visco fuse to another core of powder of some sort.

Fuse made with adhesive tape cannot be used in cross-matching time fuse with the hole punch method. Adhesive tape match cannot be used for cross-matching by the method of splitting the time fuse. After the tape has burned, I noticed there is always a sticky residue from plastic and adhesive. If I use the wrong type of tape, the nitrate in the powder will attack the adhesive and this chemistry is anybody's guess! I do know on a few occasions that this residue was hygroscopic and had drawn enough water to stop the burning of the tape match.

I cannot believe that any companies are using igniter cord, quarry cord, or Brazilian cord in their aerial shell production. I thought only uninformed amateurs were doing that!

Another thing I cannot believe is that I've seen people injecting HOT hot melt glue on bare quickmatch that is in a LOADED item! Or the HOT hot melt glue is put into the loaded item, then the bare quickmatch is put in, and then HOT hot melt is put on both! Foolhardy are they? Not with me around!!!

What about this thing of trying to cross-match with the igniter cord and/or Brazilian cord with the heavy plastic layer on the outside? This is ludicrous. Any old pyro knows that it should never light or pass the fire on. It does work, but not very well. My feeling is that if a 100% performance quota is not maintained, the item shouldn't be used or done. Why should hobbyists or amateurs on a budget who have spent all the time and work on making fireworks, try to save a few pennies and skimp on the fuse? If the fuse fails in any way, the fireworks malfunctions or doesn't work at all. That is more reason why shortcutting on the match is not my way. I use good quality time fuse and black-match for cross-match, which is essential for safety and quality control! If I need to save money, I do it on the labels or the external coloring and decorating papers, not where the functioning of the fire transfer may make all that work fail.

A lot of people tell me they do not know how to get or make a small bare match that is good enough for cross-matching. I will tell you the basics of that. I will start with a few do's and don'ts, and nevers.

1. Never make match for cross-matching with other than commercially-made powder.

2. Never use more than needed of any adhesive, starch, sodium carboxymethylcellose (CMC), and especially dextrin. Use only 1 1/2%

of whatever adhesive used. By using more, it will make a nice clean shiny fuse but it will burn slow and will not transfer fire correctly.

3. Do use a good quality cord, yarn or textile string that absorbs some of the powder.

4. Dry the wet match fast, but **safely.** This is so that the nitrate will not leach out or crystallize out too much. A little is okay but very little! I found that moving air around and over the wet match is just about as good as raising the temperature too high. There is no need to raise the temperature over 100° F - moving the air is just as good.

5. Use a sizing die smaller than the hole that the cross-match is to be inserted into. A die can be made out of just about any material that is somewhat resistant to wear. I use stainless steel tubes. Copper tubing can be used for short runs; the match eventually will wear through the tube. A hole drilled into a piece of 1/4" or thicker steel will work for controlling the size of the match, although tubes work better. The size of the hole in the die I use is .112" in diameter.

6. On drying, the fuse always re-crystallizes and enlarges by itself. If I use too much string per the size of the hole, this also will cause the match to get larger on drying. There is a ratio of the size of the string and the amount of strings per hole size that will make a good solid match. Not enough string will make lumpy and uneven match that doesn't have good rigidity. The old military specifications for quickmatch called for a match that maintained a certain rigid or deflection standard per given length. The military called for a cotton wick with a certain breaking strength and only a minimum of ounces of wick per 100 linear yards of quickmatch. Trial and error will work this out

7. By cutting the finished match at a sharp angle (let's say 25 or 165 degrees, depending on the angle of view), this gives me a sharp point to start in the hole that is punched in the time fuse. When the match goes through the hole, it should be loose but not so it can fall out. When the cross-match is in the time fuse, I take pliers and squeeze the time fuse down onto the cross-match. This is done to intimately marry the time fuse powder core with the cross-match powder. Also, if there was any tar across the powder core in the time fuse, it would be squeezed out of the way and the powder would push the tar away.

I have seen shells that have a piece of Brazilian or Quarry cord (or whatever they call it) passed through the hole and it was just hanging in there like a bell clapper. There was no contact with the time fuse powder core on either piece of fuse. It's a wonder it even worked at all. In fact, that's why the shell was brought to me. It was found at a show done by someone else. These types of shells have been made only in the USA and I hope it is not a trend. If it is, there will be a lot of shells laying on the ground after shows for someone to pick up and get themselves injured. Personal and property damage claims will follow!

Igniter cord doesn't have enough outer covering to help protect and keep the powder core in place after it is bent or twisted. Also, the Brazilian Quarry cord, and igniter cord companies do not allow use of their products on any fireworks for just that reason. I've heard that they are very adamant about it to the point of suing if using their products for that. They are not fireworks people at all. They are explosive engineers and understand fire transfer. They know these products were not made to be used for this application. The plastic on the outside of these products was placed there so they don't take side ignition easily. I suggest not trying to use them for what they were designed NOT to do!

I don't use any plastic materials, wires or anything that will not take or transfer fire rapidly. If a bare wire igniter such as nichrome is used, the wire has to be in direct contact with the powder core of the fuse in all cases. Close doesn't count in 100% fire transfer scenarios.

How to prepare a time fuse? It is being done a lot of ways but I feel there is only ONE way! I punch a hole into the time fuse's exact center. The hole for a 1/4" time fuse should not be over .125" or 1/8". I make all my own punching machinery, but a good punch from a tool supplier in the Chicago area can be bought, or made. The punch is not really a punch as is assumed for making holes in steel. I use a piece of tool steel .125" in diameter on one end, grinding a point onto it at about 170° with a good edge where the taper stops. The punch side is round and the piercing end and side is tapered to a point. This goes into another block of tool steel with a .126" hole that goes all the way through the block. The block has a hole in it large enough to allow the time fuse to pass through it, but not to be too loose. I think the hole would be 1/4" (.250) for most of the good time fuse made. The fuse hole and the punch hole are perpendicular to each other's center line. When the punch goes through the fuse, it pushes a small piece of the fuse out but really presses a hole, forcing the fuse wall material into the other side wall of the fuse. This will give the fuse some added strength, but doesn't leave much tar across the powder train of the time fuse. When I do it correctly, the hole with not shrink back and cause problems with installing the cross-match into the hole. Again, after it is centered, (the cross-match in the time fuse) I squeeze the time fuse to make a good snug fit between the cross-match and the time fuse's powder core.

I've learned that splitting a time fuse does work in most cases but the tying of the cross-match is very essential. Again, I use a good piece of blackmatch. The match size compared to the size of the time fuse is essential. The geometry of the cross-match should be flat instead of round to fit tightly into the crotch of the split time fuse so the powder doesn't fall out in storage and shipping. I also dip-prime the split time fuse, which works if the prime is good and doesn't fall out. I had a case once where the nitrocellulose lacquer was actually painted over the time fuse and caused it to stop the fire transfer.

I have found that the best way is to punch a hole in a good time fuse, cross-match with a good bare match, squeeze the two together for intimate contact, and then dip prime the whole thing. But I don't place too much prime on the outside so as to cause a delay of the ignition. I don't know of any manufacturer of time fuse in the world who does not recommend the above process. Who said pyrotechnics was easy and a sure thing? Mr. Murphy from Murphy's Law?

Long story short: To correctly transfer fire, it should be from intimate contact of powder to powder with no appreciable membrane covering or space separation that could stop the transfer of the fire.

TIME FUSE LENGTH

by Lin Collins

Ah yes, the age-old dilemma revisited upon fledgling powderheads... "How long do I cut my time fuse?"

There are many kinds of time fuse (Japanese Hosoya, Chinese varieties 1 or 2, American from Precocious Pyrotechnics or Rozzi 3/8", etc.) A time fuse with a 3 second per inch burn rate is a fairly good place to start.

You must first decide if you really do, in fact, wish the shell to open at its apogee. Depending upon what type of contents, you may want it to open while ascending, as with long burn tubular inserts for example, or with timed effects. Assuming a simple single star break, 3 seconds total burn is a good starting point.

Many factors (besides fuse length) come into play: shell weight, amount of lift, quality of lift, fit in gun, angle of gun, shell length, gun length, etc. Ignoring these factors for the moment to concentrate on time fusing leads us to the following questions: Type of hole made for crossmatch (pierce or punch), type of crossmatch (if match at all), quality of crossmatch, secondary priming (if any), top or bottom fusing technique, and, as above, burn rate. Too many factors to go into each in detail here.

With a top-fused shell a good place to start is with 3 seconds between crossmatch holes, and adjust as needed, bottom fused shells can use shorter fuses but they are not to be recommended. There's a physical limit as to how short to go with spun fuses (I've used 5/8" centers in timed effects with difficulty). Simply, there must be enough length to protrude through discs, paper, string, etc.

As for spiking, one can learn to "block" the string around the top of the shell and not touch the fuse at all, but this should be attempted only after the basic technique has been mastered.

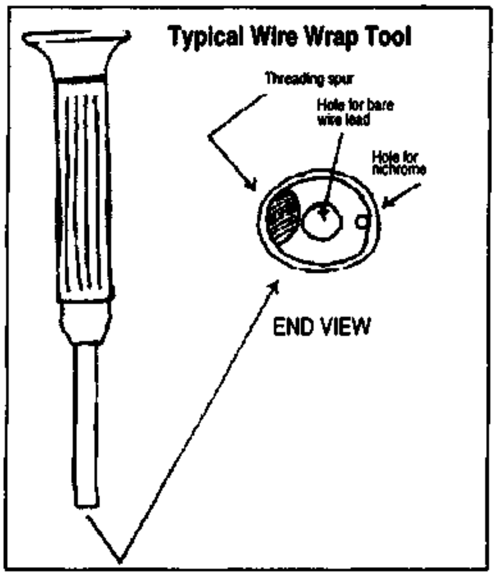
Good match must be used for crossmatching (I've never liked thermolite for this purpose) and passfires. As for pasting in, nothing beats good ol wheat paste-soaked Kraft. It need *not* be virgin paper. Almost always I use recycled Kraft for pasting - even heavy multi-breaks. Supermarket bags work fine! Remember, the paste job on a canister shell is for fireproofing and overall structure - not burst containment. LC

ELECTRIC MATCHES

by Carl Denninger

Electric matches are my favorite method of initiating pyrotechnics. I make my own so I can get exactly what I need for a particular application. Many commercially manufactured matches use a very thin bridge wire of a wire gauge size of somewhere around 50 gauge. This size wire is very difficult to work with! I like a size 32 gauge of wire, as it is heavy enough to allow handling by hands not of a surgeon. However, it takes a hefty current of around an amp to make it glow red-hot. Instantaneous ignition requires 3 or more amps. I would guess though, that static electricity and radio frequency radiation would be even less of a concern as compared to commercial matches. I bought a pound of this 32-gauge nichrome bare wire from a company, which supplies it for manufacturers of electric heater elements for less than $100.00. I use about four inches per match and the spool appears to have miles of wire on it! So the cost is some where around 3 matches for a penny!

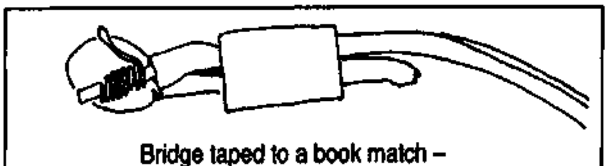
The secret to dependable matches is the ability to make a very good electrical connection between the dissimilar metal of the nickel and chromium of the nichrome and the copper of the lead wire. Soldering works and is dependable if you can find a flux that will flow the solder on the nichrome but will not destroy the copper wire by corrosion. I have found a method of connection which is not only fast, cheap, and dependable, but easy on the eyes and big fingers. It borrows tools and techniques from the electronics prototyping arena and is known as "wire wrapping". A special tool called a wire-wrapping tool is used. It's available from Radio Shack for a few dollars and is shown here.

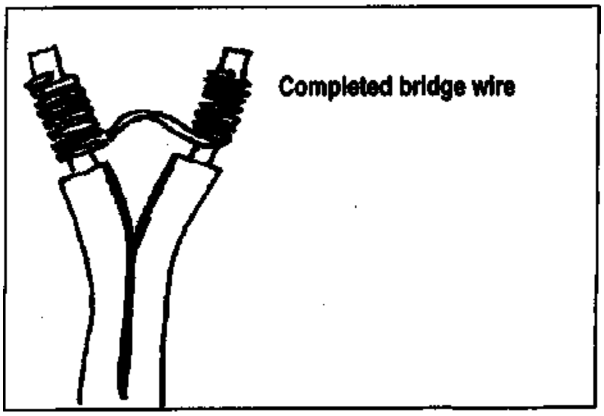


Typical Wire Wrap Tool

This tool has two holes in the end of its shaft. The bared end of the lead wire is inserted into the larger hole and around an inch and one half of nichrome wire is inserted into the small hole. The tool allows you to wrap 20 or so wraps around the lead wire very quickly and so tightly that a gas seal is developed that will prevent minor corrosion of the copper wire from disturbing the electrical connection. A quarter inch bridge is left and the remaining inch and one half or so of nichrome is wrapped around the second lead wire completing the bridge. With a little practice, about 2 minutes per match is required.

These are completed by dipping in nitre cellulose lacquer, BP, or any favorite ignition mix. My favorite for general use takes a paper match, the bridge wire contacting the match head and separating the two lead wires from shorting out. Paper tape is wrapped around the lead wire and the matchstick, holding it in place. This assembly can be used as is or dipped in NC lacquer or BP to hold everything in place.


Bridge taped to a book match – ready to dip or use as is.


Completed bridge wire

The use of matches in these assemblies gives proof to the politically correct name of electric match. CD

CHLORATE COMPOSITIONS IN QUICK MATCH

By K.L. & B.J. Kosanke

After the 1999 PGI convention, we were told about a type of quick match that had been sold there and which was suspected of being made using a chlorate oxidizer. The individual's suspicion was based on his perception of its extremely fast burn rate. Subsequently, a sample of that fuse was spot tested and found to contain a nitrate but not a chlorate. Sometime later, the authors were given a sample of quick match thought to be of the same type. The burn rate of the quick match was observed to be most vigorous, however, there was an insufficient amount for the authors to make a usefully quantitative measurement of its burn rate. Small amounts of the composition were removed from the black match portion of this fast burning quick match, and two tests for the presence of chlorate were performed. The first test was the concentrated hydrochloric acid test, in which a few drops of the acid are placed on the composition. The presence of a chlorate is revealed by a modest rate of chlorine dioxide gas production, with its characteristic color and odor.[1,2] The second test was the analine-HCl spot test, in which some of the composition is dissolved in a tiny amount of water, the water is decanted and treated with a drop of analine-HCl test reagent.[1,3] The presence of a chlorate is revealed by the appearance of first a red then blue color. Again, both test results were negative for the presence of a chlorate. Accordingly, another possible explanation for the vigorous burn rate of the quick match was sought.

The design of the quick match was typical of the fuse seen in recent years being used on some higher quality products from China. The fuse had a series of 5 individual strings, each of which was well coated with a pyrotechnic composition that remains noticeably more flexible than that of traditional products. These strands were laid side by side and surrounded with match pipe that was quite flat. This configuration is illustrated in Figure 1 and identified as *Recent Chinese.* This manner of construction is in contrast to the configuration most commonly used in the US (also illustrated in Figure 1 and identified as Typical US), in which the collection of strings are coated as a group with a Black Powder slurry and forming a somewhat rounded grouping of the strings.

One significant difference between the two configurations is the total amount of surface area of exposed black match composition. For the Recent Chinese fuse, the surface area is proportional to 5pD, where D is the diameter of each individual black match strand. Based on measurements of

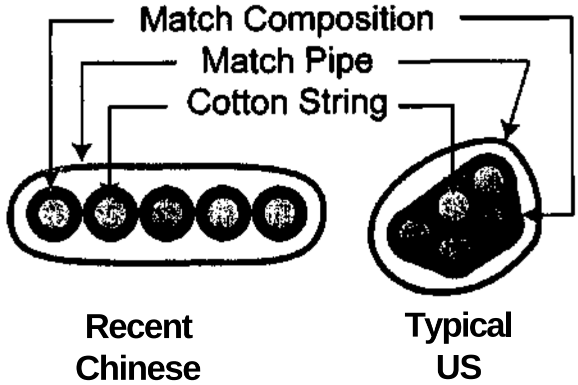


Figure 1. Illustration of the configuration of two types of quick match.

typical US black match, the overall diameter for the group of threads is typically no more than about 3D, thus giving a surface area proportional to no more than about 3pD. Accordingly, the Recent Chinese fuse has nearly twice the burning surface area. If it is assumed that the compositions are otherwise effectively the same in their burning characteristics, the Recent Chinese fuse will produce nearly twice the flame as the Typical US black match. Based on our understanding of the manner of functioning of quick match,[4,5] the greater volume of flame produced will result in a greater *initial* rate of burning. (Ultimately, the rate of burning of unobstructed quick match is mostly determined by the strength of its match pipe.)

The Recent Chinese quick match has another property that may cause it to appear to be especially fierce burning. The method generally used to slow the burning of quick match is to close the fire path between the black match and the match pipe. This is found to work well for the Typical US quick match, where the closure of the match pipe around the central black match can easily be made with a moderately tight wrap of string, and which causes approximately a 1/4 second delay.[6] On the other hand, when the same method is attempted with the Recent Chinese style of quick match, it will be most difficult to get a complete closure of the fire paths. This is because small spaces (fire paths) between the individual strands of black match will persist (see Figure 2), unless the composition on the black match strands is sufficiently crushed to completely fill the gaps. Accordingly, this type of quick match will be quite difficult to slow using the normal methods of fire path closure, and thus probably suggesting to users that its burning is especially fierce.

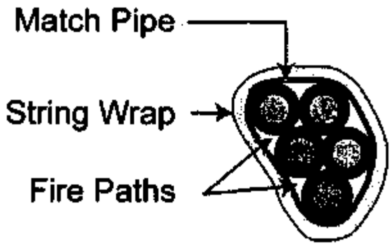


Figure 2. Illustration of the difficulty of closing fire paths to slow the burn rate of the Recent Chinese quick match.

Although it is somewhat understandable that this Recent Chinese quick match was suspected of having been made using a chlorate oxidizer, both its high burn rate and the difficulty with slowing its burn rate can be explained based on its manner of construction. Over the years, the authors have tested many suspect samples of quick match. However, except for a type of quick match used on Horse Brand shells for many years (and possibly still today), none of the others was found to contain chlorates. (Note that is not to say that no quick match ever has been or is being made using a chlorate oxidizer, just that we have not found any except for Horse Brand shell leaders.)

Figure 3 is an illustration of one form of the Horse Brand fuse found to contain a chlorate oxidizer. The quick match shell leader contains two fuse elements. One is a somewhat conventional strand of black match, although it tends to be made of a single thicker strand of fairly coarse cord and to which the powder coating tends to adhere only poorly. This powder coating is found to contain no chlorate, but it is found to contain sulfur, and is presumably hand-made Black Powder. (In some cases, especially on larger shells, this quick match has two strands of black match.) The second fuse element is a single (but sometimes double) strand of so-called Chinese fuse, made with a powder core wrapped in tissue paper, which is similar to the type of fuse typically used on small firecrackers. It is in this Chinese fuse that the chlorate oxidizer is found to be present.

The problem with the presence of chlorate in one element of this Horse Brand fuse is exacerbated by the presence of sulfur in the other element. When this fuse is cut or the Chinese fuse becomes sufficiently damaged through handling, there will be a commingling of the chlorate and sulfur compositions, with all the sensitiveness problems that are known to result.![7,8]) (For example, in some recent testing of the impact sensitiveness of these Horse Brand fuse compositions, the combination of the two compositions was found to be 2.5 times as sensitive as the rough Black Powder composition alone.) Over the years, there have been a number of serious accidents thought to have been caused by this fuse.

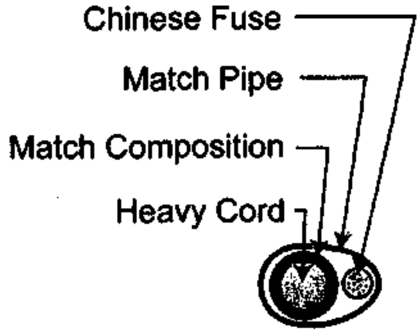


Figure 3. Example of one type of Horse Brand quick match shell leader found to contain a chlorate oxidizer.

Acknowledgment

The authors are grateful to S. Majdali for initially identifying the suspect quick match (sold at the 1999 PGI convention) and for performing the initial spot tests that identified the lack of chlorate and the presence of nitrate in the fuse composition. We also wish to thank R. Fullam for providing a sample of quick match for our laboratory testing.

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ELECTRIC MATCHES: RAMP FIRING CURRENT

K. L & B. J. Kosanke

Introduction

A study of electric match (e-match) sensitiveness and performance has recently been completed, and a summary of the results is being presented as a series of short articles. This is the eighth article in the series[l] and presents the results of a test to reveal aspects of the firing characteristics for the same collection of 10 e-match types as in the previous articles.

Ramp Firing Current Test

The ramp firing current test was selected because it was thought to be able to reveal much about an e-match's performance in a relatively small number of trials (typically about 25 match firings). In these tests, e-matches are subjected to a rapidly increasing electric current while being monitored to detect, the moment the match ignites (as evidenced by the production of light). The setup for these tests is shown in Figure 1. The ramp current power supply provides the firing current; however, that current starts at zero and increases progressively. Further, the rate of increase is adjustable (i.e., the current can be set to rise relatively slowly, rise rapidly, or anywhere between). The current is monitored as a voltage drop across an NBS calibrated resistor, using one channel (A) of a digital oscilloscope. The e-match under test is located inside a light-tight enclosure along with a photo detector. When the match fires, the light produced is sensed by the photo detector and, after conditioning, the signal is directed to the second oscilloscope channel (B).

Figure 2 presents data typical of that produced during the ramp firing current test of a single e-match. The e-match firing current starts to increase from zero at time tO. At time tl (18.9 ms) the photo detector firsts senses light from the firing e-match. (The photo detector is adjusted to be extremely sensitive to light, such that it rapidly saturates and holds a constant value as the e-match burns. Also, to make the two traces in Figure 2 easier to see, the trace of the photo detector was shifted downward slightly.) At the time of first light output, the firing current If has risen to 418 mA. The firing current continues to rise reaching approximately 650 mA at time t2 (29.9 ms), when the bridgewire fuses (melts) to open the circuit, thus dropping the electric current back to zero. (In Figure 2, the minor fluctuations seen in the oscilloscope traces are background noise mostly pick-up from a nearby commercial radio transmission tower.)

In Figure 2, the time of e-match firing is equated with the first light produced by the match. Actually, the ignition of the e-match composition adjacent to the bridgewire must occur slightly earlier. For gas producing compositions, the time between the ignition and external light production is relatively small. Previous testing by the authors suggests the interval for one type of gas producing composition is no more than a small fraction of a millisecond. One e-match manufacturer suggests that the time between ignition and light production may be as much as 2 ms for some gas producing compositions. [2] However, for mostly gasless compositions, the time interval could be considerably greater still.

The ramp firing current tests for each e-match type were repeated a number of times, using a collection of different rates of current increase. For each test the firing time tl (first light production) and the current flowing at that time If were recorded. Figure 3 (for Daveyfire AN28-B matches) is typical of the data produced. Note that under the condition of a rapid ramp current increase, the minimum firing time of approximately 15 ms is produced with a ramp firing current of approximately 500 mA. At the other extreme, using more slowly increasing currents, when the ramp firing currents were as low as approximately 250 mA, a wide range of firing times was produced. Further, under these conditions, some match tips failed to ignite (shown in Figure 3 as open data points and are arbitrarily plotted at 500 ms). The scatter of data points about the curve plotted in Figure 3 is thought to reflect a combination of the normally expected uncertainties in the

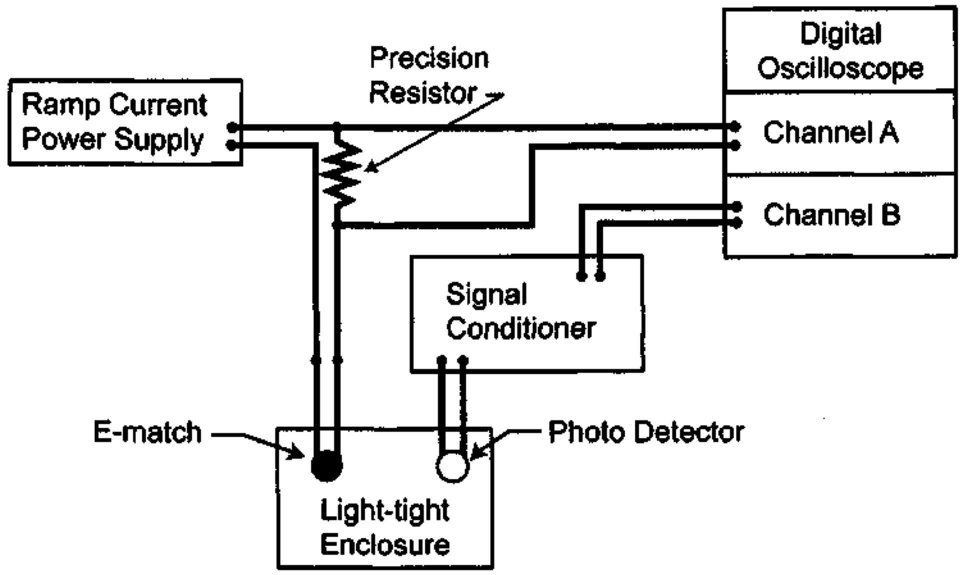

Figure 1. The configuration of equipment used to make the ramp current measurements.

ignition process, plus minor manufacturing variations between the e-matches. This amount of scatter is fairly typical of that seen for most other e-match types tested.

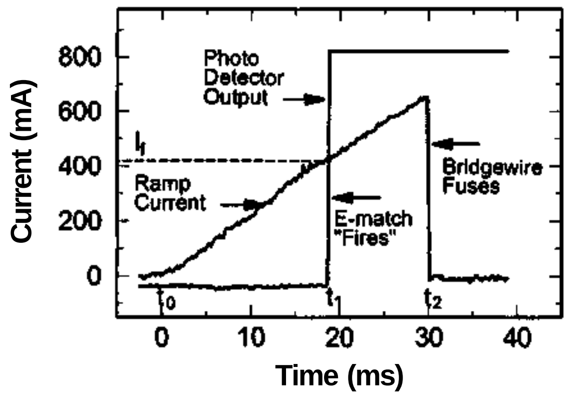

Figure 2. Typical ramp firing current test data from a firing e-match (Daveyfire AN28-B), showing both firing current and photo detector output.

For some e-match types and under some conditions, the bridgewire fuses before the match fires (i.e., before light is emitted). The types of e-matches experiencing fusing before firing and the conditions under which this occurred are discussed briefly below; see Table 1 and its notes. When fuse-before-firing occurred, the firing current If was taken to be that which was flowing at the moment of fusing, whereas the firing times continue to be the time to the first light output, tl.

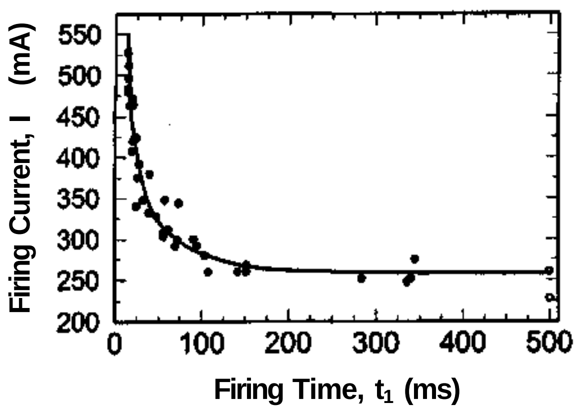

Figure 3. Ramp firing current data for Daveyfire AN28-B electric matches.

Results

The results of the ramp firing current tests are summarized in Table 1. (A more complete presentation of the results will be presented in a future article[3] along with a full set of graphs and some electron micrographs.) The approximate minimum firing time gives some indication of the rapidity with which the e-match types fire. In actual application, with approximately constant applied currents, the firings will occur more rapidly than in these tests. However, even if typical firing times

Table 1. Ramp Current Firing Results.

Supplier Name	Product Designation	Minimum Firing Time / Current (a) (ms)	Minimum Firing Time / Current (a) (mA)	Ave. Min. Firing Current (c)	Statistical Spread (d)	First Light Versus Fusing Time (e)	Other Notes
Aero Pyro		14	600	325	Slightly Broader	Before	
Daveyfire	AN28-B	15	500	250	Average	Before	
	AN28-BR	15	500	250	Average	Before	
	AN28-F	(b)	(b)	(b)	Much Broader	Slightly After (f)	
Luna Tech	BGZD	27	600	300	Average	Variable (g)	
	Flash	35	1900	1250	Slightly Broader	After	(h)
	OXRAL	19	600	200	Slightly Narrower	Before	
Martinez Sp.	E-Max	17	500	300	Average -	Before	
	E-Max Mini	15	600	375	Slightly Broader	Before	
	Titan	28	900	450	Much Narrower	Near Same	(h)

a) Minimum firing times and the corresponding currents are approximations and only apply for the conditions of these tests. These values were determined subjectively by examination of the plotted results for each e-match type in the area where the curves (like that shown as Figure 3) become near vertical. (Firing times are actually times to first light production.) It was felt appropriate to report those ramp-firing currents to only the nearest 100 mA. These currents are not the same as "All-Fire" currents for the e-matches.

b) These results varied so widely (See Figure 4) that it was not felt to be appropriate to attempt to assign values.

c) Average minimum firing currents are approximations and only apply for the conditions of these tests. These values were determined subjectively by examination of the plotted results for each e-match type in the area where the curves (like that shown as Figure 3) become near horizontal. It was felt appropriate to report those ramp-firing currents to only the nearest 25 mA. These currents are not the same as "no-fire" currents for the e-matches.

d) The statistical spread in the data is a subjective estimate of the degree to which the collection of each type e-match produced consistent results. This is an estimate of how close on average the data points fell to the curve fit line. See Figure 3 for example, which is defined as having an average data spread.

e) "Before" indicates that the e-match produced light before its bridgewire fused, as in Figure 2. "After" indicates that the e-match produced light after the bridgewire fused, as in Figure 5.

f) At higher ramp currents, light production occurred after the bridgewire fused, whereas at somewhat lesser currents the firing and fusing were essentially simultaneous.

g) Two production lots of Luna Tech's BGZD e-matches were used in this study and insufficient care was taken to identify exactly which matches were used in these ramp-current tests. While the firing times and currents seemed to be consistent between the two lots, the fusing times seemed to be different. Most e-matches produced light before their bridgewires fused; others fired at about the same time the bridgewire fused. The reason for the difference was not discovered.

h) Occasionally when using minimal firing current, there was an incomplete ignition of the e-match composition, with only the tip igniting (Luna Tech) or one side igniting (Martinez Specialty).

were as long as those listed in Table 1, they would all be rapid enough to be of no concern in designing a fireworks display. Of somewhat more interest is the corresponding ramp current for these firing times. These give an indication of the minimum reliable firing current for the e-matches. Note that for the normal sensitiveness e-matches, these currents all range from 500 to 600 mA. In contrast, the low sensitiveness e-matches require greater firing current. For example, the Martinez Specialty Titan matches require about 50% more current, and the Luna Tech Flash matches require at least 300% more current, than do the normal sensitiveness matches. The ramp firing data for a collection of Daveyfire AN28-F matches is presented in Figure 4. The scatter in the data is such that no reliable estimate could be made for the minimum firing time and its corresponding ramp firing current; however, it is apparent that it too requires significantly more firing current than e-matches of normal sensitiveness.

An estimate of the average minimum ramp current resulting in firing of each type e-match is also presented in Table 1. While this estimate is related to no-fire current, it is somewhat greater as a result of the statistical spread (uncertainty) found in the data. The data for normal sensitiveness e-matches ranges from about 200 to 375 mA, suggesting that no-fire currents probably are in the range of 150 to 300 mA.

Perhaps the most interesting ramp current results are the statistical spreads observed during the testing. For the purposes of this study, the spread demonstrated in Figure 3 for the Daveyfire AN28-B e-matches was considered to be typical (average). Note in Table 1 that most e-matches were designated as being average, or only slightly narrower or broader. However, one e-match type, Martinez Specialty Titan matches, had a statistical spread significantly narrower than average, and one e-match type, Daveyfire AN28-F matches, had a statistical spread significantly broader than average (see Figure 4). (As in Figure 3, the two data points shown as open dots in Figure 4 were instances where the e-matches did not ignite and are arbitrarily plotted with a firing time of 500 ms.) It would seem that matches with lesser spreads might prove to be more reliable (predictable) in their performance, while those with wider spreads would be less predictable in their performance. This could possibly translate to their being less reliable in series firing of many matches. However, this has not been proven, and it is not known the extent to which such differences would be noticeable in actual use.

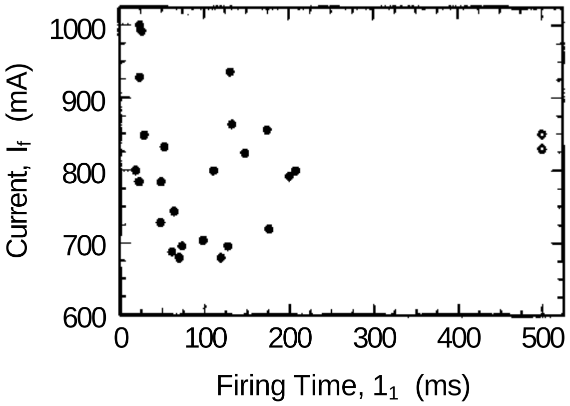

Figure 4. Ramp firing current data for Daveyfire AN28-F electric matches.

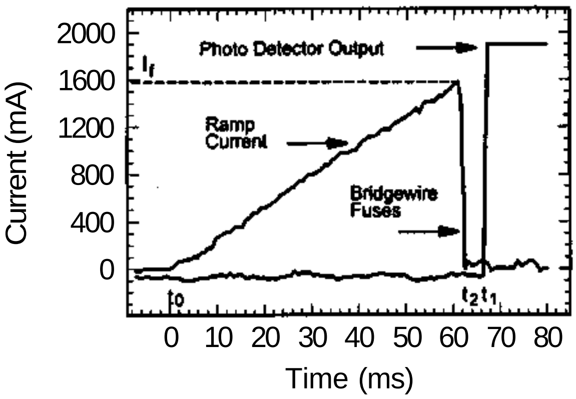

Figure 5. An example of the ramp current test data when the bridgewire fuses shortly before there is light output (Luna Tech Flash match).

In those cases when e-matches fired (produced light) significantly after their bridgewires fused, there is a potential concern that under some circumstances, they could conceivably fail to fire at all, especially if fired in a series circuit of many e-matches. However, this has not been confirmed by testing, and it may merely be the result of the e-matches burning internally prior to their external light emission. However, for two of the more rapidly rising ramp currents used in the testing of Luna Tech Flash Matches, it was observed that the bridgewires fused without successfully producing an ignition of the e-match. The reason for this was not determined. (The fire after fuse question will be considered further in the next article of this series.)

Acknowledgments

The authors gratefully acknowledge that the four electric match suppliers provided samples of their products, at no cost, for testing. Further, the American Pyrotechnic Association provided a grant to help cover some of the costs of this study. Finally, the authors appreciate the technical comments provided by L. Weinman, M. Williams, and P. Martinez on an earlier draft of this article. Note that while many of the company and product names are apparently registered trademarks, they have not been specifically identified as such in this article. ì

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FIREBALL EFFECTS WITH INEXPENSIVE MATERIALS

by J. Larry Mattingly

Fireball effects can be inexpensively produced in display or effects situations that demand and permit their use. The material selected to produce the fireball is critical. I have found that "calf starter" is a fairly inexpensive material that is easily obtained.

I have used all these: Cenex products, Purina, Land O' Lakes Feeds and a couple of products in plain brown wrapper with no brand as sold at feed stores. The big factor in choosing a product is the fat content. I try to find a calf starter/milk substitute with a fat content over 20%. I have seen it as high as 41%. The more fat the better. Most of these materials come in 50 lb. bags, so there will be enough for two or three effects.

Most prudent techs assemble the effect fairly closely as follows: I use a 5-gal. plastic bucket (if the effect is successful, it is destroyed). I place an electric match in the center of the bottom of the bucket and hold it in place with a small piece of tape, then pour in about 1 1/4 lbs. of 2 or 3 FA *(not FG)*. It is poured in a cone from the center out, covering the bottom of the bucket, with a small cone in the center. Then that is covered gently with a large commercial size coffee filter. Everybody has their own preferences. Some techs use facial tissue, toilet paper, or cheap/thin paper towels. The idea is to keep the powders separated without inhibiting flame transfer.

Gently, I say GENTLY, I sift whatever powder is being used into the bucket. Some techs get a double handful and put their hands right down in the bucket and rub them back and forth, spreading the powder in even layers across the whole bucket. It is very important not to "clump" the powder or cause it to settle. I try to set this item up right where it is going to be fired. Moving the pails around or picking them up and setting them down can cause the powder to settle. The less of that the better.

Most of the effects I have observed, that were set up as described above, produce a yellow-to-orange fireball 8-10-12 feet in diameter that rolls up 15-18 feet or a bit more. This effect must not be done with anything above it. Placing several of these buckets about ten feet apart in a line produces a pretty good "wall of fire" where other more serious effects (gasoline/det cord, foo gas or the like) might not be feasible. Prudent techs would not, under any conditions, fire this effect closer then 150 feet to spectators. Individual situations might allow for different distances, but I have seen pieces of bucket fly nearly 100 feet.

There will be enough material for a test shot or two, so it is recommended that the effect be tested in a safe place so that the operator will know exactly what to expect. JLM

WHAT IS *PYROGOLF?*

by Charley Wilson

Some questions were asked on the PML: What is pyrogolf? What are the rules? How do you make a golf ball mortar? How does one load the "golfgun"? Loose powder? Sealed in some type of cup that is attached? How is ignition accomplished?

Pyrogolf was invented by Guy Lichtenwalter, and was first briefly described in AFN. The "event" was first staged at the PGII convention in Stevens Point/Plover WI. It was Guy's idea to compare his powder with that of two other individuals who claimed that maple charcoal is superior to others. There were some problems with standards at the first shoot; the maple based powder and my powder had smaller grain size than did Guy's. As you know, a smaller grain size makes for a faster burn. Even so, Guy's powder made from black willow won the "event". JF won the events at Muskegon and Amana with a black willow based powder.

The mortar has gone through some changes over the years. The amount of powder used has been gradually reduced all the way down to 2 grams, due to the fact that we kept losing golf balls.

Going from memory, the mortar is about 12" high and about 1 3/4" i.d. There is about 1/8" clearance for the ball all around. The base of the mortar is removable for cleaning and is made from a machined piece of aluminum. It has a chamber with sloped sides and a center firing spot - visco fuse is inserted through the side into chamber.

This mortar is made from steel, a section of automobile exhaust pipe.

The concept is quite simple. The mortar is cleaned, loaded with fuse and then 2 grams of powder dumped in. The golf ball is then dropped into the gun. The fuse is lit. A bunch of people with good eyes and stop watches stand around. When the thump is heard, start timing. When the ball hits the ground, stop timing. We try to use the same ball for all tests.

The average of all the timers is used as the measure of the powder's efficacy. All powders are sieved on the site to (I think it was) -10 +20 making it about 2FA size.

The handmade willow based powders, and my narrowleaf cottonwood and Jack's alder buckthorn will out perform Goex by a substantial margin.

Rice hulls coated with this powder will make a bigger burst than commercial meal D (in the same proportions). CW

NITRIC ACID LOVES SULFURIC ACID

by Carl Denninger

Mixtures of concentrated nitric and sulfuric acid are used to nitrate materials such as cotton to make guncotton and paper to make flash paper. The action of the nitric acid is well understood by the amateur chemist but the reason for the sulfuric acid had puzzled me to no end. There is no sulfur odor in the combustion gases of nitrocellulose so one must conclude there is no reaction with the sulfuric acid; yet nitrating cotton is unsuccessful without H_2SO_4.

The answer comes to me from a chemistry teacher. He or she wishes to remain nameless. It seems that sulfuric acids affinity to absorb water is its claim to fame here. It steals the water diluting the nitric acid and the water resulting from nitric acid and cotton reactions. Thorough nitrating of the cotton requires extremely concentrated nitric acid. Commercially, the sulfuric acid is recycled by removing the water, and the nitric acid becomes depleted and is replenished.

The marriage of nitric and sulfuric acids certainly seems a marriage made in hell! Especially when one considers this mixture is the foundation for many high explosives, besides nitrocellulose, nitroglycerin, trinitrotoluene (TNT), etc. CD

GHOST MINES & COLORED ALCOHOL FLAMES

By Chris Spurrell

In the normal evolution of fireworks, you learn how to make something, then you make a larger one, then you make an incredibly huge one, then you make a couple more of those, then you start to look for ways to make it more interesting, maybe even prettier and smaller. Well, that's been my experience with liquid fueled fireballs - especially ones that can be fired out of steel mortars.

I started small. A friend of mine, True Thomas, a professional storyteller, wanted to create some "atmosphere" at one of his outdoor gigs. He wanted some flames in the background to burn with an "eerie" light. Well, I had a bit of experience with coloring alcohol flames and thought I'd give it a shot.

Green is easy. I mix a teaspoon or two of boric acid in a gallon of methyl alcohol and that's it. The boric acid actually reacts with the methyl alcohol to give you methyl borate, which is volatile. The boron in the flame gives it a very pronounced green color. The mix can be burned in an alcohol lamp or in the open (sterno can sort of thing). My buddy used a stainless steel bowl placed in a dish full of sand. Of course, once he had green he wanted other colors, which were a little more difficult.

In order to get an element to color an alcohol flame you have to get it into the flame itself. And, unlike the boron, it's either tough or undesirable to produce a volatile metal compound. We fussed with that a while until we hit on the idea of a wick. Turned out that a piece of steel wool in the bowl of alcohol did the trick. So now we could produce colored alcohol flames in a rainbow of colors.

The elements chosen are obvious but the actual chemicals are a comprise among solubility in methyl alcohol, cost and availability. Turns out that roughly 50 grams per gallon always works. In some cases that doesn't all dissolve but with calcium chloride or sodium chloride, who cares?

Red: Lithium chloride (any soluble lithium salt)

Orange: Calcium chloride

Yellow: Sodium chloride

Green: Boric acid

Blue: (nothing - alcohol burns blue)

Violet: Potassium iodide

This was a fun, low-level, non-pyrotechnic backyard project. The next step was to go large. I had been firing gasoline fireballs out of some mortars. Starting with a half gallon I had gradually worked up to blowing three gallons of gasoline out of a six-inch steel mortar using a charge of 40 to 120 grams of FFg for lift. So why not shoot colored alcohol flames? Several folks at the Western Pyrotechnic Association's "Do-It" had a chance to witness my first shots of the half-gallon "Lampare Mines". Admittedly that was a bad name because many people were expecting an aerial effect. Upon seeing a daytime mpeg of these colored alcohol fireballs Harry Gilliam coined the phrase "Ghost Mines". I like it.

I'll launch some of these at the WWB XII using the following gear:

Mortar: 4" iron pipe 2' long

Lift: 40g FFg powder, a pinch of sponge titanium and an electric match in a very small (jeweler's supply) zip lock baggie that is tightly wrapped with both clear packing tape and masking tape to minimize any in leakage of alcohol.

Fuel: One gallon methyl alcohol with 50g of coloring agent

Method: I will fill the mortar with alcohol-salt solution, then lower in the black powder charge. If the charge is tightly packed it won't float. I'll fire it from the friendly end of 50' of shooting wire!

Drawbacks: Typically there is some burning alcohol left behind in the mortar. HDPE and paper don't last too long.

Supplies: Methyl alcohol at the local lab supply, or fancy hobby shop, for $10/gal. Ethyl alcohol may work on some but the denaturing agent tends to give you a yellow flame. I hear that boric acid doesn't work with ethyl alcohol.

No Man's Land: To get a really beautiful sky blue color six grams of copper chloride and 200 ml. of methylene chloride (chlorine donor) are added to the gallon of methyl alcohol. Great color but it also makes phosgene. Any chlorine donor will do that. That is why I do not use strontium and barium.CS

INDOOR PYROTECHNIC ELECTROSTATIC DISCHARGE HAZARD

By K. L. Kosanke

An investigation of an unfortunate accident involving indoor pyrotechnics was completed a little while ago. This article is being written in the hope that by suggesting a trivially simple step, similar accidents might be avoided in the future.

The accident occurred during the demonstration of indoor pyrotechnic effects in the course of obtaining a permit for their use. The particular effect being demonstrated was a concussion mortar. The mortars in question had not been fired for days; earlier on the day of the accident the concussion mortars had been put in place in a carpeted area; there were electric matches installed in the mortars; and firing control wiring had been attached to the electric matches, but that wiring was not connected to the firing controller. The pyrotechnic operator had previously mixed the concussion powder but had not yet loaded the mortars. With the one ounce supply of concussion powder in hand, the operator approached the first mortar. He opened the bottle of powder and poured out a cap-full of powder. As best as can be determined, as the powder was poured into the mortar, an explosion occurred involving the essentially full bottle of powder that he was holding in his other hand. The force of the explosion was sufficient to cause the traumatic amputation of some fingers.

One likely scenario for the cause and sequence of the accident is as follows. As the result of walking on the carpeting, the pyrotechnic operator had built-up a significant charge of static electricity on his body. As he began pouring the concussion powder, an electrostatic discharge occurred from the operator to the mortar. This might have been a result of a dielectric breakdown through the flowing powder or as the result of the pyrotechnic operator touching the metal mortar. As a result of the electrostatic discharge, the powder being poured into the mortar was ignited. (The discharge might have directly ignited the powder being poured; or the discharge might have ignited the electric match, which in turn ignited the powder.) Apparently an incendive spark produced by the burning concussion mortar then entered the open bottle of powder in the pyrotechnic operator's other hand, causing the ignition and explosion of the bottle of powder, and in turn causing the severe damage to his hand.

Assuming the cause and course of the accident were as described, this accident could easily have been avoided by using a well established safety precaution. The pyrotechnic operator could simply have touched the metal concussion mortar for an instant before opening the bottle of powder. In this way the charge on the operator and that on the mortars would have been equalized by an electrostatic discharge occurring at that time. (Having such electrostatic discharges occur safely is the principle behind having grounded touch plates or other means of discharging personnel entering magazines and process buildings.) In the case of this accident, had the operator caused the discharge to occur by first touched the mortar, at worst the electric match installed in that mortar might have fired, or if the other mortar had already been loaded with concussion powder, its electric match and powder might have fired. However, even if this had happened, assuming no one was in the proximity of the other concussion mortar, it is unlikely there would have been an injury.

Note that: as is often the case in investigating accidents, not all of the facts are clearly established or completely free of dispute; not all concussion powders and e-matches are equally sensitive to accidental ignition from electrostatic discharges; not all indoor venues are equally likely to produce electrostatic charges on people and/or equipment; and not all concussion powders produce equally powerful explosive effects. Nonetheless, while it is always appropriate to consider the hazards of each situation, it is prudent to take basic precautions as a matter of habit. KLK

FLAME PROJECTORS

By Amanda McLean

The lower the height of the flame projector tube, the wider and thinner the effect. To get a tall, slim but full column of flame, you need a tube shaped like that, although you must be careful to not make the tube too thin as this will compress the gunpowder. In the wild, bad old days in the beginning of theatrical pyrotechnics, roadies would use rain gutters around the outside of the stage and put kilos of gunpowder in them to make a trail of fire around the stage. This is not recommended.

You can color the gunpowder with barium nitrate to make green (3 g sprinkled over 250 g will do), and red with strontium nitrate. I believe on one tour a long time ago we used silicon dioxide to make a whiter color. I have not tried to make blue. These colors are hard to notice in daylight, although the strongest is red, which is very vivid, even in daylight.

It is important to cover your flame projectors to prevent cross firing. I usually put aluminum foil, taping it around the tube. Do not tape over the top as that would compress the gunpowder even more. Just before the show, I poke a very small hole in the middle of the foil, and it rips open like a banana when the projector is fired. Some people use Rosco Black Wrap, taping it on one side only. Then it lifts off and hangs on the side when the projector is fired (unfortunately for the rest of the show.)

We have also done a lot of study into various quantities of gunpowder to use. Strangely enough, you can still get a flame projector with even 65 g of most quicker burning gunpowders. It doesn't have the push and heat you get from larger amounts, but is almost as tall and has almost the same duration. Some people use loads of up to 250 g of gunpowder per projector. I would not recommend exceeding that. When you have found a smokeless gunpowder you like, experiment with loads. If you are happy with a 65 g projector, why waste the money on 250 g?

Following is a list of the different kinds of smokeless gunpowder that may be used.

About the same speed and appropriate for flame projectors are:

- Kemira N 320
- I.C.I. Neo disc No. 0
- Hercules (Alliant) Green Dot
- Rottweil RWS P 804
- Du Pont 700 x/IMR Hi-Skor 700-X
- Winchester W 231

Also on my chart as being this speed (but I have not yet tried out): Hodgdon TRAP 100 and Hercules (Alliant) Red Dot ICI NGSP80. My favorites are Kemira N 320 and I.C.I. Neo disc No.O

These may be hard to get in some countries, so if you get in a pinch, just ask the gunsmith what would burn at the same speed. Remember, it is best to buy it locally rather than try to ship it.

Important is the placement of the igniter. Usually the best place in my opinion, is with the head sticking up about an inch from the bottom of the projector tube. Most igniters will ignite gunpowder.

Do not put your face over a flame projector when loading it, and wear safety glasses. AM

IMPROVED E-MATCH TECHNIQUES

by John Eier

Frank Joy's article in the April edition of AFN (#223) called *Building Electric Matches* got me to thinking about my own article in AFN some years ago, and how I have improved the technique.

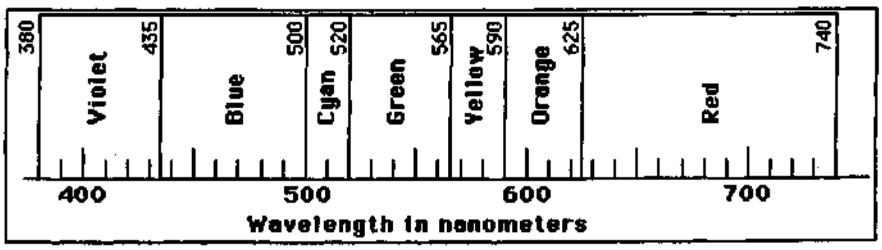
I simplified the method of attaching the bridge wire to the copper leads. I used to wind the bridge wire around the copper lead and bend the end of the copper over the wrapped bridge and crimp it down. No solder needed. The last three or four years I flatten the copper wire, make sharp bend and lay the bridge wire over the flatten wire and crimp it. Again no solder needed. JRE

NITROCELLULOSE FLAME PROJECTORS

By Russ Nickel, Next F/X, Inc.

As we all know flame projectors are used extensively in theatrical pyrotechnics to great effect. They are relatively cheap for what they do and make quite a show of color and heat while giving off minimal smoke. We manufacturers have spent some time refining the best ways to do it. Here are some of the things I have learned along the way.

Red is fairly simple to do with the addition of small amounts strontium nitrate. Actually according to my Ocean Optics optical spectrometer, it's not really a red but a deep orange. The lack of chlorine to form the SrCl molecule, causes the production of SrOH which radiates at the high end of orange (620nm) , very near red (680nm) in the visible spectrum.



I have attempted to introduce free chlorine in this reaction but the donors either did not decompose at a low enough temperature, gave off objectionable hydrogen chloride gas or produced too much smoke to necessitate the small shift into the red. This difference is difficult to detect with the eye, so we decided 620 was good enough.

Green is a bit more difficult to make well since typical barium salts have a higher decomposition temperature than strontium. Also we had the same problems introducing free chlorine. Of all the colorants tried, barium chlorate worked the best because of its low decomposition temperature. Unfortunately we refuse to use chlorates of any kind, so we chose to use barium nitrate. There are a couple of tricks that one can use to bump up the temperature slightly to improve the color when using the nitrate but you will have to discover those for yourself as I did.

Yellow is a very easy color to make with the addition of a very small amount of sodium. I prefer the nitrate, and can use it because of the low relative humidity in Montana. However, most any sodium salt used in pyrotechnics will do the job. You really can't make a mistake when creating yellow. The results will be bright since sodium is a powerful atomic emitter even at low nitrocellulose combustion temperatures.

Blue is the trick! After years of tinkering with it and failing miserably, a hint from a friend who works as an explosive chemist at Los Alamos, solved the problem. We are just about to start selling blue flame projectors as soon as the approvals from BAM, CERL and DOT are obtained. Since the chemistry is very atypical, not on the APA 87-1 list of approved chemicals, as well as being a trade secret, I'm going to keep my lips zipped on this one. But I can tell you it is one of the best non-toxic, smokeless blue flames I have ever seen. Making even a poor blue is difficult using commercial smokeless powder and or nitrocellulose fiber/fluff due to residual sodium contamination in the manufacture. I have been able to process NC in lab size batches to remove the sodium with ion exchange resins but the hassle is just not worth the effort.

A side note here about sodium contamination: Most pyro chemists would be alarmed by how much sodium there actually is in most oxidizers, especially ammonium perchlorate. Nothing kills blue faster. We routinely burn samples in the spectrometer looking for the telltale 580nm peak.

One of the easiest methods to drastically improve the quality of your flame color, reduce smoke and smell, is to salt the colorant into the nitrocellulose chips themselves. This is accomplished simply by wetting the powder to dampness with distilled water, sprinkling in your nitrate colorant, agitating to blend well and then drying the resulting mix. We do this in big tumblers 100 lbs. at a time.

There is an interesting story about the first time I did this on a large scale. We were still using double base powder at the time. I wetted the NC by spraying water and stirring with my ungloved hand. Anyone who has any experience with nitroglycerine knows what happened next. Oh My God. . . . .never before have I felt a headache of that magnitude.

You have to experiment with how much colorant to use, depending on your perception of what is a good color. You will find that much less is required then when making colored flames by simply sprinkling it on dry. Test your results indoors or at night from a distance since ambient light will influence your color judgment.

One final note on selecting the proper smokeless powder. I have tested many, and personally I like single base powders best. Burning nitrocellulose is what gives you the large flame envelope. The nitroglycerin in double base powder is there as a burn rate modifier, plasticising agent and help to improve the oxygen balance. This is good for small arms propellants, but does nothing in a flame projector except reduce the flame envelope and make some extra smoke. Try it yourself and see.

Obviously this is just my experience and your results will almost certainly vary. RN

NITROCELLULOSE FLAME PROJECTORS

by Harold Upton, Australasian Spectaculars

We use a lot of flame projectors both indoors and outdoors. We manufacture them ourselves using smokeless powder (nitrocellulose as used for reloading ammunition).

The flames can be colored by adding 10 grams of powdered barium nitrate to 100 grams smokeless powder for green, and 7g of powdered strontium nitrate to 100g smokeless powder for red.

We use 50mm cardboard cases (mortars) left over from multi-shot cakes. Up to 200mm in length is used to create an awesome indoor/outdoor effect.

When we want something unobtrusive we just cut the tube down in size and paint it to match the stage (black or white or whatever). We have given up with totally unobtrusive in return for very safe. We use a 70mm to 80mm steel tube welded to a 150mm x 150mm plate with the tube being 200 to 300mm long. The cardboard case is placed in this for added security. Works fine for concerts though too big for VIP events.

Everything new must be tested in a safe open (non-public) place before attempting in public in case there is a problem with chemicals or manufacture or anything else.

Check local regulations & laws as many (including Australia) require a manufacturing license for this. HU

MAKING GUNCOTTON

By Doug Biedenweg

[Here is the long-promised article on guncotton. It is a product that is much used by magicians and by a few SFX operators, and there is some use in novelty fireworks items, such as table bombs. Its production requires the use of very strong acids which usually are not in the pyrotechnist's inventory. Prudent workers will learn as much as they can about handling these materials. Proper personal protective equipment and proper work environment and habits are vital, as they are in any handling of high energy materials.]

Guncotton (cellulose nitrate) looks just like cotton but is so unstable that when a spark or flame comes in contact with it, it produces a brilliant and startling fireball and completely disappears as all of its components become atmospheric gases.

If you like to do science or magic shows guncotton is for you. I have been making it for many years now and it always amazes my high school students. In this article I explain how I make and store very high quality guncotton.

A WARNING ABOUT ACIDS:

Guncotton manufacturing requires the use of concentrated sulfuric and nitric acids. Concentrated sulfuric acid is the worst acid that you can get on your skin. It is both an oxidizing and a dehydrating agent, and it dissolves flesh very well. The operator does not want to spill it or get it on himself. It is necessary to be very careful, trying to avoid all splattering; one must not place stir bars etc. down on the table without first rinsing them off. A pair of neoprene-coated gloves are needed that can withstand submergence in the acids if the operator wants to make guncotton easily. The gloves chosen should extend up to within four to six inches of the elbow. If these cannot be found, then tongs are used and the cotton is rinsed directly as it is removed from the acids. Access to a fume hood is needed to avoid inhaling lots of acid fumes. Without access to a hood it may be possible to arrange for the use of one with a local high school chemistry teacher. Goggles must be worn. If acid splashes the area must be rinsed with lots of water. Finally when diluting acids one ***alwaus adds acid to water*** or the acid will splash out of the container and all over the operator when the poured water comes in contact with the acid surface.

MATERIALS NEEDED

- 2 pints reagent grade sulfuric acid
- 1 pint reagent grade nitric acid
- 2 liter beaker
- a large watch glass (150 mm diameter) to cover the beaker
- gloves Neoprene-coated, long, Edmont cat. no. G7169-13
- 2 polyethylene wash tubs (dishwashing tubs work great)
- a long solid glass stir bar
- 2 two ounce rolls of Johnson and Johnson 100% first aid cotton (make sure the cotton is 100% cotton or there may be a big mess)
- goggles
- sodium carbonate (5 pounds)
- scissors
- ice

All chemicals, beakers, watch glasses, and gloves are available from Chem Lab Supplies, Unit C, 1060 Ortega Way, Placentia, CA 92870. (714) 630-7902 (they sell to the general public)

PROCEDURE

1) The acids are cooled in a freezer and then packed in ice as they are transported to the fume hood.

2) Goggles are put on.

3) All items are removed from the fume hood.

4) One of your wash tubs is placed in the fume hood and the 2000 ml beaker is put into it.

5) The neoprene coated gloves are put on, then the hood is turned on and the shield is partially dropped down. The nitric acid is added to the beaker by pouring it down the stir bar. Now the sulfuric acid is poured into

the beaker on top of the nitric acid, and the two acids are stirred together.

6) Ice is carefully added to the wash tub so that it surrounds the 2000 ml beaker. ICE IS NOT put in the beaker with the acids! Then water is added to the ice so that it can cool down the beaker.

7) While the acid mixture is cooling in the hood one roll of cotton is opened and cut into squares that are a tiny bit larger than the area of the top of the 2000 ml beaker. The squares will be layered in the acid mixture so their size is not critical, but I try to cut them so the corners just rest on the edge of the beaker's mouth.

8) After allowing the acid mixture to cool for 20 minutes, with the glove back on, the beaker with acids is carefully lifted out of the ice water bath. The ice water mixture is dumped out and the tub is dried and then put back under the fume hood. The beaker is carefully returned to the center of the empty tub.

9) Using the stir bar, one square of cotton is pushed under the acids.

10) This is continued until no more cotton squares will fit into the acids without the cotton being above the surface of the acids. All squares must be totally submerged in the acids, with no edges sticking out.

11) The watch glass is placed on top of the beaker.

12) The fume hood is left on and the cotton is left in the acid mixture for 5 to 8 hours (I normally begin making the cotton in the evening and I leave it in the acid mixture over night).

13) After eight hours the second tub is placed under the hood beside the one with the cotton and acid in it. I put my gloves back on and under the fume hood begin removing each layer of cotton. To remove the cotton I simply grab the first layer with my gloves (making sure I have acid resistant gloves!), pull it out, and over the beaker squeeze as much acid out as possible. When I have squeezed out as much acid as I can, I place the cotton square into the second tub and begin with the next square. When done squeezing out all of the squares, and holding my breath, I transfer the tray with the cotton in it into a separate sink. The water is turned on (I have a sink that dispenses distilled water so I use this in all my rinsings, but I doubt that this makes much of a difference) so that it runs onto the cotton, and then I leave the area. I also leave my gloves in the sink.

14) After about five or ten minutes I return to the area and begin to thoroughly rinse out the cotton. First I put on the gloves and squeeze out each piece of cotton under the water in the tray. Now I pick up each piece of cotton and rinse it thoroughly and repeatedly under the running water, trying to avoid splashing the water around as it has acid mixed with it. After several minutes of rinsing I move all of the cotton to one side of the tray and pour some sodium carbonate into the empty side. I stir up the sodium carbonate so that it gets thoroughly mixed into the water and swirls on top of the cotton. The cotton should get a yellow brown tinge at this point. I let the cotton sit in the tray with the sodium carbonate solution for about two minutes, then pick up each piece and rinse it until the yellow brown color is completely gone. When I have finished cleansing each piece of cotton I repeat the sodium carbonate treatment one more time and rinse the cotton again to remove all traces of yellow brown color. I normally do the final rinses with my bare hands because it gives me better control of the cotton when rinsing.

15) When all of the cotton is white I tilt the tray slightly and place a support under it so that it can remain slightly tilted. Then I adjust the water to a very slow rate and let it trickle into the tray holding the cotton. I let the water continue to run into the tray for 7 or 8 hours (I have to make sure to get all of the acid out of the cotton).

16) The acid is still strong enough for another batch, so if I intend to make more, before I leave I return to the fume hood and place a second batch of cotton under the acid in tub number one.

17) After the 8 hour rinse I squeeze the water out of the cotton for the last time. After pulling the cotton apart to maximize the surface area I place it along the edges of the tray (some extra trays may be needed now) and set the trays up some place where the cotton

can be left to dry undisturbed for several days (I would not dry this out under heat lamps).

18) If I made a second batch, I would treat it the same way as the first.

19) To dispose of the acid mixture it must first be neutralized. In the fume hood, wearing my gloves, I lift the acid out of the tub and fill the tub about one third full of water. Then I pour about one-third of the acid into the water in the tub. With the water still running into the tub I begin sprinkling sodium carbonate into this mixture. It will foam up a lot. Once the foaming has subsided I continue adding sodium carbonate in cycles until I get no more foam. At this point the mixture may be poured down the sink. I continue neutralizing the rest of the acid until all of it has been disposed.

20) When the guncotton is dried I normally pull it apart to fluff it up and pull out all of the tiny clumps of hard cotton that will not fluff to dispose of later. I store the cotton in a shoebox. After neutralization in this manner, it can be stored for over a year. It must not be placed in any kind of plastic container or zip loc bag (it gives off acidic fumes and will deteriorate) and definitely I would never stick it in any closed hard container.

HOW TO USE THE COTTON

I start with a piece about the size of a ping-pong ball. I pull it off and place it in the middle of a cleared table, then remove the rest of the guncotton to a remote location and close the shoe box. I light a match, and from a distance of about one foot, toss the match onto the small ball of guncotton. It is surprising to see the intense fire ball that results. If the batch was made well there should be little or no residue left from the reaction.

OTHER THINGS TO TRY

I also show my students how with minimal confinement guncotton will cause explosions. To do this I get Fuji film canisters that have a snap-on cap and I drill a hole in the top with an X-acto knife to fit a piece of visco fuse. I then place a small piece of cotton into the canister and screw on the lid. Behind a safety shield I light the visco and get an explosion about the size of a standard firecracker. No shrapnel is produced. The explosion simply blows the cap straight upward. The only danger is the burning visco that falls back to the ground.

My students also use a 9- volt battery, a normally open/normally closed lever switch, and tungsten wire, to design jewelry boxes or greeting cards that produce tiny fire balls when they are opened. Students love these devices and they really are not that dangerous as long as the person opening the card or box is prepared for the surprise. DB

[Editorial notes: The theory and practice of nitrocellulose production is extensively covered in *The Chemistry of Powder and Explosives,* which says that the secret of successful production is in neutralizing the acid, which is only partially accomplished by the sodium carbonate. In commercial production, the nitrated material is *boiled* repeatedly in distilled water, with flushing between boils. As T.L. Davis points out in the book, "The acid is adsorbed, or bound to the product in such manner that it is not easily washed away by water or even dilute soda solution; many boilings and washings are necessary to remove it. [It has been] found that the acid is removed rapidly and completely if the [product] is digested or washed with a solution of some substance which is adsorbed by nitrocellulose with greater avidity than the acid is adsorbed, that is, with a solution of some substance which has a greater *adhesion tension* for N/C than the acid has. ... A 0.5% solution of urea in water may be used. ...[Nitrocellulose] is intrinsically unstable, even at room temperatures [and has been] found to evolve gas at the rate of about 0.7 cc per gram per day at 100°, 0.01 cc per gram per day at 75°. [The gas produced contains] carbon monoxide, nitrous oxide, nitrogen and a trace of hydrocarbons." Thus it can be seen that even properly made guncotton will eventually decompose, and if not carefully neutralized, will decompose rather quickly.] DB

A METHOD OF PRODUCING FLASH MATERIALS

By John Henry Grossman, MD

[The late John Henry Grossman was an Honorary Life President of the Magic Collector's Association, an international "Magical" columnist in his "Ask the Doctor" and "Americana" columns. In 1980 he told us that he had done "a great deal of experimentation with [flash paper] materials [and] I have flash materials that I made 20 years ago that are just as stable and fast as when first made. If you want to make a good product, you must be willing to put in the time to make it right." Flash paper may not be main-line fireworks, but pyros do bump into a need for it from time to time, so with the late Dr. Grossman's express consent, we present his famous technique and procedure.]

Slowly mix four volumes of concentrated sulfuric acid (Specific Gravity 1.84) with five volumes of fuming nitric acid (Specific Gravity 1.49 to 1.50) by pouring the sulfuric acid slowly into the nitric acid. The mixture must be made in a Pyrex glass vessel since a good deal of heat is evolved. One must avoid spattering as the solutions are very corrosive. After the mixture is made, it must be covered to prevent the adsorption of moisture, but loosely so, as with a watch glass over the top of the beaker. The solution should stand for 24 hours before use so as to allow full sulfonation to take place.

Actual nitration should be done out of doors since irritating fumes are produced. A tub containing a large volume of water should be at hand to drown the paper after it has been nitrated. A large glass photographic tray is best for the acid solution and the paper must be placed in the tray and removed and immersed in the water bath by means of glass rods. Approximately ten to twenty minutes in the acid bath is usually long enough. A fine grade of white tissue paper is best, and for a very fast paper, Japanese Lens Paper (used for cleaning microscope lenses) can be used but is not as opaque as tissue paper.

As many as ten, or more, sheets of paper may be placed one upon another in the acid bath but they should be staggered so that the edge of each piece can be seized singly. The stack is then turned over and the sheets removed *one at a time* and transferred to the wash water. This method saves time in the process of nitration but great care must be taken to avoid splashing of acid if sheets of paper adhere. Several trays of acid can also be used and a single sheet placed in each tray. In every case, when sheets are transferred to the water bath this must be done singly and not in groups.

One must be careful not to introduce any water into the acid bath by accident. As the paper is removed from the acid bath it must be thrown into a very large volume of water to be washed. If the amount of water is not large enough, the paper will heat up and jellify. This will also occur unless the paper is introduced in the water *one sheet at a time.* After the paper is nitrated and in the wash, it must be rewashed several times and then collected in a large pail of fresh water.

The paper must now be stabilized, by boiling, in order to hydrolyze split products in the nitration. Unless this is done, the product will not keep since it will release acid, break down, and become useless, this is a point which is almost entirely unknown.

Merely bring the paper to a boil in a large quantity of water in the pail and keep it boiling for about three hours. After the first boil, pour off the supernatant water, add fresh water, and boil again for one hour, Pour this water off, add fresh water and boil a third time for one hour. After the third boiling, pour off the water and wash the paper in fresh water. Following the three stabilizing boils, the paper will still have slight traces of split products which are chemically attached or adsorbed upon it. To remove these one must soak the paper in a 0.5% solution of urea for one hour. This has a greater affinity for the paper than the split products and frees the paper of them. After this step the paper is again washed in clean water and is hung out on a clothesline (like laundry) to dry.

When it is fully dry, it should be stored in air tight glass containers as it will otherwise pick up moisture and become slow. Screw capped (hard plastic top) glass jars, such as bulk chemicals are supplied in, are best. Paper treated this way never develops brown coloration, has no odor or taste and can be kept indefinitely, as long as it is stored in a cool place *well away from heat* This material can actually be eaten without harm and I have kept it as long as ten years.

Absorbent cotton can be treated if it is teased out in long thin sheets before nitration.

These materials can be dyed different colors by dipping in alcoholic solution of aniline dyes. They can also be made to burn with a green flame by immersing in aqueous solutions of barium salts, or with a red flame by soaking in aqueous solutions of strontium salts, and subsequently drying. However, the paper will always be slower after such treatment.

This is an original method perfected and developed by me in my private laboratory. The method is time consuming and the materials involved are dangerous to handle but it is the only means of obtaining an end product which is completely satisfactory in every way.

Anyone who undertakes the preparation of this product must do so at his own risk and will be best advised not to attempt it unless he has a good background in chemistry. It is best to wear protective rubber gloves and goggles, and to bear in mind that a single slip can result in very serious burns of the hands, feet, or face and even blindness. JHG

FOLLOWUP TO GROSSMAN'S FLASH PAPER METHOD

by Chris Spurrell

I'm a little bit puzzled by all the formalism that is used to describe the methods for making flash paper. My first experience with it was in Organic Chemistry lab where we would casually mix equal volumes of concentrated (not fuming!) nitric and sulfuric acids and then dunk in some paper towel scraps. We'd wash them off in the sink and use the fragments in various ashtrays around school for our rather simplistic amusement. True, the methods recently described (and available in *Chemistry of Powder & Explosives)* are superior and result in a much more stable product. But the bottom line is "You have to have either a well stocked and ventilated laboratory or be out of your mind to mess with this stuff." It's been argued that I qualify in both areas.

First of all, those acids really are extremely corrosive. One drop in the wrong place can be a life changing experience. Second, the fumes coming off are oxides of nitrogen (NOx) which are as toxic as hydrogen cyanide (LC 50 around 100 ppm). And, much like Hallmark, NOx is a gift that keeps on giving. You can receive a lethal dose and walk away, only to ponder your imminent chemical pneumonia-induced death.

This is no way to "smell the smoke".

No, I'm not trying to bum y'all out. It's just that there are OPTIONS. Options include:

1) Walking into the nearest magic supply store and buying it (and some flash cotton and some flash cord at the same time).

2) If the state (like my CA) doesn't allow that, it may be ordered from magic supply stores over the Internet.

3) If neither strikes your fancy it can be ordered from laboratory supply catalogs. Seems that some of the high quality filter paper used in water analysis is pure cellulose nitrate. Yup, pure flash paper and expect to pay a premium.

4) Buying some nitrocellulose lacquer from one of the pyro suppliers and cutting it with enough acetone so that it's easy to dispense with a spray bottle. It can be sprayed on a piece of flat polyethylene and when it's dry, that big ol sheet of flash paper can be pulled off (more on this below).

5) Soaking smokeless powder in lacquer thinner and following the above steps (this is the only one I haven't tried).

6) Soaking the paper in a boiling concentrated solution of potassium chlorate and letting it dry. Burns like flash paper but isn't smokeless.

DESIGNER FLASH

Go back to method 4 and before the stuff is dry a VERY small amount of fine sponge titanium powder can be sprinkled on. If you can see it, it's almost too much. Now the flash paper will erupt with a shower of bright white sparks. Using barium chlorate makes it burns bright green (and it's shock sensitive - I gotta try that stuff). A good way to disperse/dispense the powders is to place them on a fine screen (80 mesh or so) and tap it lightly as it is moved over the drying lacquer. I'm sure there are other colors/effects possible. CS

CHRISTMAS CRACKERS

By Ian von Maltitz

Way back in 1995 as our family was preparing for our first Christmas in the USA we noticed that something was missing - Christmas crackers!

We discovered that Christmas crackers had just not caught on as an American tradition, and thus were not available in the stores. In fact, Christmas crackers were originally a British tradition that had made its way to former British colonies, including South Africa, where we had emigrated from.

Having Christmas without crackers was like having 4th of July without fireworks. It was just unthinkable. So we set out to make our own.

Rounding up the necessary ingredients was relatively easy. We bought some crepe paper and managed to scrounge some paper tubes. (Any pyro worth his salt is good at finding paper tubes.) However, the most important ingredient was the most challenging. This was the 'bang' part, or 'snap' as it is referred to in the trade.

It was a bit of an ego thing, I suppose. I knew my reputation was on the line if I could not come up with the necessary pyrotechnic ingredient to make our Christmas crackers go bang. Making our own snaps from raw ingredients was also out of the question. We lived in an apartment and proper snaps also required a rather dangerous substance - silver fulminate. But there were other options.

Back in South Africa we had tried our hands at making our own Christmas crackers. Bought Christmas crackers were readily available, but making one's own was considered fun. There was also another compelling reason. Most bought crackers contained junky trinkets. Making one's own crackers got around this problem. The crackers themselves were easy enough to make if one could find the right stuff to make it go bang.

I couldn't find a supplier of cracker snaps, so I opted for something similar. This was the popular pull cracker, a.k.a. a *booby trap* or *pulling firework.* These could be bought from certain shops that stocked fireworks. Luckily some of these stocked fireworks year round. Unhappily I found the fireworks situation different in Colorado than most other places in the USA. Here the sale of fireworks is highly seasonal, and finding booby traps around Christmas time is very difficult.

Not to be outdone, I found a place that sold party poppers. I figured that these contained something similar to booby traps. I was both right and wrong. They did indeed contain devices like booby traps, but these only had a string on one end. I did get around this problem, but not without spending a lot more time on each substitute snap than the rest of the cracker. But we did have Christmas crackers to celebrate our first Christmas in the USA, and one way or another, we have had them at Christmas since then.

Just what is a Christmas cracker, and where did it originate? A Christmas cracker is basically a cardboard tube wrapped in a twist of paper, in a similar way to which individual pieces of candy are wrapped. This similarity is not just coincidental, as will be seen when we discuss the history of its origins. Each Christmas cracker typically contains a small gift, a paper hat, and a slip of paper printed with a joke or riddle. Added to this is a snap to make it go bang. It is literally pulled apart by two people in order to release its contents, accompanied by the sound and smell of the exploding snap. Note that I deliberately left out the word 'sight' in the last sentence, as the explosion takes place out of sight, inside the cracker.

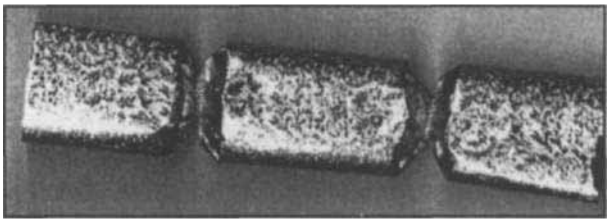


Figure 1: A Christmas Cracker

The Christmas cracker originated in Britain over 150 years ago. It has been a strong tradition there and in other countries since then. Today tens of millions of Christmas crackers are made every year. This market is expanding into other areas to include birthdays, weddings, and other festive occasions.

The original Christmas cracker was invented by a British confectioner called Tom Smith. His original inspiration came during a visit to Paris in 1840 when he noticed the French practice of wrapping individual pieces of candy in twists of waxed paper. He brought this idea back to Britain and sold his version of it in time for Christmas. It was an instant hit. Customers liked it and so did Smith's competitors, who soon copied the idea. Smith then progressively added value to his wrapped candy by first including small pieces of paper containing love mottoes', and later small trinkets.

Tom Smith's idea had grown from a creative way to wrap candy to a full-grown novelty that had the added element of surprise. But Smith still felt it was missing something. That something suddenly popped into his mind one day when he heard a burning log crackle in the fireplace. He would add an explosive sound to his novelty candy. The Christmas cracker was born.

It took Tom Smith nearly two years to perfect a viable explosive device to be used in the first Christmas cracker. Too violent an explosion, and the device would be dangerous. Too weak an explosion would make it a waste of time and effort. The final product was a small amount of explosive activated by friction between two pieces of thin cardboard.

Some of the so-called authoritative accounts claim that the explosive substance was saltpeter. This is hardly credible. If saltpeter had such powerful properties activated by friction, I probably would not have the fingers to type this article. In all probability, Smith used some type of fulminate.

Christmas crackers were so successful that Tom Smith started exporting them to foreign counties. This brought with it a problem all too familiar to manufacturers today: a company in the Far East copied his idea and started exporting them to Britain.

Much more can be said about the history of Christmas crackers, but as this is intended to be a how-to article, the above will have to suffice.

There are different ways to make Christmas crackers, and I will focus on methods that have worked well for me. At the end of this article I have references to web sites that show different approaches to making Christmas crackers. Personally, I don't think these other methods are ways of achieving the same result, because I have found that some methods are superior to others. I also approach Christmas crackers from a pyro perspective where I feel the most important characteristic of a Christmas cracker is its ability to explode without a misfire.

This article does not describe how to make the explosive device itself, otherwise known as a snap. These typically use silver fulminate, a very dangerous substance. Instead of making snaps, one is advised to purchase them. There is a supplier in the USA who sells these in lots of 144, at approximately ten cents a pop (pun intended). Otherwise one can use a booby trap, obtainable from fireworks suppliers and some novelty outlets.

A snap is made from two thin strips of cardboard glued together with some fulminate between the sections where the strips overlap. A booby trap is a very thin paper tube with a thin string protruding from each end. Both devices are activated by pulling on both ends; in the case of the snap on the cardboard strips, and in the case of the booby trap on the ends of the strings. A proper snap is the better choice as it can be used without modification. A booby trap is unlikely to work properly without the strings being attached to cardboard strips, ensuring a better grip.

Booby traps are problematic in that their explosive power is much greater than that of an average snap. This can result in the rest of the contents of the cracker being damaged when the booby trap explodes. Apart from damage caused by the explosive power, contents can actually get burned. Some have gotten around this problem by encasing the rest of the contents in a piece of aluminum foil.

Traditionally low to mid-priced Christmas crackers have been made from crepe paper. More expensive crackers are often made with the types of paper found in expensive gift wrapping paper, including metallic foil type paper. An essential quality of any paper used to make Christmas crackers is its ability to tear easily. However it must not tear too easily, and thus tissue papers used to wrap presents are unsuitable. I have found crepe paper the easiest to work with. The method that I am about to describe uses crepe paper.

When I make Christmas crackers, I gather the following materials:

- Snaps or booby traps
- Crepe paper
- Paper tubes (usually from used rolls of toilet paper)
- Glue sticks (with fresh glue)
- Small trinket
- Slip of paper with a joke or riddle.

I also use a ruler (for measuring) and scissors (for cutting).

The dimensions given in the following description are for a tube from a roll of toilet paper having approximate dimensions of 4 1/2 inches by l 1/2 inches.

I have illustrated certain steps with sketches to explain them better.

l)Cut a piece of crepe paper with a length of 14 inches and a width of 12 inches. Note that the length must be cut along the grain of the paper.

2) Lay the piece of crepe paper on a flat surface.

3) Measure 7 inches from one side of the length and mark it with a pencil, i.e. make a mark at the midpoint.

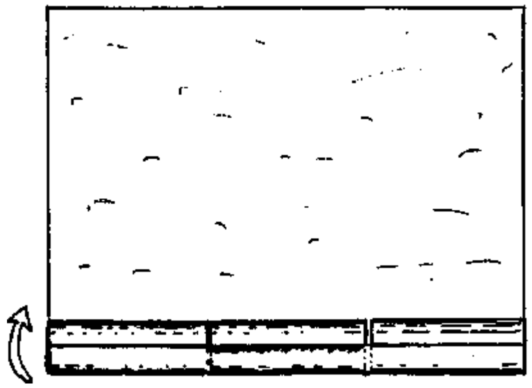
4) Measure 2 1/4 inches from one end of the paper tube and mark it with a pencil.

5) With the glue stick run a line of glue from one end of the paper roll to the other.

6) Position the glue side of the paper tube downwards and with both the midpoints of the paper and the tube aligned, glue the tube to the paper along its edge.

7) Get two other tubes and position them on either end of the paper tube.

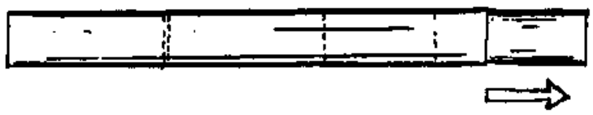
8) Roll the paper over all three tubes until the last inch of the paper is reached.



9) Run some glue with the glue stick along the edge of the paper in line with the center roll. This needs to be done carefully so as not to tear the paper by accident.

10) Press the glued section of the paper against the roll so that it becomes firmly glued to the underlying layer of paper.

11) Holding the center tube in one hand, withdraw one of the other tubes approximately two inches from the other.



12) Slowly twist the two tubes in opposite directions until the two tubes meet each other. This step needs to be done carefully to avoid tearing the paper. This operation is done to effectively close the one end of the middle section, leaving a hole barely wide enough to pass the snap through.

13) Withdraw the end tube that you have just twisted. It is no longer needed.

14) Thread the snap through the small hole in the twisted section.

15) Get the trinket, paper hat, and whatever else you may have chosen and drop them into the middle section of the cracker through the open end.

16) Repeat steps 11 and 12 with the open end, being careful to twist the tubes the same way. This means that when the cracker is pulled the twists tighten against each other, rather than loosen.

The cracker is now ready for Christmas. Some cracker makers glue a sticker or small ornament to the middle section. This is optional.

The twists in the crepe paper can untwist over time. One way around this problem is to grasp the middle section with one hand and insert the forefinger of the other hand in the one end section. Now push slowly against the center of the twis so that it is forced into the center section. Repeat this with the other end.

I have just described a method that works for me. What follows is a brief focus on some other techniques that are used in both commercial and homemade manufacture of Christmas crackers. It is worth noting that a large percentage of Christmas crackers are still made by hand, and some of the techniques described would be applicable to both commercial and handmade crackers.

Where crepe paper is not the paper of choice, a different method is needed to enclose the middle section of the cracker. One can twist crepe paper without tearing it. This is difficult to achieve with other paper. Crepe paper also has the property of retaining its twist. Regular paper untwists more easily. A way around this problem it to crimp the paper, rather than twist it. One can do this with one's fingers or try a variation on the technique used to choke gerbs as described in Weingart.

If you use ordinary wrapping paper, you will need to hold the crimp in place with a piece of string or ribbon. Foil-backed paper holds a crimp well and doesn't need anything else to retain the crimp.

A feature commonly found in commercially made crackers is a stiffener on each end. This is used to prevent the walls of the paper wrapping from collapsing. This is important in crackers that need to be transported (often halfway across the world), but is optional in homemade crackers. If you wish to include this feature, use very thin cardboard that will crush easily when the cracker is pulled.

Another way of inserting the snap is to glue it on both ends to the wrapping paper and then to roll it together with the wrapping paper so that the snap is on the outside of the paper tubes.

That wraps up this discussion on making Christmas crackers. I have included some references to websites where some other approaches are described. Also included are references to websites of suppliers of cracker components.

No discussion on Christmas crackers is complete without a description on how to pull them properly. The secret is to squeeze the end of the cracker very firmly when pulling it. Failure to do so can result in the cracker ripping open without the snap being pulled. A merry and blessed Christmas to all AFN readers.

Suppliers in the USA

www.christmas-crackers-usa.com
(a.k.a. www.oldenglishcrackers.com)

Suppliers in the UK

http://mkn.co.uk
www.hobbiecraft.co.uk
www.kereds.co.uk
www.craftdepot.co.uk

Suppliers in New Zealand

www.goldingcraft.com

Tutorials on Cracker Making

www.christmas-crackers-usa.com/make-your-own-crackers.htm
www.megan.scatterbrain.org/notmartha/tomake/partycracker.html
www.goldingcraft.com/cracker.htm IvM

FIREWORKS THAT WORK- THE LOG SPLITTER

By Carl Denninger

Oh, sure; we've all enjoyed fireworks that have worked very well, but here I wish to explore their ability to do *physical* work. It is very interesting to me to see just how much energy is released by this pyrotechnic chemistry I have mixed and rammed, literally, with my bare hands. It has also instilled a healthy respect for all fireworks compositions, be they flash or lift or even stars.

I heat my home with wood and in the state of Wisconsin that statement means work, a lot of work! So I designed and built a propellant actuated log splitter to help with the chores and get a fireworks "fix" at a time of the year when no shows or meets are to be had. I contacted the BATF about the use of such a device and found out that a similar device was patented in the late 1800's, which used black powder as a propellant, and also a device for splitting fence rails using a blasting cap. The hydraulic log splitter has done away with these devices, being no doubt safer yet rather expensive to own, and leaving a big footprint in the garage. The folks in Wisconsin who regulate explosives and fireworks have told me that propellant for propellant-actuated devices are not regulated by my state. However, I make no claim as to the legality of using this device.

The log splitter, described in the following drawings is made entirely of steel. I will describe the physical dimensions of my machine but I do not believe them to be critical. A wedge was flame cut from a 2" thick plate, being 14" long and 2 1/2" wide at the top. It was then welded to the slug which is a piece of 3" round stock, 3" long. The barrel is a piece of 4 1/2" round stock, 5" long, with a 3 1/8" hole bored through it. This barrel is then welded to a 2" thick slice of 10" round stock. A hole is bored through the side of the barrel to allow a length of visco. If I use loose powder charges I would mill out a cup in the top of the slug but I prefer a measured charge in a package like those shown in the drawing, with different charges depending on the size, type and cross grain of each particular log. These devices look like small salutes but may or may not explode very well outside of this device, depending on the composition inside.

To use, I drive the wedge /slug assembly securely into the end of the log with a mall. I then tap the sides as necessary to position the wedge reasonably straight up and down. A pre-made propellant assembly is installed by threading the visco out the hole in the bottom/ side of the barrel. The barrel/weight assembly is then set on top of the wedge/-slug. One would wish to avoid putting one's head over this machine for the same reason you wouldn't when loading a shell in a mortar tube! The fuse is lit and I retreat to a safe distance, bearing in mind that the steel could fail and spray shrapnel and also that the 18 pound barrel assembly will be returning to earth in a big hurry in a few seconds.

The rules of conservation of energy apply here. For every action there is an opposite and equal reaction. The very same energy blowing the barrel into the air acts on the wedge. If the wedge is not driven through the log I used too small of a charge. A new charge is loaded and the process is repeated. If the wedge is driven deeply into the ground under where the log was standing, then the charge was too great.

I can evaluate the amount of energy I am getting out of my propellants by recording the time the barrel assembly is air-borne. An ounce of commercial black powder might give it 4 seconds of flight. It might take 2 or more ounces of home-made BP to do the same or a half ounce of aluminum flash. The short barrel of this device makes best use of extremely fast reactions, but the huge pressures developed inside cause some unexpected results, such as cheaper aluminum powders equaling results from German black. Very economical propellants made from powdered sugar and potassium nitrate also work well.

The apex of the barrel's flight can be determined by the formula for acceleration due to gravity. When it falls back to earth the barrel assembly decelerates at the same rate it accelerates. The acceleration force of gravity is 32 feet per second squared, assuming of course, that there is no air resistance, which is reasonable in this case of flying chucks of steel! One can make some very useful observations from this activity by timing the barrel's flight with a stop watch and knowing the actual weight of the barrel assembly.

We can determine the maximum velocity of the barrel by using the formula:

(time/ 2) x 32 = feet per second

or

(time / 2) x 47 = miles per hour

Where time is measured in seconds and is divided by 2 because of the deceleration on assent and acceleration on return. An average flight might be 4 seconds. We divide 4 by 2 to get 2 and then multiply this by 32 to get a top speed of 64 feet per second, or using the second formula, 94 miles per hour, which means more to most folks. This formula works the same for mortar-fired shells such as a dud which hits the ground say 10 seconds after firing and therefore had a muzzle speed of 235 miles per hour!

We can also determine the azimuth or highest point of accent by just knowing the time elapsed from when the barrel fired to when it hit the ground using the formula:

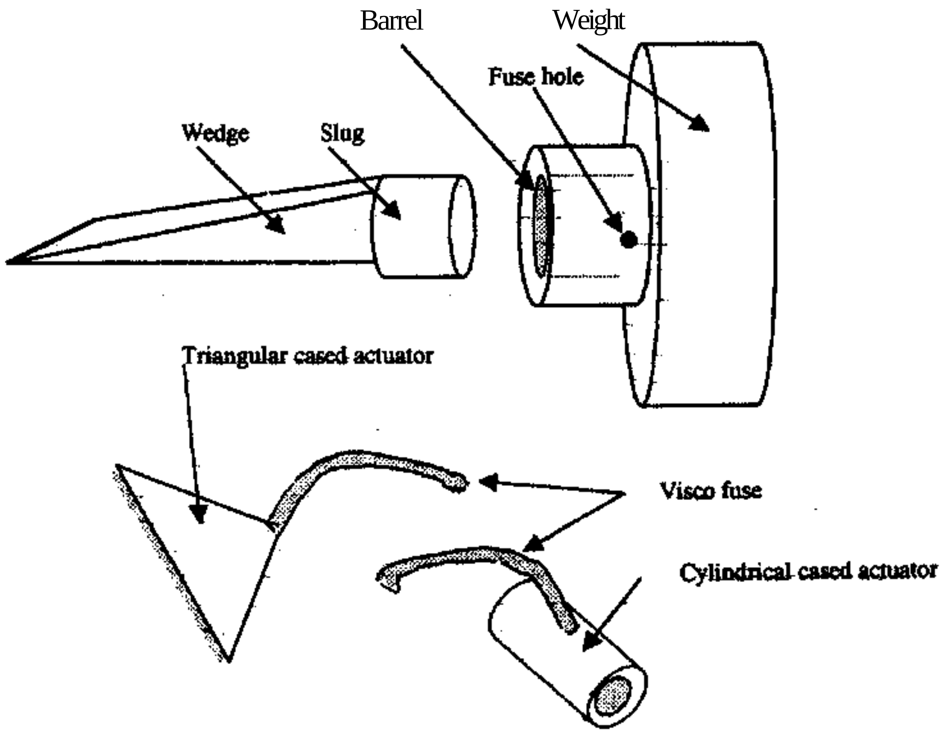
(time / 2)squared x 18 = feet

So my 4 seconds divided by 2 which equals 2 and then squared equals 4 which is then multiplied by 18 to find that my steel barrel flies to a height of 72 feet! Again if we apply this to the dud shell above that hit the ground 10 seconds after firing, we find it's azimuth to be 400 feet.

A last formula which is more useful in comparing different propellant formulas, mixing techniques, particle size, etc., is:

(V squared x pounds) / 2 = foot pounds

Here the energy is calculated, the energy being the *work* performed by the expanding gases and the very essence of salute and burst compositions. Where V equals the velocity found in the first formula, which was 64 feet per second, times the weight of the barrel assembly, which is 18 pounds in my case, 64 times 18 = 512. 512 is divided by 2 to yield an energy of 256 foot pounds. In the case of the dud shell we shall assume a shell weight of 0.25 pound and therefore a muzzle energy of 3200 foot pounds. A considerably greater amount of energy is required to launch a quarter pound shell than split the average tree trunk! So go ahead and make some fireworks that work! CD



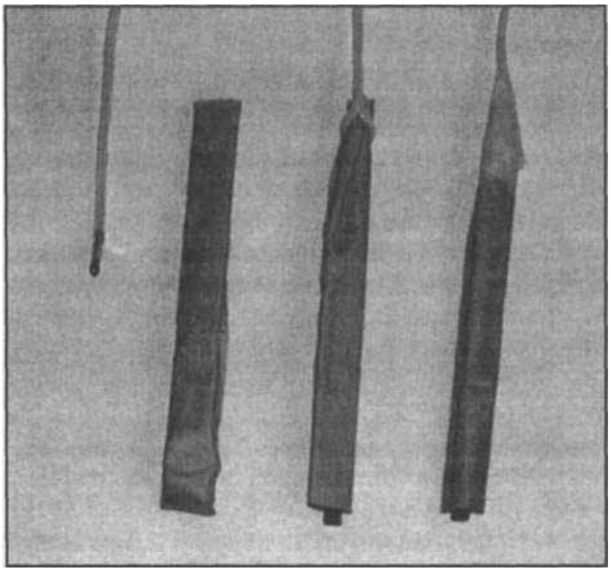
ELECTRIC FIRING OF CAKE FRONTS

By Tom Dimock

Here's how I prep Consumer Fireworks cakes for electrical firing. It isn't quick, but I do it all back in the shop, and it really speeds up setup time at the show and makes me feel pretty good about the safety aspects.

ATTACHING THE E-MATCH

For each device, I cut about a 4" piece of quickmatch, and insert an E-match into one end. I tie the E-match wire around the quickmatch to hold it in place and tape that end with a short piece of masking tape. I make up these little units a hundred or so at a time and always have a box of them on hand - the matches I use have very short wires, maybe 6" long.



PREPARING THE CAKE

To prep a cake, I dig the fuse out to where it enters the cake, and cut it off to about one inch long. I slide one of my little igniter units over the remaining visco and then tape it to the cake with a couple of strips of masking tape, making sure there are at least two layers of tape over the end of the quickmatch and the hole in the cake. Because the end of the quickmatch is right at the hole in the cake, the flame spitting out tends to be directed into the hole, giving immediate ignition. It also lights the short piece of visco as a backup ignition, but it has been my experience that most of the cakes start firing immediately upon the E-match being fired.

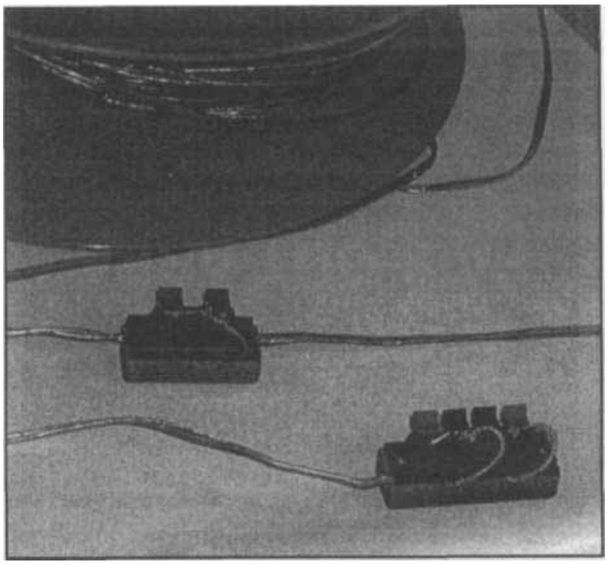
I then fasten each cake down to a piece of scrap plywood just as wide as the cake, and extending past it for a couple of inches in the other direction. I use a strip of duct tape going down the side of the cake, under the base board, and up the other side. I then do one wrap of duct tape all the way around the cake, going over the first piece of tape. This secures them strongly enough to the base that I've never had one come loose during a show. The base boards have a couple of holes drilled near the exposed ends, where I use T-pins (a 12" dock spike with a 4" piece of rebar welded across the top) to pin them to the ground. After the show, a sharp kick to the side of the dead cake will pop it loose from the base, and you can pull the pins and collect the bases for re-use.

Over the years I've amassed a pretty good collection of these little bases, so now it's seldom that I get a new cake that does not fit on one of my bases. I also have a box full of small sticks of wood that I can put under one side of the base to cant them away from the crowd slightly, if the site needs that. For shows where I know I'll need to cant the cakes, I tape the sticks to the bottom of the base when I attach the cakes. This mounting technique can (and maybe should) also be used to mount cakes for manual firing.

MAKING FRONTLINES

Consumer Fireworks cakes in a show are not something I shoot one at a time. I'll put out a front of at least six, and sometimes twelve or more cakes in a long front. One of the things that was always very tiresome about doing this, was wiring the matches for a front in series, using good old yellow fireworks wire. And then after the show the wire was pretty much a loss, as it is really hard to get much use out of wire that has been tapped into every 10 or 12 feet. So I invented Frontlines.

These are sections of 16 gauge speaker wire, with a two position terminal block attached every 12 1/2 feet. At the ends are four position terminal blocks. All of the blocks are connected so as to make the unit into one big series-wired loop. At each block I attach a small shorting clip made out of a corrosion resistant wire, attached by a short piece of string. My standard Frontlines are 125 feet long, giving me eleven firing positions spaced 12V2 feet apart. I keep them stored on the orange or yellow extension cord reels you can find at most hardware stores.



SETTING UP THE FRONT

To set up a front, I roll out the wire, making sure that all of the shorting clips are in place. At one end I remove one of the clips and attach my Blaster's Ohmmeter and make sure I'm showing low resistance. Then I fasten down a cake next to each firing position that I'm going to use, and plug the E-match leads into the block. The secret here is to have a helper checking with the Blaster's Ohmmeter after each one is wired, so that you catch any bad connection or bad match problems as they happen. By the time all of the cakes on a front are wired in, you can have a high degree of confidence that when you connect the front to your firing system, you'll get a clean circuit on the first try. When all of the cakes are connected, if the resistance shown on the Blaster's Ohmmeter is equal to or less than the voltage of your shooting system, you will know that you are going to have at least one amp available, which should be an all-fire current for most matches. This sounds a little fussy and complicated, but it really speeds up the setup. On one show where we use quite a lot of fronts, we cut the setup time for the fronts from four hours to less than one, and the time spent trying to find bad connections from over an hour to nothing. TD

YOUR OWN CONSUMER FIREWORKS DISPLAY

By Larry Crump

SPECIAL DISCLAIMER: It would be impossible for me to cover every aspect of every possible kind of consumer fireworks display in this page. These are suggestions to make your display a safer and better one. It is YOUR responsibility to determine the usability and advisability of any and all information I have provided on my web site. This information assumes the fireworks will be fired by an adult or with proper adult supervision, in accordance with all laws in your area.

When I get sufficient inquiries on something about fireworks, I try to provide a web page for that information. This page is going to assume that you live in a location where consumer fireworks are legal and available. If that's not true where you live, I'm sorry about that. Start writing your legislators and tell them you want fireworks legal in your county, state, country or wherever.

Consumer fireworks are much safer now, and more exciting than perhaps they have ever been. You have decided you want to put on a fireworks display for you family and friends for some special occasion. In the United States our big fireworks day is July 4, our Independence Day. In the UK it is November 5, Guy Fawkes Day. Every country has special dates that have fireworks connected with them, but almost any time is a good time for fireworks, right?

I'm going to give you some suggestions about how the pros prepare for a display. They are all applicable whether it's for a huge professional spectacular, or the kind of smaller consumer fireworks show you have in mind. Remember, what should be foremost in your mind at all times is SAFETY. Don't spoil your event by being careless. Keeping fireworks legal requires that we use them carefully and safely.

STEP 1: CHOOSING THE SITE FOR YOUR DISPLAY

Professional displays require developing a written site plan and survey. You should at least make a mental one. There are three physical areas you need to consider the suitability for:

1. The Spectator Area: Spectators should be a safe distance away from where the fireworks will be fired and where the fireworks will "travel". For small ground fireworks, such as fountains and wheels, many countries require keeping the spectators at least 16 feet (5 meters) away. For display and aerial fireworks, 80 feet (25 meters) is the minimum. Spectators should be upwind from the fireworks so sparks do not blow in their direction. It is advisable to tell your audience they must stay behind a marker stake or other item you have provided to define the front of the spectator area.

2. The Firing Area: The display area should be level ground, free of dry grass, brush or other combustible material. Obstacles that might be tripped over in the dark while firing the display should be removed, if possible. There should be no houses or other buildings in the immediate area. Certainly your display should NOT be conducted near a hospital, nursing home or other facility like that.

3. The Fallout Area: This is the area where the spent aerial fireworks will fall back to the ground. That area is larger than the display area, much larger. It too must be free of things that can burn, and there should be no spectators there. Again, no buildings in that area either.

STEP 2: CHOOSING YOUR FIREWORKS

If the display is confined to a small space, then only ground fireworks should be used. There are many varieties of fountains, wheels and novelty items that can provide a lot of fun. If you have plenty of room and can do so safely, then by all means use the full variety of fireworks available to you. Aerial fireworks come in the following general categories:

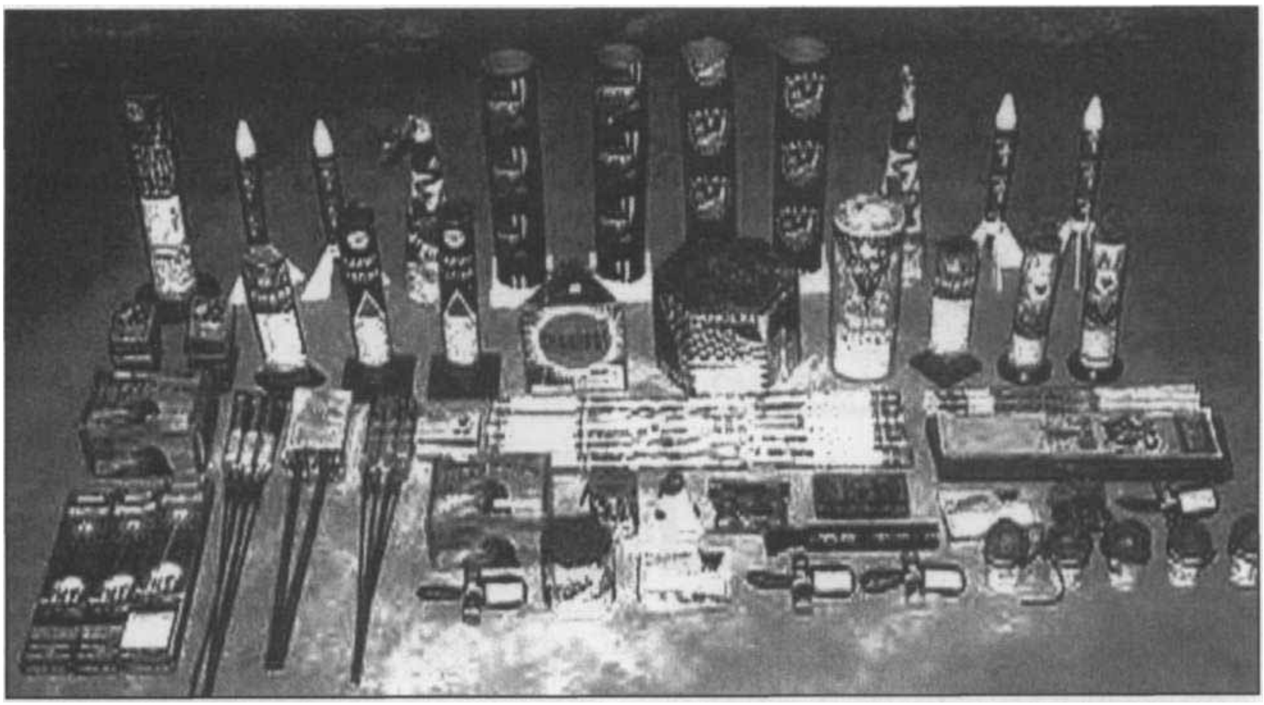
1) Roman candles
2) Multi-shot repeaters (called "cakes" in some places)
3) Rockets
4) Single tube shells, comets and mines

5) Reloadable shells kits (usually with 6 or 12 shells and one mortar to fire them from)

6) Helicopters (winged fireworks)

7) Finned missiles

Some of these categories may not be legal in your area. Examples of all of these, and some cone-shaped and tube-shaped fountains can be see in the photo below.



STEP 3: HOW MANY FIREWORKS DO YOU NEED?

I will assume you are able to use a full range of aerial fireworks. One way to pace a display and provide plenty of variety is to fire your display in ROUNDS. A single round might consist of a fountain, three rockets, a Roman candle, a helicopter, a single tube aerial effect and a "cake". That round, on average, might take 2.5 to 3 minutes to fire. Make your own choices as to what fireworks a round will contain. If you want a 30 minute show, then plan on having enough different fireworks for approximately 10 rounds. Try to buy as many different effects as possible; don't fire the same fountain, rocket, cake or other effect again and again.

STEP 4: SAFETY

There are several good fireworks safety sites on the Internet. Seek them out and follow their recommendations. Click this link to go to my safety page, and it will also link you to some others. Click your return button when finished reading the safety information to come back to this page:
www.wf.net/~lcrump1/safetv.htm

STEP 5: SETTING UP THE DISPLAY

It is best to do the setup during daylight hours, if possible. Placement of the fireworks should consider how far each individual piece is likely to travel. Ground and low level fireworks are closer to the audience, high flying ones further away. Displays are more delightful if they build in excitement as they go along and finish with a noticeable grand finale. Consider firing your larger effects later in the show and finish with something spectacular like the biggest cake. The plot plan diagram on the next page might be one you want to consider. It works well for me.

You need a source of water for fire safety purposes. A loaded stream fire extinguisher or two is nice, but most people don't have those. If you are not in a location with a water hose, take several gallons of water (10 to 20 liters) with you in a container that can be easily and quickly poured, if you needed it.

Be mindful of the kind of clothes you wear

while firing your fireworks. They should not be easily flammable and the thicker they are and the more they cover, the better personal protection you will have. Safety glasses or safety goggles are a MUST. Inexpensive ones can be found at many hardware stores and are definitely worth it for your eye protection.

Make sure each firer has a good flashlight with fresh batteries to use during the display.

STEP 6: FIRING THE DISPLAY

Hopefully any wind present during the day has died down to almost none by show time. Be aware that the wind could have changed directions before the display. If it does, the position of the fireworks might have to change to insure the spectators are still upwind and the fallout area is downwind. Firing a display in high wind should not be attempted. Be aware that rockets will "weathervane" into a strong wind and could actually fly toward your audience, a real no-no.

It is difficult to light fireworks in any wind

with cigarette lighters. Stick-type "punk" lighters are better but not ideal. I use a self-igniting propane torch such as the BernzOmatic Trigger Start 4000. Its 5-inch flame lights with the push of a button and goes out immediately when the button is released. Be advised that it will light most safety fuses very quickly, so be prepared for that.

You might want to have one person light the fountains and other ground items and a second person fire the aerials. This will reduce the amount of walking, which will make your display have better continuity and less gaps in time.

STEP 7: THE POST-SHOW CLEANUP

When the fireworks display is over the spectators will probably leave, but you still have important work to do. If any fireworks did not light, give them at least fifteen minutes before approaching them for disposal. Inspect the entire area to make sure there are no fireworks or other things still smoldering. Pour water from your water source on any suspected areas. Don't leave your used fireworks to litter the landscape, which is a complaint some people have about fireworks. Bag up all spent fireworks in double-bagged plastic trash bags. Each 30 gallon (92 liter) double bag can hold about 30 pounds (14 KG) of spent fireworks. It's not a good idea to burn those spent casings to dispose of them, sometimes there are unfired components that would ignite unexpectedly.

If you did everything safely, you had a safe and fun fireworks show that made your audience very happy. LC

PREPARATION OF SILVER NITRATE

FOR USE IN THE SILVER NITRATE-MAGNESIUM DEMONSTRATION

[Although silver nitrate finds infrequent use in fireworks, chemistry teachers have found that the silver nitrate/magnesium reaction is an excellent demonstration to help keep their students awake and interested. Here a chemistry teacher tells how he solved the problem of being unable to obtain suitable silver nitrate.]

By Stewart Tick

As a demonstration of an exothermic, single-displacement reaction, the silver nitrate-magnesium powder reaction is certainly one of the most dramatic and effective in the chemistry teacher's bag of tricks. The brilliant white flare caused by adding one drop of water to a mixture of these two chemicals never fails to leave students literally dazzled. As I recently discovered, however, the success of this demonstration depends primarily on the purity and crystal size of the silver nitrate that is used in the mixture.

Until this year, I had always performed this demonstration with silver nitrate from an old bottle of fairly large crystals that was in the chemical storeroom here at South Fork when I came here in 1993. This year, the old bottle was finally used up, so I opened a new bottle of reagent-grade silver nitrate with fine crystals, and promptly discovered that the demonstration didn't work any more. I got the usual bubbling and the release of gases, but the magnesium failed to ignite. Apparently, the purity of the nitrate and the size of the crystals affect the rate of reaction. (Perhaps the impurities act as catalysts for this reaction.)

I solved the problem by making my own, much less expensive silver nitrate. I obtained a worn, pre-1965 half dollar coin from a coin dealer for $1.50. (The collectors aren't interested in them unless they are in very good condition.) Working under a fume hood, I placed it into a glass beaker with 70 ml. of concentrated (68-70%) nitric acid, and proceeded to warm it on a hot plate. (Contrary to widely-held belief, it is not illegal to destroy American currency, but only to alter it for purposes of deception.) Before long, the reaction began, and the red fumes of nitrogen dioxide gas (warning-toxic!) appeared. When the solution was bubbling rapidly, I took it off the heat, and allowed the silver to dissolve completely. The next day, there were large crystals of silver nitrate at the bottom of the beaker. I poured off the blue solution of copper nitrate on top of the crystals (silver coins were 10% copper), and washed the crystals repeatedly with acetone until all of the blue color from the copper nitrate was gone, and the crystals were pure white. Copper nitrate is very hygroscopic, and must be removed. Fortunately, the removal is easily accomplished, since copper nitrate dissolves fairly well in acetone, while silver nitrate is almost insoluble in this organic solvent.

Within 12 hours, the crystals were completely dry, and I was pleased to find that they worked even better in the magnesium demonstration than the crystals from the old bottle. All that needs to be done is to add an equal volume of fine magnesium powder to one gram of the silver nitrate crystals (no need to grind the crystals). After gently mixing the two ingredients, add one drop of water, and the magnesium will ignite in one or two seconds, much to the surprise and delight of students. In fact, the new crystals cause such a rapid reaction that I had to decrease the amount that I used for the demonstration to one gram. With two grams, particles of hot magnesium were scattered about for quite a distance, and I had no desire to *accidentally set my wastepaper basket on fire) ST*

MORE ON SILVER FULMINATE

by Stewart Tick

I've finally discover what I did wrong when I attempted to prepare a small quantity of silver fulminate. I just didn't give it enough time! The reaction will work fine at room temperature, but it must be left overnight. Here's my procedure:

I added 5 grams of silver metal to 35 ml of concentrated (68-70%) nitric acid in a 100 ml beaker. The beaker was warmed on a hot plate until a brisk reaction began and red fumes of nitrogen dioxide (caution - toxic!) appeared. The beaker was removed from the heat and the reaction was allowed to continue until the silver was completely dissolved. Then the entire contents of the beaker, including the solid silver nitrate found at the bottom, was added to a 150 ml beaker which contained 50 ml of ethanol. (Denatured ethanol will work just fine.) The mixture is stirred with a glass rod and then allowed to sit overnight.

Nothing appeared to be happening at this point, but the next morning a white, powdery precipitate of silver fulminate was found at the bottom of the beaker. This was collected on a filter and dried in a cool place, then was gently removed from the filter with a plastic spoon, and stored. I use it with my Chemistry students in the same manner as the silver acerylide as described in the earlier article. ST

CANDLE BATTERIES

By Paul Bregel

Many people want to use bundles of Roman candles as part of their display, either tied on to a set piece or as a stand-alone piece. A properly made battery can be a fine addition to a display. Recently a friend read me some information he found on the Internet about my method of constructing candle batteries. I thought I would reconstruct an article I wrote for the PGI Bulletin a few years ago (but don't recall ever seeing in print).

This method was designed for the common Consumer Fireworks (1.4) candle but I have safely used it for display candles up to 3" in diameter. Batteries are usually made in groups of 7, 13 or 36. Three-dozen candles is generally the best amount to use for a stand-alone battery. Also, if you use thirty-six you get four bundles per standard gross case. I always use the same type of candle per bundle, not a mixed group, because it looks better to the audience. Mixed effects give you mud.

To Make a Candle Battery:

The candles are gathered into a circle (an empty salute core can aid in holding them) and then are tied 6" from the top and bottom with a good stout twine. The twine should be wrapped twice around the bundle and closed with a clove hitch, finishing with a half hitch. Next a shell end disc will be needed that can cover the bottom without overhang. I use a 5 1/2" disc, which gives a solid bottom to the bundle and helps each star to attain the same height.

Now a 14" square of 40 lb. Kraft paper is liberally pasted on both sides and gently crumpled (it's called to "break" the paper) to work the paste in. The bundle is turned upside down on a dry part of the workbench and the shell disc is placed on it. Then the pasted paper is laid on and smoothed down on the sides and molded into the bundle, which is dried overnight.

Next session requires a piece of paper that is 2 1/2 times the circumference of the bundle and 10" wide. A stripe is pasted on, 3" to 4" wide, along the long edge and up one end. Starting from the unpasted end, the nosing paper is wrapped around the bundle, making sure that the fuse end of the candles is 2" past the paste stripe. The paper is rolled to the end, then the sides are smoothed down tightly and up the pasted end. The assembly is now allowed to dry.

A 40 lb. piece of Kraft paper is cut to the height of the bundle and four times the circumference (this is known as "a turn"). Both sides are pasted liberally but it is unnecessary to break the paper. Beginning at one end, the bundle is rolled up, making sure that the paper is barely to the fuse end. If there is any overhang on the bottom, it is pleated down. Then the bundle is stood on end and the sides are smoothed down, working it close to the candles to free any air bubbles. Wrinkles can be worked out this way. The bundle must dry overnight.

The bundle is nosed by taking a handful of bare match and laying it atop the candles fuses. A length of piped match is inserted, with about 3" bared on one end. The Kraft paper from the second step is gathered and tied shut with a clove hitch around the piped match. The battery is done and ready for use. It can be lashed to a stake in the ground, or buried about one third into the ground, or even placed in a tube.

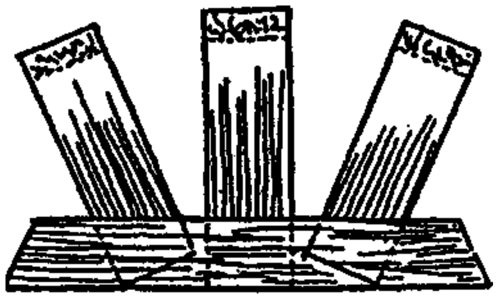
Some common questions:

What if a candle explodes? This is unlikely. I've made several thousand of these bundles without an explosion, but for those less confident, the maker can try pasting two 1-ft. wide bands of 60 or 80 lb. Kraft under the side panels. As a rule, I use this technique when I make Flashing Thunder candle batteries.

Can slurry prime and rough powder be used in place of bare match? Yes, I've done that. The slurry is painted on and dusted with powder before the second (nosing) step. It must be carefully dried before finishing the battery in the usual manner. Personally I find this method to be a lot more work and there isn't that free lighting effect. When the match catches fire it is full of dross and the effect is showy - a free show for the audience not seen with the slurry prime method.

What about using tape, such as masking or duct tape? In my opinion, using tape is very bad for three reasons. First, that type of tape is known to hold for a short period of time. The battery can't be made up several months in advance with any assurance that it will hold together. This would make for a dangerous situation. Second is that there is too much tape failure in humid or very cold weather. The third reason is that a properly made battery looks better as it is set up. When I first started in fireworks I was told that if I build anything it should *look* good. And I should be proud of my work. I like mine to look good before and during its use.

Remember, whether in a line or a formation or a Union Battery, a properly constructed battery is a great addition to any display and should be used accordingly. PB



Union Battery, per Weingart. Historically red, white & blue.

KING OF ITS CLASS - CLARK'S GIANT STEEL FOUNTAIN

by Dan Williams

INSPIRING EFFECT

One of the first descriptions of an amateur pyro project that really excited me was the one about Clark's Giant Steel Fountain. The description is tucked away at the very end of the list of projects in Tom Perigrin's book "Introductory Practical Pyrotechnics." The description first appeared in Tennyson L. Davis', "The Chemistry of Powder and Explosives." In Perigrin's book he states, "The purpose of reproducing the method is to inspire the reader." I was not only inspired, but quite captivated by the visual image of "a column of scintillating fire, 100 feet or more in height, of the general shape of a cedar tree." It left an impression on my imagination that occupied my daydreams during many a boring meeting at work. In vain I searched the Internet and other sources for more information. Someday, I told myself, regardless of cost or effort, I would attempt to build a device that could live up to this fantastic image in my mind. Little did I know that not even my wildest imagination could capture the thrill of the real thing in action.

THE TUBE IS THE SECRET

For those unfamiliar with the original project description, a very unusual tube is called for in the materials list. It is a paper tube with a 4 inch outside diameter, 2 inch inside diameter and 1 inch thick walls. This is not a common size tube that can be easily found. Therefore, anyone who has ambitions to make the fountain faces the daunting prospect of having to make one of these monster paper tubes himself. This challenge was partly responsible for the failure of my first attempt. Much later, when I again turned my attention to this project, my experience from the first attempt motivated me to try and find a better approach. I reasoned that I could justify the considerable effort to make the tube if a method could be devised to allow it to be reused instead of having to go to all the trouble of making a new one for every fountain. The plan I finally came up with was to use a commonly available 2 inch paper tube with 1/8n. thick walls, such as the Skylighter #TU2200, as a disposable liner in the containment system. The structural strength of the containment system would still be a very thick walled paper tube, but this time I would use a short-cut. I planned to roll a tube with an inside diameter of 2 1/2 inches and an outside diameter of 3 inches. This meant that I only had to endure the task of hand rolling a tube with 3/8-inch thick walls. This tube could then be glued inside a common 3 inch paper mortar tube which has 1/2-inch walls. Added all together, the liner, the hand-rolled tube and the mortar tube yielded a final tube with 1-in. thick walls, exactly as specified by the venerable Davis. Convinced that I finally had the perfect solution, I set out to roll the tube and realize the dream.

The problem from my earlier attempt seemed to stem from the fact that I used traditional water-based glues. Unfortunately, water causes cellulose fibers to expand. If moisture from the glue is unevenly distributed on the paper, uneven expansion leads to wrinkles in the paper, ultimately causing voids in the layers and a spongy, low strength tube. For this reason I decided to try to roll my tube using fiberglass resin as the adhesive. Alas, even with the new short-cut in mind, my patience was finally over-taxed. Even with the greatest of care to start the roll straight, it eventually wandered off center and defied every attempt to realign it. Discouragement dampened my enthusiasm and the dream began to fade.

The image of this pyrotechnic "holy grail" might have faded into complete oblivion, had it not been rekindled by the innovations of Dawntreader Pyrotechnic Specialties. They have recently added to their product line an impressive paper tube that has been custom specified for this fountain project. It costs $12.95 for the finished item, if you want a single use fountain tube. It consists of two tubes with 1/2-inch thick walls, one glued inside the other. Thus, if you want to achieve a little bit of reusability, you can purchase just one of the outer tubes and buy a new inner tube for each fountain, using them in the manner of my "disposable liner" concept. Either way, you can save yourself all the heart ache I went through, by using these newly available products from Dawntreader.

GOING DOWN BLIND ALLEYS

I suppose it would be instructive to describe some of the other blind alleys I went down before eventually finding success. Although the original description calls for ramming the tube full of composition and then drilling out a central core with a long auger bit, I felt that this was a rather inelegant way to do it. I determined to make tooling that would form the core with a spindle, using a cored ram in the fashion of a typical black powder rocket motor. Not having the means to make them nor the funds to custom order a machined spindle and ram, I had to improvise. I pride myself as a scrounger and found an oak stair rail baluster that had about the right taper I was looking for. By mounting this to an oak ramming base and sealing it all with several coats of polyurethane, I had what looked like a passable spindle. For the ram, I used 1 1/2 inch black pipe, fitted with interchangeable oak plugs. To save a thousand words, refer to the drawing for dimensions and details.

FINALLY MAKING THE FOUNTAIN

With the tooling done and a few tubes from Dawntreader, I was ready to scale the mountain and finally attempt to make the fountain. I first experimented with making the clay nozzle. I used a large splitting maul to strike the ram to compact the treated bentonite clay around the spindle base. Now this may seem like a simple task, but it's not one that can be undertaken casually. You either need a very brave friend to hold the tube and ram steady while you relieve all your life's pent up frustrations on them with the sledge hammer, or you need a sturdy jig to securely hold every thing still. I highly recommend the latter, since a jig will not curse at you when you strike a glancing blow with the sledge. My solution was to place my ramming base and tube assembly in a large metal bucket and then fill the bucket with potato sized rocks. This is then placed on a solid concrete floor that can handle the punishment. The ram and spindle seemed to work well until I tried to extract the spindle to inspect the nozzle. The extraction caused large chunks of the nozzle clay to come out with it and the oak spindle was deeply scarred. My conclusion was that even oak is just too compressible to serve as the spindle material.

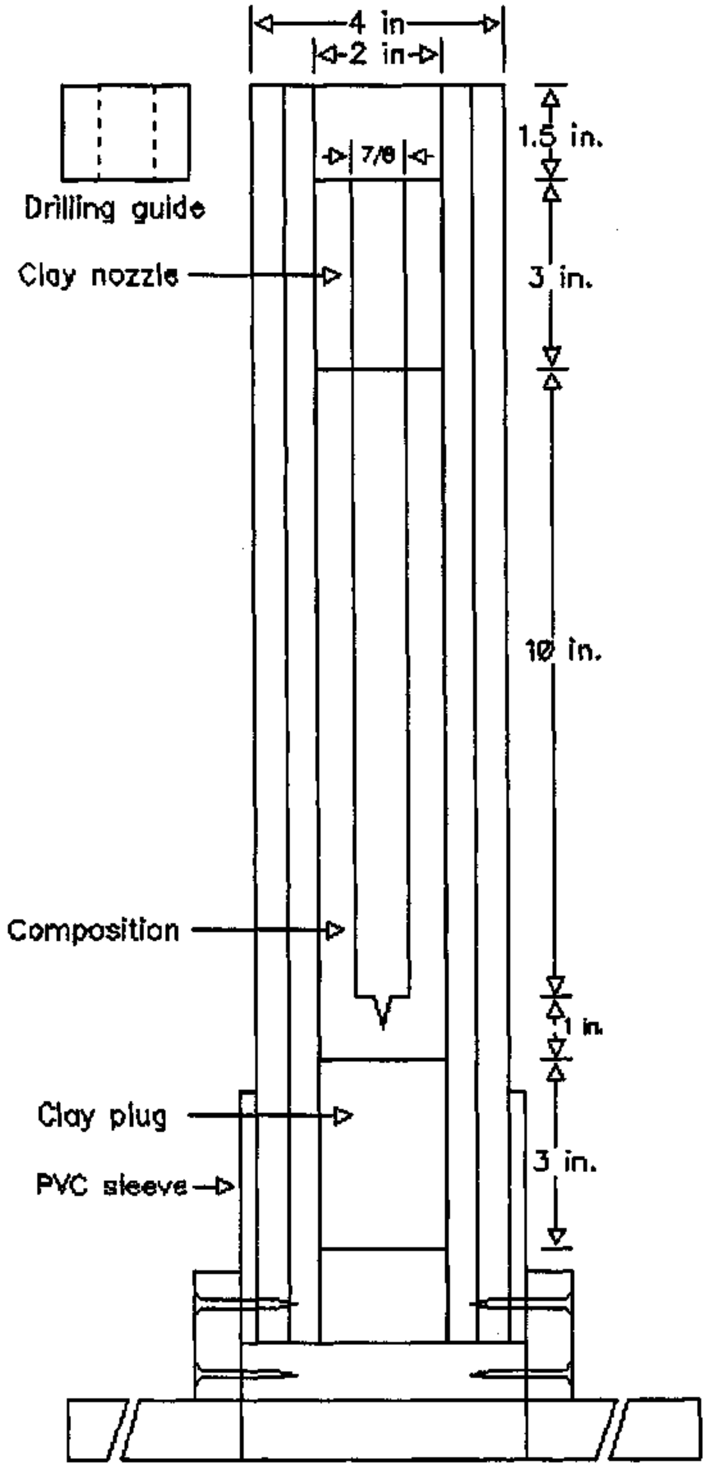
With the spindle idea dead, I headed off to Home Depot to buy a "Naileater" drill bit for drilling the fountain core. This is a 7/8-inch diameter by 18 inches long auger type bit that costs about $22. It's a man sized bit that requires a man sized drill with at least a V6-in. chuck. Perhaps I enjoyed this project so much because it so convincingly reinforced my masculine gender identity. Anyway, on to the next step, which is preparation of the fountain composition.

THE IMPORTANT STEEL FILINGS

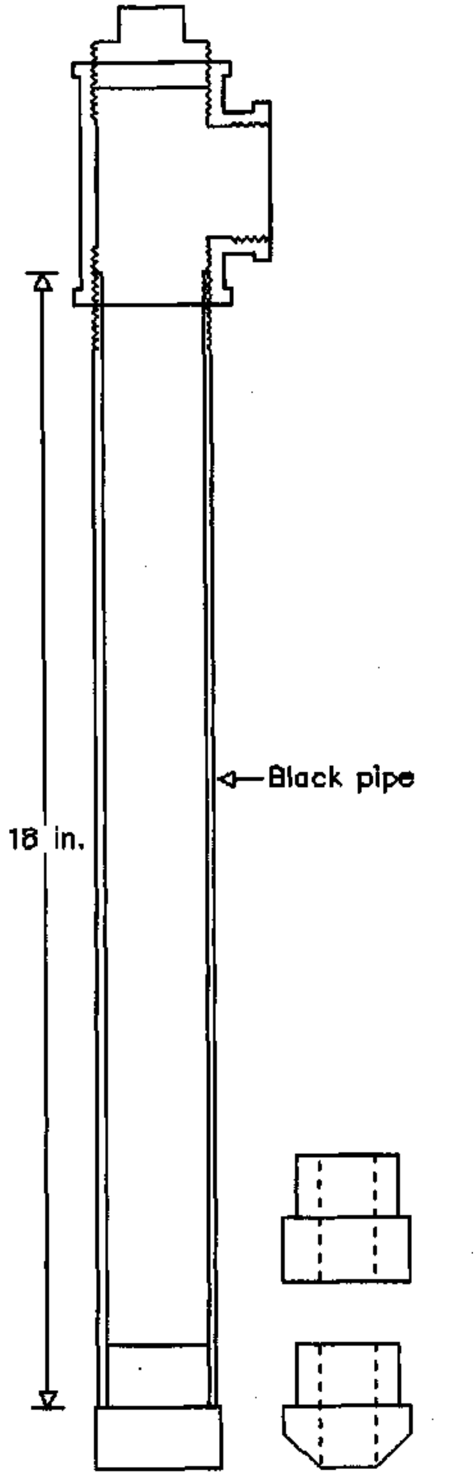
The steel filings, which give this fountain part of its name, are a very important part of the composition. High carbon steel between 8 and 30 mesh is called for. I used Skylighter iron borings (#CH8160), crushed and screened to +20 mesh. To this I added an equal weight of high carbon iron filings (#CH8156) screened to +40. If you want to avoid having your precious filings turn to useless rust in the fountain, they should be treated with linseed oil or paraffin. I had the best luck by adding enough boiled linseed oil to evenly coat all the particles, being careful to not over-saturate them. The filings are then sprinkled thinly and evenly on waxed paper to dry. Stirring and re-sprinkling after about 12 hours breaks up the clumps. They are not thoroughly dry until after 4 or 5 days.

GETTING THE MIX RIGHT

Mixing the composition is fairly straightforward. Needed is a good sized bucket to mix a batch of 1400 grams, composed of 1000 grams of potassium nitrate, 200 grams of powdered Red gum and 200 grams of treated iron. I simply screened the potassium nitrate and Red gum together at least three times and then folded in the metal filings with a spoon. The original recipe calls for 50% alcohol/water to dampen the mix prior to loading it in the tube to partially dissolve both the oxidizer and Red gum. This allows the mix to solidify into a good, hard fuel grain. I decided to try straight denatured alcohol so the solvent would evaporate faster and lessen the



Fountain and Base



Ram and End Plugs

likelihood that the potassium nitrate could attack the iron filings. A good way to add the solvent is to use a spray bottle and mist it on the composition while stirring. The mix will darken to a beautiful burgundy color as it becomes damp. The exact amount of solvent to add is a matter of judgment. You don't want it wet enough to become a lump of dough as you do when making a batch of stars. It should remain loose and crumbly, but will clump together with a little pressure. You definitely will want a lidded container to store the composition in while it is being rammed in the tube. The alcohol will evaporate very quickly without it and allow your mix to become crusty little rocks. This might allow voids to remain in the compressed grain of the fountain because dry composition will not compress well nor fuse into a solid matrix. The result could be an overpressure and explosion of the painstakingly built fountain, so it is important to make sure the comp stays damp until it's safely in the tube.

LOADING THE TUBE

Now the fun begins in earnest. To begin the loading of the tube, I place a l 1/2 inch plug of solid hardwood in the nozzle end of the tube and place that end down in my bucket, which is then filled with rocks. The plug will cause the nozzle to be recessed instead of flush with the end of the tube. I then ram the nozzle clay in three increments of 100 grams of bentonite each, adjusting until the nozzle clay is 3 inches deep. This is followed by 11 inches of dampened composition. I used a scoop whose capacity was a half cup to measure the increments of fountain comp. This amount compresses into about 1 inch of added length for each increment. Finally, the bottom clay plug is formed with three more increments of the wax treated bentonite, leaving 1 1/2 inches of empty space in the 20 inch tube.

The subject of ramming bears a little more discussion. As briefly mentioned above, I made my ram from 1 1/2 inch black pipe. The end which receives the blows from the splitting maul has a T-fitting threaded on it with a threaded plug at the very top to form a target for the maul. Although I have never seen a spark created from this practice, a safety minded person would probably cringe at the idea. Many good alternatives are available for minimizing the risks of this ramming procedure. First, cleanliness is always a good policy. I was very careful to avoid loose composition on top of the fountain tube, on the floor or anywhere near the ramming station. Another good possibility is to create an aluminum or other non-sparking metal plug to use at the top of the black pipe. Another excellent alternative is provided by Dawntreader Pyrotechnic Specialties. They can provide either of two versions of a hardwood dowel for the ram. Finally, the alternative I like the best is the one I settled on myself. I'm getting old and I got tired of wielding the splitting maul. A fairly simple modification to my rocket press allowed me to avoid ramming with the maul altogether and replace it with much safer hydraulic pressing. Anyone who has made their own hydraulic press with 3/4" threaded rods can extend the height capacity of their press by adding extensions to the rods. For less than $10, I purchased two more 3-ft. rods and two additional nuts. A single nut seems to hold the threaded rods together well enough to handle the stress of my 6 ton hydraulic jack. A picture of this modification and other parts of the project can be found on my web site at:
www.ctel.net/~dwilliams/clarksgiant/clarksgiant.html.

DRILLING OUT THE CORE

All that remains to be done is drill the core, mount the fountain to a base and add a fuse. To drill out the core, I clamped the now filled tube to my workbench in a horizontal position, with the nozzle end extending an inch or so over the edge. The 1 1/2" inch solid wood plug is then removed and replaced with one that has a 7/8-inch hole in the middle to act as a guide for drilling the core straight and centered. A tray is placed under the mouth of the tube to catch the clay and composition tailings that are produced by the drilling. It is very important to use a drill that gives variable speed control to drive the "naileater" bit. With very slight pressure on the drill trigger, the hole is drilled very slowly to avoid causing any heat buildup. A piece of tape, or other means of making a mark on the drill bit at 14 1/2 inches from the tip, will set the core depth just right at 10 inches into the composition. A good measure of patience must now be exerted to allow the packed composition to thoroughly dry. Approximately 2 weeks is recommended.

FINISHING AND FIRING!

Now a means of securely supporting the fountain must be devised. Remember that this piece is much like a powerful rocket motor turned upside down. I wouldn't be surprised if its thrust is in excess of 50 pounds and I wanted to make sure it stayed put while in action. Few things can dampen the thrill of lighting your first giant fountain like seeing it take out your neighbor's picture window. I built a base with crossed pieces of wood, somewhat like a Christmas tree stand. A 4-inch length of 4" i.d. FVC pipe is used to clamp the bottom to the wood base. The base has holes in it near the ends of the cross pieces where common tent pegs can be driven into the ground to anchor the assembly. Another easy possibility would be to drive a sturdy stake into the ground and simply use duct tape to attach the fountain tube to it.

A fuse can be fashioned several ways, remembering that this piece needs a good deal of fire to get it going. I used a 4 foot length of quick match with 6 inches of paper tubing removed from one end and 18 inches of it removed from the other end. Two six inch lengths of the bare black match are cut from the long exposed end and bound together alongside the remaining six inches to form a bundle of three pieces of parallel black match. For a little insurance, I painted the whole end with a thick solution of nitrocellulose lacquer and liberally dusted it with 3FA black powder. If you have any concern over the final appearance of your creation, the next step can be very effective. I like to use a large piece of left over Christmas wrapping paper to wrap around the entire outside of the fountain tube. This is secured with tape and the top is gathered together with string to act as a nosing to hold the fuse in place.

Many pyrotechnic hobbyists will tell you that a good deal of the fun is in the construction of their creations. After all, the show time is probably only 1/100th of the construction time for most of them. I have to admit, however, that the thrill of that little 1/100th is hard to beat. The occasion of lighting off my first giant fountain was no exception.

Upon lighting the fuse, my first worry was to quickly put a good deal of distance between myself and my potential ground bomb. Nervously, I waited while the fuse continued to burn. When the fire reached the quick match tube, the fountain sprang to life quite quickly with a 50 foot high shower of golden branching sparks. This grew steadily to about 70 feet in height with an accompanying throaty hiss like a rocket motor. The great shower of sparks filled my whole field of view and seemed to light up the entire valley. Even after the fountain had finished, the excited expressions of delight from the audience continued for some time. For me, this is probably the best part of it all. The memory of awestruck little faces and the glee in others eyes lingers long after the smoke has blown away. DW

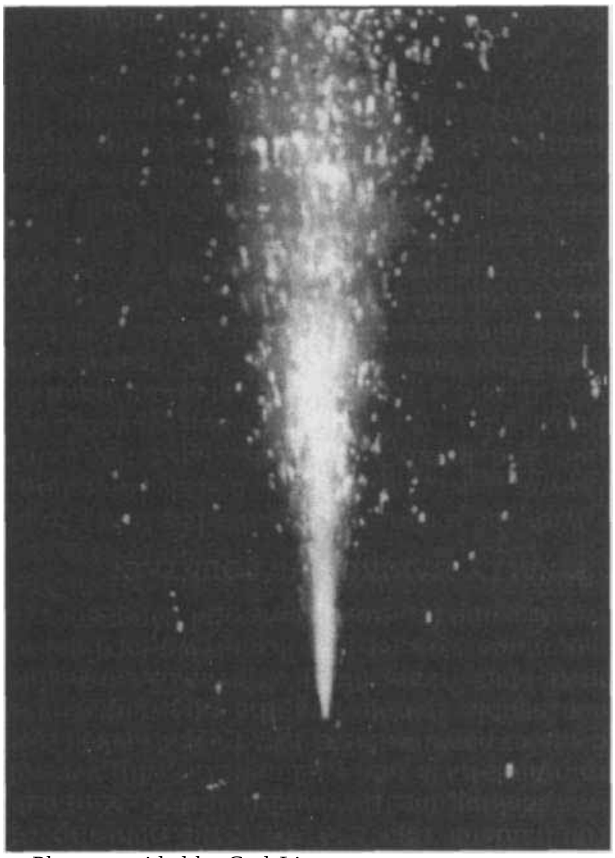


Photo provided by Carl Litton

CLARK'S GIANT STEEL FOUNTAIN II

Reaching for the Mark

by Carl Litton

The ***Giant Steel Fountain of Allen F. Clark.*** How many of us get an instant mental image, or maybe even a small twinge of excitement seeing that name? I would guess there is hardly a pyro enthusiast worth his/her salt in whom the fearsome image of the 100-foot-high column of flame and the savage throaty roar don't dance somewhere along the periphery of imagination. Described by Dr. Tennyson Davis, Professor of Organic Chemistry at MIT and Director of Research at National Fireworks, Inc. (ca. 1943), in his pivotal work *Chemistry of Powder and Explosives*[1] - one of the leading early modern treatises on the subject of energetic materials - this mammoth ground display device not only sits atop the class of gerbs and fountains, but quite possibly creates, by its very nature, a class unto itself.

It has been our purpose over the last year or two to spearhead a drive to resurrect this legend. Having finally found, after protracted searching, a tube winder both willing and capable of producing the monster tube necessary for this piece, we had a few hundred made and donated a number of these to several research-oriented pyrotechnicians interested in this unique class of big-bore monster fountains, among them, the worthy Mr. Dan Williams of Windham, Maine. Although the record of several failed attempts to construct CGSF (along with the usual sporadic, unverifiable, anecdotal claims) may be found in the lore and literature, on the evening of April 2nd, 2001, Dan Williams became the first researcher of the modern era to document for publication a successful burn of the Giant Fountain. The experiments and trial were chronicled in his fine article featured in the July 2001 anniversary issue of this newsletter and the photographic record may be seen on his website

www.ctel.net/~dwilliams/clarksgiant/clarksgiant.html

Not only a supremely resourceful hobbyist, exacting technician, and generally good guy, Dan is arguably among the very best teachers of pyro art and craft on the scene today, and his well-known website contains a wealth of extremely useful information of which I'm sure a great many of us have availed ourselves at one time or another. With his approval, this may be considered part 2 of the series, reporting the findings of current research into the formulation and construction techniques for Clark's Fountain. This article makes public the results of our recent modifications to the original procedure (both pressed and rammed), various special effect formulations we have tested successfully in our field trials at this year's *Florida Fall Fireworks Festival* gathering of the Florida Pyrotechnic Arts Guild, and our achieving of the grail of giant fountain research: the 100-foot-high fire column of legend.

Our group recorded its first successful burn over Memorial Day weekend 2001 in Shreveport. This piece was built almost completely in accordance with the original specifications: hand-rammed with a heavy sledge and wooden dowel and using cast iron turnings of 8-40 mesh as the metallic component of the fuel. Our only deviations were the use of a 16-lb. sledge in lieu of one weighing 15 pounds[2] and a greater overall bore depth to facilitate complete ignition of the fuel grain along its entire length at the outset of the burn. A small group witnessed the burning of this piece, which, at the pinnacle of its breath-taking splendor, reached a measured height of between 75 and 80 feet. Since then, we have devoted our efforts to observing and recording the effects of various modifications to the fuel mixture to produce some interesting special effects in the flame and to finding ways to increase the savage ferocity of the display in pursuit of the full 100-foot fire column necessary for complete satisfaction.

FINE TUNING THE DESIGN

Early experimentation revealed several stumbling blocks in the original design as set forth by Davis[3]. Though not mentioned in the instructions, the incorporation of paraffin wax at a rate of 10% into the bentonite for the upper and lower end plugs appears to be necessary in order to prevent a high percentage of blown nozzles. Our work has also shown that paraffin is superior to oil in protecting the metal fuel particles from premature oxidation and is optimally incorporated at a rate of 8% added in addition (over) the total weight of metal for coarse fuels, amounting to 16g with every 200g of metal fuel - the quantity required for constructing a single fountain. This must be reduced to around 4-5% for fine material to prevent clumping. The recommended 10-inch overall core depth is not sufficient to engage the entire fuel grain in the burn at once and results in considerably lower flame height. We have settled on 16 inches, which dramatically increases flame height while shortening the burn duration and ail-but eliminating the lengthy low "after flame" accompanying the 10-inch bored pieces.

The choice of wetting solvent is particularly important, affecting as it does both the intimacy of mixing and the drying time of the completed piece. We have found that the use of a solvent with any water content at all results in grossly protracted drying times for this piece, containing as it does on the order of a kilo and a half of comp. No less than one month of drying seems to be required to give a fountain capable of its full potential when an aqueous solvent system is used. We normally recommend the use of 100% 2-propanol (iso-propyl alcohol - b.p. 82.4°C / vapor pressure[4] 33 / evaporation rate[5] 2.8) for the average hobbyist. The comp will remain tractable long enough to complete the loading in moderate weather and the piece dries completely in 2 1/2 to 3 weeks. We recently employed a forced-drying method out of necessity on the four fountains we prepared with isopropyl alcohol for the FPAG *Florida Fall Fireworks Festival* by directing a box fan on high setting down the bore round-the-clock for 8 days. Consensual agreement of observers questioned was 45-55 feet of flame height on three of the pieces and 65-75 feet on the fourth. An additional 15-20% increase in performance is obtained by allowing passive drying for the full 3 weeks. For the advanced worker with both the necessary skill and all the proper tools to accomplish the loading quickly and correctly, the solvent of choice is 100% absolute methanol. Methanol better dissolves the ingredients for more intimate mixing and with a b.p. of 64.6°C (vapor pressure 16.8 / evaporation rate 4.6), gives a finished piece that will dry in just a few days. Conversely, the comp wetted with methanol is a serious challenge to load before it dries out, producing crusty lumps that can leave voids in the fuel grain and result in an explosion. But we did use methanol as the solvent in our most recent piece that finally broke the long-sought 100-foot barrier.

The choice of ramming *vs.* pressing appears to be mostly aesthetic and a matter of the preferences and proclivities of the technician. Most of our test pieces have been hand-rammed with a 161b. John Henry and either an aluminum or hard maple dowel. The results, as you may have seen, were most gratifying. Recently, through the generosity of Mr. Robert Snow of Memphis, we were able to press pieces in the traditional manner of the rocket makers, obtaining about 3000 pounds of force per square inch on his large press. The result was not distinguishable from pieces rammed with a heavy sledge swung from the elbow (not the shoulder) five times per increment of comp[6]. Four to five large handful increments are all that are generally necessary by either method. For the exacting technician who prefers pressing, a most impressive 8-piece set of tooling has been created by the redoubtable Mr. Rich Wolter of Montello, WI[7], toolmaker extraordinaire, friend, and exceptional gentleman, for use with our MONSTER CGSF tube. This tooling may be seen at:

http://www.dawntreader.net/shoppinacart/Daper.html.

The 13-pound set is a truly singular example of the toolmaker's art.

For rammed fountains, we created a support jig out of two cinder blocks stacked with the openings facing upward and braced on all four sides with 4-inch thick solid cement blocks stacked three high. This ramming station is situated on a smooth level concrete surface. The tube is fitted inside of a piece of 4-inch PVC pipe 18-inches long and this assembly is inserted upside down into one of the openings in the stacked blocks and braced in the vertical position with a triangular wooden shim. The boring out of the core is commenced immediately upon completion of the final clay plug. We favor the use of a long 7/8" auger bit in a slow speed (<100 rpm) heavy VSR drill. The usual warnings apply to drilling and great care should be taken if a steel drill bit is used. We have recently had a long spade bit made for us out of brass.

VARIATIONS ON A THEME

The original composition formulation is: 5 parts fine potassium nitrate, 1 part fine-powdered red gum, and 1 part 8-40 mesh cast iron turnings. The result is nothing short of awe-inspiring, but as a scientist by training and adventurer by nature, I could not help wondering what effects other formulations might have on the display. It came to my attention that all efforts to incorporate titanium into the fuel mixture had led to catastrophic failures of similar pieces[8]. This inspired me to attempt the inclusion of more exotic metal fuels in the construction of a CGSF. Having just been invited by my good friends Rich and Carol Ogden of Lake Butler, FL to attend the FPAG *Florida Fall Fireworks Festival* as a vendor during the first week of November 2001, this seemed the perfect forum for public trials of the new formulations I had in mind - wonderful that is, if they succeeded; abysmally disastrous if they failed. At any rate, they did succeed, much to the delight of the crowd. The table below lists the formulations I used for these pieces:

A "basic iron mix" (BIM) was prepared and used in all pieces so that they might still be rightly called Giant *Steel* Fountains, as follows:

MATERIAL	WEIGHT IN GRAMS	CONTAINS 8% PARAFFIN COATING
8-40 mesh cast iron	815	yes
15-40 mesh chilled iron	389	yes
Medium iron powder, 80-100 mesh	50	yes
Cast iron borings, Skylighter	50	yes
Ferrotitanium 100 mesh	10	no

1,400 grams of composition were mixed for each piece, containing: 1,000 grams of potassium nitrate, 200 grams of red gum, and the following metal fuel mixtures:

NO.	ITEM #1	ITEM #2	ITEM #3	ITEM #4
3	BIM216g			
4	BIM 108g	417 Stainless Steel flakes 90g	Zinc dust lOg	
1	BIM 198g	Magnesium chips* 5-18 mesh 11*	Sponge titanium 40-60 mesh lOg	
2	BIM lOOg	417 Stainless Steel flakes 75g	Aluminum mix** 15g	Zinc dust 15g

* 10% paraffin coated
** Equal weights: Transmet K-107 firefly flake, 20-micron spherical, and bright coarse flake aluminum

The results were most spectacular; photos are going up on our website at this time:

www.dawntreader.net/fpag2001 .html.

SIZE DOES MATTER

Having become, in the traditional manner of men, somewhat obsessed with the length of my column, I established a sort-of self-imposed mandate for the achievement of 100 feet of flame within 90 days. One of the cornerstones of my philosophical approach to life has always been to work smart - not hard. So, after considering the various options open to me to achieve my goal, I applied Occam's Chainsaw to the lot and opted for the simplest: reduction of the diameter of the nozzle choke by *lA* of an inch, requiring only the purchase of a 5/8" auger bit. True to form, the Law of Parsimony held sway and the lovely slim scintillating column of fire and sparks proceeded just past the 100-foot mark as triangulated against nearby large trees. The 7-part formulation for the metallic fuel component used was as follows:

BIM	75g
Magnesium chips* 5-18 mesh	11g
Sponge titanium 40-60 mesh	10g
Zinc dust	15g
Sparkler grade steel - Skylighter (coated) Aluminum mix**	15g
Fine copper powder	10g

* 10% paraffin coated - *Firefox brand*

** Equal weights *Transmet* K-107 "firefly" flake - *Skylighter*, 20-micron spherical, and bright coarse flake.

The spectacle was beyond words, so let's hope the pictures turn out OK. See the website for them as they become available.

CONCLUSIONS:

Big-bore giant fountains offer exceptionally fertile ground for radical experimentation and we have just begun to scratch the surface of possibility. The MONSTER casing appears to be able to withstand almost anything up to a small tactical nuke, thus allowing a wide range of formulation choices. In addition to the variations in the metal fuel described above, there is an open field for experimentation with the oxidizer system, using other nitrates for color or stronger oxidizers for even more intensity and so forth. The builder should let his imagination be his guide and common sense his handmaiden, as it were. Safety is all the more important a consideration in a piece of this magnitude - Clark's Fountain is not to be trifled with and certainly not for the faint of heart. Pleasant ramming to all[9].

[Editor's note: It is our policy to not publish formulations that require ramming of titanium-containing compositions. We do not endorse the 7-part formulation shown in this article.]

1) Davis, Tenny L., - *Chemistry of Powder and Explosives* - (New York, John Wiley & Sons Inc., 1943).

2) This may represent a typographic error in the original text, as we have found these hammers are generally manufactured only in 8, 10, 12, 16, and 20 pound weights.

3) Davis obtained the procedure from his associate at National Fireworks, Allen Clark - hence the name of the piece.

4) Kpa @ 25°C

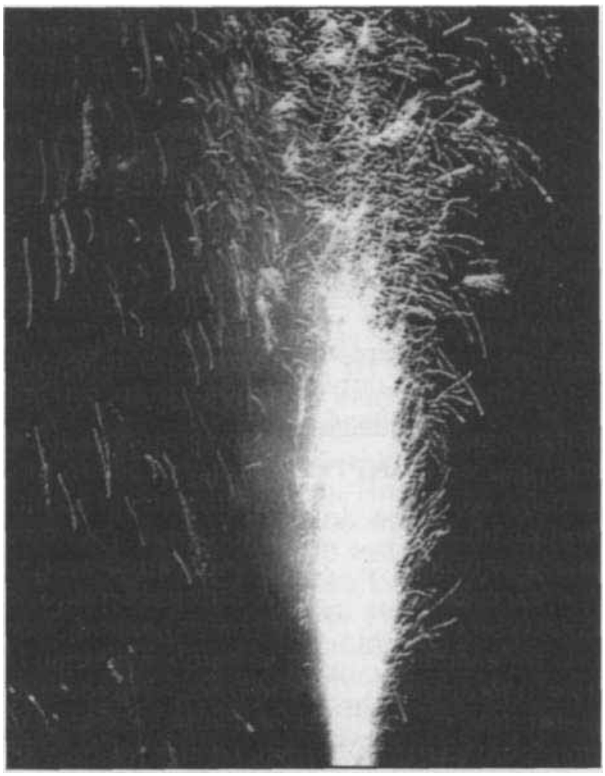
5) Unitless comparison statistic to compare the evaporation of liquids relative to butyl acetate (assigned value of 1). Larger number = faster evaporation.

6) NOTE: the use of lightweight 8 and 10 lb sledges is not recommended and has led others not only to destroyed ramming dowels from over-swinging but to disastrous CATO of the piece from incompletely consolidated fuel grains.

7) You may contact Mr. Wolter and his delightful wife Claudia by email at: wolter@merr.com. Their *Pyro Tools* catalogue is a must for the serious hobbyist.

8) Verbal communication from my friend and colleague the inimitable Mr. Harry Gilliam of Skylighter, Inc. in September of this year.

9) Special thanks to the gracious Bullock family for their kindness and hospitality, to Rich and Carol Ogden, Fred and Lee Partin, and Karol Collins of the FPAG, to Rich and Claudia Wolter, to Chris Kleinrichert (and Ethan) and Caroline and her husband for photography and support, to Bob Snow, Dan Williams, and of course, to Harry Gilliam. CL



THE MAGNESIUM + CAB-0-SIL FIASCO

By William D. Jones, Dept. of Chemistry, University of Rochester

I am writing concerning the article that appeared in AFN in November, 2000 by Lloyd Sponenburgh in which magnesium was being mixed with 'inert' cab-o-sil. Since cab-o-sil is a form of silica, and can be heated to thousands of degrees in air without combustion, it is assumed to be a safe ingredient to mix with other materials. However, I wish to relate an interesting story that may make you re-think this commonly accepted property.

1 have seen a demonstration done in chemistry class in which two large blocks of dry ice and a 3 ft. piece of magnesium ribbon are used. The ribbon is low surface area by pyro standards (1/8" x .030"), but it can be lit with a hot flame and will burn brightly at a rate of a few inches/second. In the demo, a golf-ball sized indentation is made in one of the blocks of dry-ice and the magnesium ribbon balled-up and placed in the indentation. The ribbon is then lit with a torch and the second block of dry-ice placed on top. Rather than extinguishing the flame, the entire stack of blocks lights up like a lantern, as the magnesium 'burns' and produces the bright light inside. Upon separating the blocks following the reaction, a black 'egg' of carbon is found in place of the magnesium ribbon, which contains a white powder (magnesium oxide) when broken open. It may not come as a surprise to some of you that carbon dioxide does not extinguish a magnesium fire. This is one reason why the Air Force has trouble extinguishing burning planes!

The chemical reaction that occurs is:

2 Mg + CO2 --> 2 MgO + C(graphite)

This reaction is exothermic by -193.4 kcal/mol[1], which is why the magnesium continues to 'burn'.

Now consider the same type of reaction with cab-o-sil, which is comprised of silicon dioxide. Could magnesium be capable of reducing silicon dioxide to silicon? Examination of the related equation and thermodynamics answers this question:

2 Mg + SiQ2 --> 2 MgO + Si

This reaction is exothermic by -69.7 kcal/mol. The negative heat of reaction indicates that indeed the reaction of silica and magnesium can produce heat, which is perhaps why the magnesium appeared to 'burn' in Lloyd's case. Perhaps once the material blew out of the mill, normal combustion with oxygen did take over, leading to the blinding flash and UV radiation burns. Normally, sand is safe to use on metal fires, but in this case I suspect that the fine particle size of both the magnesium and the cab-o-sil led to the ability for the reaction to start with mixing.

The moral of the story? It is probably safe to assume that mixing finely divided metal powders with cab-o-sil is NOT safe. A quick calculation of potential reactions and their exothermicity is worthwhile. Further careful experimental testing of the above hypothesis might be in order.

(1) Calculated using Heat of Formation data from: H.Y. Afeefy, J.F. Liebman, and S.E. Stein, "Neutral Thermochemical Data" in NIST Chemistry WebBook, NIST Standard Reference Database Number 69, Eds. W.G. Mallard and P.J. Linstrom, February 2000, National Institute of Standards and Technology, Gaithersburg MD, 20899 (http: //webbook.nist.gov).

HAPPINESS

The following is from the Chinese writer Chin Shengt'an:

"I am drinking with some romantic friends on a spring night and am just half-intoxicated, finding it difficult to stop drinking and equally difficult to go on. An understanding boy servant at the side suddenly brings in a package of firecrackers, about a dozen in number, and I rise from the table and go off and fire them: The smell of sulfur assails my nostrils and enters my brain and I feel comfortable all over my body. Ah, is this not happiness?"

Jack Leonard

THE EFFECT OF VARYING REACTANT COMPOSITIONS ON THE SENKO HANABI REACTION

By Mark Anticole

Ask someone to imagine fireworks and they'll often picture giant explosions and huge thunderclaps. Senko hanabi sparks, however, are a much different type of firework. Where typical pyrotechnics are larger-than-life, senko hanabi is understated. Where typical fireworks are aggressive, senko hanabi is gentle. Where typical fireworks are ear shattering, senko hanabi is silent. It is this contradiction that makes senko hanabi such a wonderful field of study. Senko hanabi seems relaxed, almost meditative. And the technique and craftsmanship required to produce the golden branches is not out of league with other Japanese traditions of flower arrangement, and Haiku.

I teach chemistry at C. Milton Wright High School in Bel Air, Maryland, and this project was inspired by a laboratory experiment that was part of a graduate level chemistry course offered at Miami University. (That course was presented by Ken and Bonnie Kosanke, and Paul Smith during the Summer of 2002.) This project delved into the ratio of the three sisters of senko hanabi (charcoal, sulfur and potassium nitrate) and attempted to find an ideal ratio to produce the most and longest lasting sparks, in addition to the most branching.

CHEMICAL BACKGROUND:

Although still not completely understood, senko hanabi reactions are generally thought to follow the following reactions.[1,2]

(1) $8\ KNOs + 11\ C + 4\ S \rightarrow 2\ K_2S_2 + 2\ K_2CO_3 + 4N_2 + 9\ CO_2$ + heat

Shimizu suggests that an excess sulfur will react to form more potassium disulfide

(2) $2\ K_2CO_3 + 5\ S \rightarrow 2\ K_2S_2 + 2\ CO_2 + SO_2$ + heat

The potassium disulfide then reacts with oxygen from the air to produce potassium sulfate

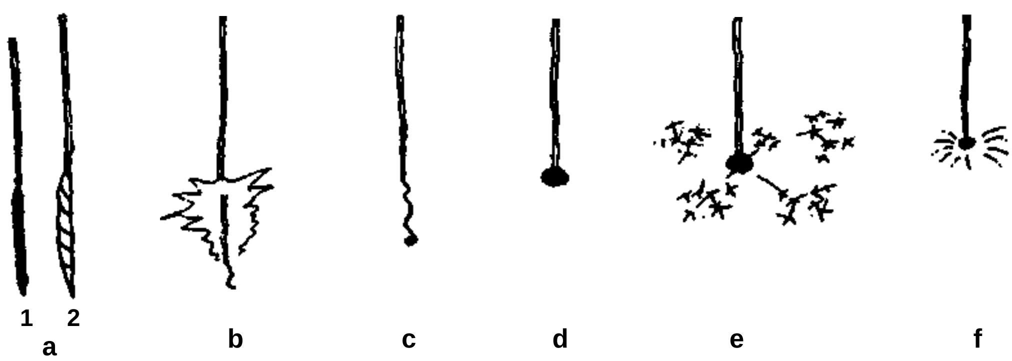
(3) $K_2S_2 + O_2 \rightarrow K_2S + SO_2$ + heat

(4) $K_2S + 2\ O_2 \rightarrow K_2SO_4$ + heat

While not understood, the charcoal is thought to react with the potassium sulfate in some way to produce the characteristic branching sparks of senko hanabi.

(5) $C + K_2SO_4 + (?) \rightarrow$ branching sparks

It is well known that the type of charcoal used is important. Besides the carbon, there are other compounds in the charcoal, both organic and inorganic that aid in the production of the branching sparks. Also important is the type of tissue paper used in forming the tiny senko hanabi fireworks, as this pyrolizes to produce additional ash and charcoal. I expect the toothpick used as support for the tissue paper, also serves as an important source of carbon for the sustaining of the branching sparks.



(a) Two typical forms of senko hanabi. (b-g) The typical senko hanabi process [2]

The senko hanabi process (see Figure 1) starts with the wrapping quickly burning, leaving a glowing ember, which then pulls up into a glowing hot ball of dross around 860° C[2]. It then enters a period of large branching reactions, followed by a period of finer, non-branching sparks as the temperature rises to around 940° C.[2] Finally, as the temperature drops, the reaction slows and eventually stops.

A PROCEDURE FOR FORMING SENKO HANABI FIREWORKS:[3])

1. If necessary grind up charcoal into powder using a mortar and pestle.

2. Weigh out the charcoal, sulfur and potassium nitrate into the desired ratio to make approximately 2 grams of the mixture.

3. Thoroughly mix the reactants in a mortar and pestle to break up any lumps. Due to the pyrotechnic nature of the reactants use extreme precautions. (Leather gloves, safety shields, gentle pressure, etc.) Clean mortar and pestle between trials.

4. Cut five strips of tissue paper approximately 3/4" by 2". Avoid too much paper, as that will weigh down your dross and it will fall off.

5. Moisten the toothpick and roll the tissue paper around one end, leaving a 'v' shaped trough. Add around 0.1 grams of senko hanabi mixture evenly along the paper, avoiding the toothpick. Gently continue to roll the paper around the mixture until it is completely contained. Repeat for the other four samples.

6. In the fume hood, suspend the senko hanabi from a small clamp on a ring stand. Make sure something like a ceramic tile is underneath it to catch any falling dross.

7. Ignite the test senko hanabi and observe spark production, branching, and length of sparking. Repeat for the other four samples.

8. Repeat steps 2-7 for any other desired ratios of sulfur, charcoal and potassium nitrate.

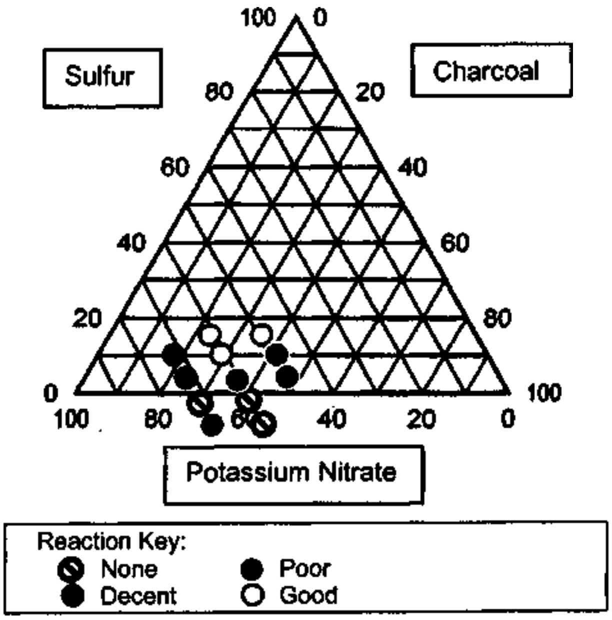
9. Dispose of any left over mixture properly.

DISCUSSION:

From working with senko hanabi over the summer, I expected to see observable differences between the different compositions. From my work with sulfur compounds and the reading I've done on senko hanabi, I expected sulfur to play an important part in the dross formation and theorized the higher sulfur ratios would favor the reaction. I wasn't sure what ratios would increase sparking or branching.

After creating enough compositions to get a better idea, I graphed the data on the triangle diagram (see Figure 2) and realized that I was getting close to an ideal mixture. Sulfur did seem to play an important role. Without it, the embers simply burned out or fell off. Only one of the four compositions with lower than 20% sulfur even had a 'poor' result. The others failed completely. All the compositions at 20% or above that I tested produced some sparks; some more than others. Large amounts of charcoal seem less important. At 20% or more most were 'poor' or 'no' sparking. Yet, at percents as low as five, there seemed to be enough to supply the reaction with the charcoal and other organics needed to start the sparking. Potassium nitrate seemed the least critical of the three. At the three different percents, I had a relatively 50-50 success more dependent on the other two components.

Figure 2. Triangle Diagram For Composition Ratios:



PROJECT RESULTS:

%KN03	%C	%S	Observations:
60	20	20	Flared out quickly, but ember burned out most of the time. Some dross formed occasionally, but little sparking was observed. **Overall: poor.**
60	10	30	Flared up and formed dross, but little sparking. When redone with increased airflow, good sparking was achieved, with some branching at the beginning. **Overall: good.**
60	15	25	Flares out, but pulls into dross. Some branching, but plenty of sparking. Sparks continue for a long time (up to 1 minute) and burn up a good part of the toothpick. **Overall: good.**
60	25	15	Burns quickly and flares apart, but no dross forms. Ash cools and falls off. **Overall: none.**
60	30	10	Burns quickly and flares apart, but no dross forms. Ash cools and falls off. **Overall: none.**
50	25	25	Flares out, and forms ember, but only pulls up into dross around 50% of the time. Some sparking apparent. **Overall: poor.**
50	20	30	Flares out, but forms dross. Some sparking occurred before dross completely pulls up. Branching visible in the early stages of the reaction. Decent length of time. **Overall: good.**
50	30 .	20	Little or no dross formation. Minor sparking if any. **Overall: poor.**
70	15	15	Quickly flares out, ember does not pull up into dross. Eventually falls off. **Overall: none.**
70	20	10	Flares out, embers likely to fall off. Remaining ember occasionally pulls up for a little sparking. **Overall: poor.**
70	10	20	Flares, but dross immediately pulls up behind reaction. Often falls off, but will spark at top if it makes it. Excellent branching occurs when it works. **Overall: decent.**
70	5	25	Similar to above. Dross chases the ignition up the tissue paper. Falls off often, but will spark at the top. **Overall: decent.**

In retrospect, I would've liked to focus more on the 60% KNO3 : 30% S : 10% C mixture, perhaps make 5% differences all around that point to see where sulfur starts hindering the reaction.

There are many variables that are difficult to control. As stated earlier, the technique of creating the sticks is difficult to do consistently and could open up other avenues of research. For example, I did notice when I left some of the tissue paper empty at the bottom of the senko hanabi I tended to get better drossing. It seemed to give the budding dross a better chance of making it up to the stick. Air flow was also an issue. I found turning on the air flow in the fume hood dramatically increased my successes. Since oxygen is a reactant, this makes sense and the increased air flow did not seem to break the fragile embers. Even the placement of the mixture inside the tissue paper could be studied. I put some around the toothpick and am still undecided regarding whether it hindered or helped the reaction. I've considered the possibility of using two different mixtures in one wrapping; one with a higher sulfur content at the bottom to expedite dross formation and a higher charcoal content towards the top to encourage branching.

CONCLUSION:

Senko hanabi still remains a very elusive reaction. Mechanisms aside, there are enough variables to keep a person busy for quite some time. The reproducibility of techniques is a serious issue that needs to be addressed by each new experimenter. I feel confident that I am approaching an ideal ratio of components and have several avenues of exploration to further refine the technique itself. Senko hanabi is not an easy process to perfect, but then again few things in life worth having are.

I'd like to thank the Kosankes for their guidance and efforts throughout this process.

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MA

LOW POWER FM & FIREWORKS

By Ken Barton

Low power FM broadcasting, also known as Microbroadcasting, has many useful applications in today's society. Examples of such transmissions familiar to some of us are done by university campus radio stations, broadcasts done for the hearing impaired in theatrical presentations, and those done by realtors to transmit information to clients who can simply park near an advertised home and listen on their auto radio to hear the features of the home. Drive-in theaters and churches have also used this concept, and even exercise clubs have recently used these to entertain, as well as provide in-house advertising to their clients as they do workouts. Recent developments in inexpensive microprocessors and precise frequency control systems, as well as some relaxation of enforcement of the FCC rules, have allowed the average consumer to purchase his own small non-licensed FM broadcasting station and be on the air himself in hours. His inexpensive equipment is now capable of producing high quality, stable, professional sounding signals rivaling that of local broadcasters.

The purpose of this article is to investigate and explore options that could be applied to fireworks presentations or demonstrations in both the professional, as well as fireworks club circles. The author will explore the equipment available to do such broadcasting and its features, its capabilities, as well as legal issues in the operation of such units.

In December 1998, the Pyrotechnic Artists of Texas utilized Low Power FM to broadcast a Christmas fireworks program of about 20 minutes in length to its membership, rather than set up an elaborate public address system. The transmitter and antenna were borrowed from DARS, The Dallas Area Rocket Society, who had used this unit quite effectively in past rocketry presentations. The PAT program was pre-recorded on compact disc, and included introductions of the club, as well as Christmas music to accompany the fireworks. PAT members were advised to bring FM "boom-boxes", or small portable FM personal radios to hear the program, or they could simply turn up the volume on their auto radios and sit nearby in lawn chairs to enjoy the program. The transmitter itself, microphone, mixer panel and CD player were all placed near the B firing line and firing control systems, where the pyrotechnicians themselves could control the progress of the audio program as well as the firing of the effects. The broadcast delivered was clear and crisp and I found the equipment very stable, and the quality to be that of a commercial station. Although we had the option of a stereo broadcast, we chose to transmit in monaural.

Such broadcasts could also have been done from a barge, an island, or a rooftop of a tall building, and the signal could have been received on a conventional FM receiver at a strategic location and be then put on a PA system. This received transmission could also be re-broadcast by a local broadcasting station, for the audience's enjoyment. Transmission on common FM frequencies also allows the program to be received by the shooters of the event, who might carry personal FM receivers with small "earbud" earphones worn beneath ear protectors. This would allow them to hear the program's progress while firing shells in close proximity. There are many options to fireworks Microbroadcasting yet to be explored. Some experimentation has also been done using broadcast DTMF audio tone cueing of the firing of rocketry by the Dallas Area Rocket Society organization. Still other ideas involve FM subcarrier transmissions called SCA, that cannot be heard by the listener but can be decoded with special circuitry at the receiver, for use as cues for choreographed fireworks presentations.

The FM Transmitters & Accessories

We will discuss equipment produced by Ramsey Electronics of Victor, NY, as this was the equipment used for the broadcast previously mentioned. Ramsey offers equipment available for use on 12 Volts DC, as well as 120 Volts AC. The 12 DC operation of some of the transmitters as well as the accessories available, allows remote operation of the broadcast equipment on a 12 volt lead-acid cell such as a garden tractor battery, for many days. These transmitters are offered both as kits designed to save the builder money, as well as in fully wired versions for those who wish not to tackle electronics kit building. The kit systems allow expansion of the system in much the same manner as a component stereo system, and this allows the user to utilize components he may already have, such as mixer panels or equalizer units. Both transmit units allow easily changing the broadcast frequency precisely anywhere in the common FM band between 88-108 MHz, by either front pan-el buttons, (FM-100), or by DIP switches on the kit transmitter, (FM-25A).

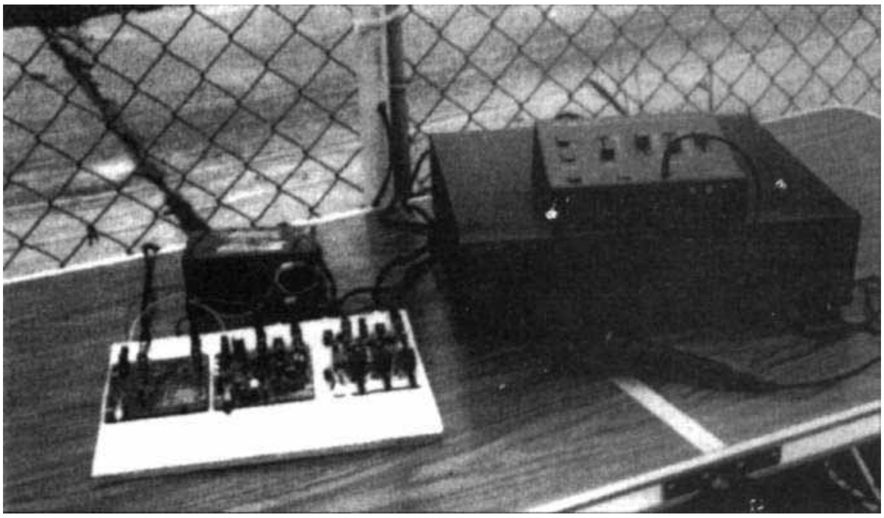
I purchased the Ramsey kits described and found them to be relatively easy for nearly anyone to construct, even those of limited electronics knowledge, if the directions are carefully followed. The manuals that come with these kits are very well detailed and each assembly step includes a "check-off as you go" pattern of assembly which begins by familiarizing the reader with the parts included with the kit. The builder begins with an inventory of the parts, and then the manual goes onward to include detailed information of how the system functions, a pictorial diagram of the parts placement, a clear two page schematic diagram, and troubleshooting information on how to correct problems if they should occur. An inexpensive repair service is also offered should the worst happen, and the builder finds his unit will not operate after completion. In all cases, only a voltmeter is required to do simple adjustments in final assembly, and great detail is given regarding these few adjustments. The Ramsey kits remind me of the Heathkit concept that was so popular many years ago, and is also based on high quality Amateur Radio kit equipment, as Heath once produced.

The Transmitters

Author's Note: Transmitters or their accessories that are of the higher power capabilities, that could be interpreted by the Federal Communications Commission as being "illegal", are marked with an asterisk (*) and italics. (More detail on legalities later in text.)

The FM-100 transmitter, (Kit/Assembled version), is advertised as "The Super Pro FM Stereo Broadcasting Station", and has built-in mixing capabilities for both a microphone and other line level inputs such as a CD player, MD player, or tape system. This unit also has a digital frequency display on the front panel, and comes with a rugged metal case. This unit is intended only for 120VAC operation, but could be powered by a generator or a DC to AC power inverter for remote operation. This unit sells for $249.95.

A *High Power** "Export only" version of this same unit in kit form is $329.95. A *High Power** "Ex-port only" version of this same unit fully assembled is $399.95. Both the above units require the purchaser to submit a statement that he/she will export these units out of the United States.



The FM-25 Kit Transmitter, built by the author and discussed in detail here, operates on either 12VDC or 120VAC (AC adapter/-plastic case included). This unit is a very sophisticated quartz controlled microprocessor-based transmission system. Its user selected broadcast frequency is phase-locked loop frequency synthesized, and falls well within the FCC guidelines for FM frequency stability as well as transmission bandwidth. This FM Stereo transmitter is of the lower power category, but it's not a toy nor cheaply made. It comes with a plastic case enclosure and simple whip antenna, and all hardware to produce a nice looking unit that measures 5 1/4" x 5" x 1 1/2". Equipment not supplied to build this kit: a small soldering iron, solder, small needle nose pliers, diagonal wire cutters, and the author highly recommends obtaining a magnifying glass, due to the tiny markings on the parts. De-soldering braid is also recommended to remove a part that might find its way into a wrong location and must be removed later. Price of the kit is $129.95. The kit manufacturer's estimated completion time for a Beginner 10 hrs, Intermediate 6 hrs, and an advanced builder, 4 hrs. The printed circuit board that comes with the unit is very well marked, and a mechanical parts layout drawing is also included for ease of assembly. Take your time building this unit, read the instructions carefully, and don't rush the completion. You'll have an excellent working system you will be proud of. The current consumption of the transmitter was checked and found to be approximately 80 milliamperes, and would operate many days on a small garden tractor 12volt lead-acid battery such as the type used with many professional firing systems.

Transmitter Accessory Options

The Ramsey STC-1 Audio processor, companion option to the FM-25A, allows the broadcaster to control and pre-emphasize Bass, Presence, and Brilliance to add a more pleasing sound with more punch to the transmitted audio signal. It features audio adjustable audio level clipping/limiting to reduce over-modulation distortion, and utilizes an elaborate Butterworth low pass filter to eliminate squeals or other noises generated by some inexpensive CD players and other sources that could cause irritating noises in the received signal. Again, this unit allows the transmitted audio to more closely approach broadcast quality comparisons. It sells in kit form for $59.95, or is available fully wired for $99.95 with case. This audio processor, like the transmitter, operates on 9-12VDC, and draws approximately 50 milliamperes of current at 12VDC as checked by the author.

The LPA-1 *RF Linear Power Booster Amplifier** is described as being a general purpose broadband amplifier that covers the incredibly wide range of frequencies from 100 kHz to 1GHz. When the LPA-1 is used with the FM-25A, the transmitted power of the FM-25A is increased substantially, approaching and perhaps exceeding one watt of output power for much longer distance FM transmission. Although one watt doesn't sound like much compared to a local station radiating perhaps 30,000 watts of power, this system has been used for broadcast coverage of entire islands in the Caribbean, using high gain, strategically placed antennas. The quality of the antenna is as important as that of the transmitter itself. Don't skimp on it, and don't rely on the small whip antenna included with the FM-25A to deliver large area coverage. It won't happen. Use a good external antenna (described next) for the best transmitter performance. Like the FM-25A kit itself, the LPA-1 kit has two options of power gain as described in the text. Again, it is suggested that you select only the transmit gain necessary to cover the intended broadcast area. Using more power than necessary may cause unintentional interference with others on the frequency selected.

The LPA-1 kit sells for $39.95 for the basic kit, and is a very simple unit consisting of only 27 components to be installed in the circuit board. Ramsey estimates the time required to build the unit as being 2.3 hrs for a beginner, 1.3 hours for intermediate kit builder, and 1 hour for the advanced builder. Like the other kits, follow the directions carefully, and you'll most likely have no problems with the assembly.

A Better Antenna

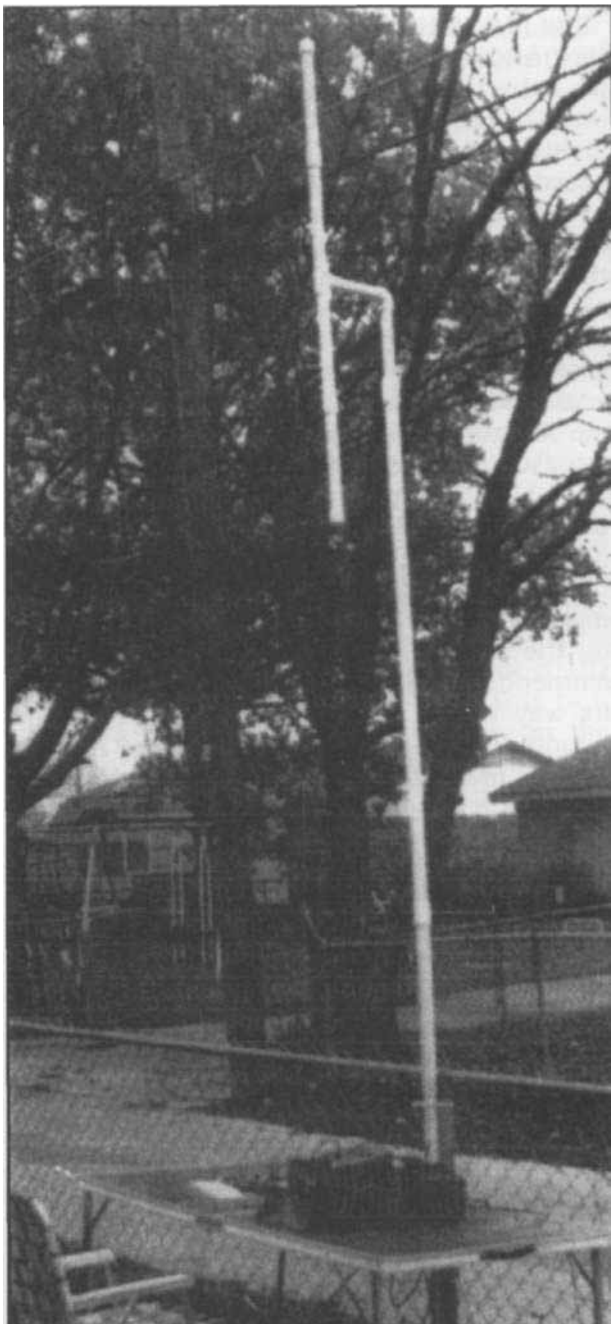
The Ramsey Tru-Match FM Broadcast Antenna Kit is designed for both the FM-100 and FM-25 systems mentioned previously, and main-tains precise tuning between the transmitter and antenna necessary to prevent mismatching that could otherwise damage the transmitter or power booster circuitry. This antenna is a rugged, well-designed unit of the folded dipole type. It's weather resistant, and is contained in one inch schedule 40 PVC pipe, and features connections to the transmitter using standard 75 Ohm TV coaxial cable, like that of conventional TV cable systems. As such, the wire and connectors used are conveniently available at any Radio Shack or building supply store. The antenna could be erected using standard rooftop steel antenna mast. The author chose to use a 10-ft. mast made of inexpensive 1 1/4" PVC pipe consisting of two sections, each cut 5-ft. in length from a standard 10-ft. piece and joined with unions. Having the two pieces cut to five feet allows for easy disassembly and transport in a short bed pickup truck (see mast construction detail). This antenna mast can be attached beside a wooden utility pole, or any other firm object, as long as the radiator element itself is not placed near a metal obstruction. The author used heavy duty tie-wraps to attach this to existing fence posts. The antenna also features a swiveling radiator element to allow horizontal or vertical polarization of the transmitted signal.

The antenna is shown in the vertical polarization configuration, as this works best with Boom Boxes, personal FM radios, and auto radios having vertially polarized whip antennas. The antenna sells for $39.95 and can be shipped only as a kit, as it is too large for shipping when assembled. Some soldering is required, and the PVC cement to attach the sections is not supplied.

Ramsey's estimated time for completion of the antenna is three hours for the beginner, two hours for an intermediate builder, and one hour for the advanced builder.

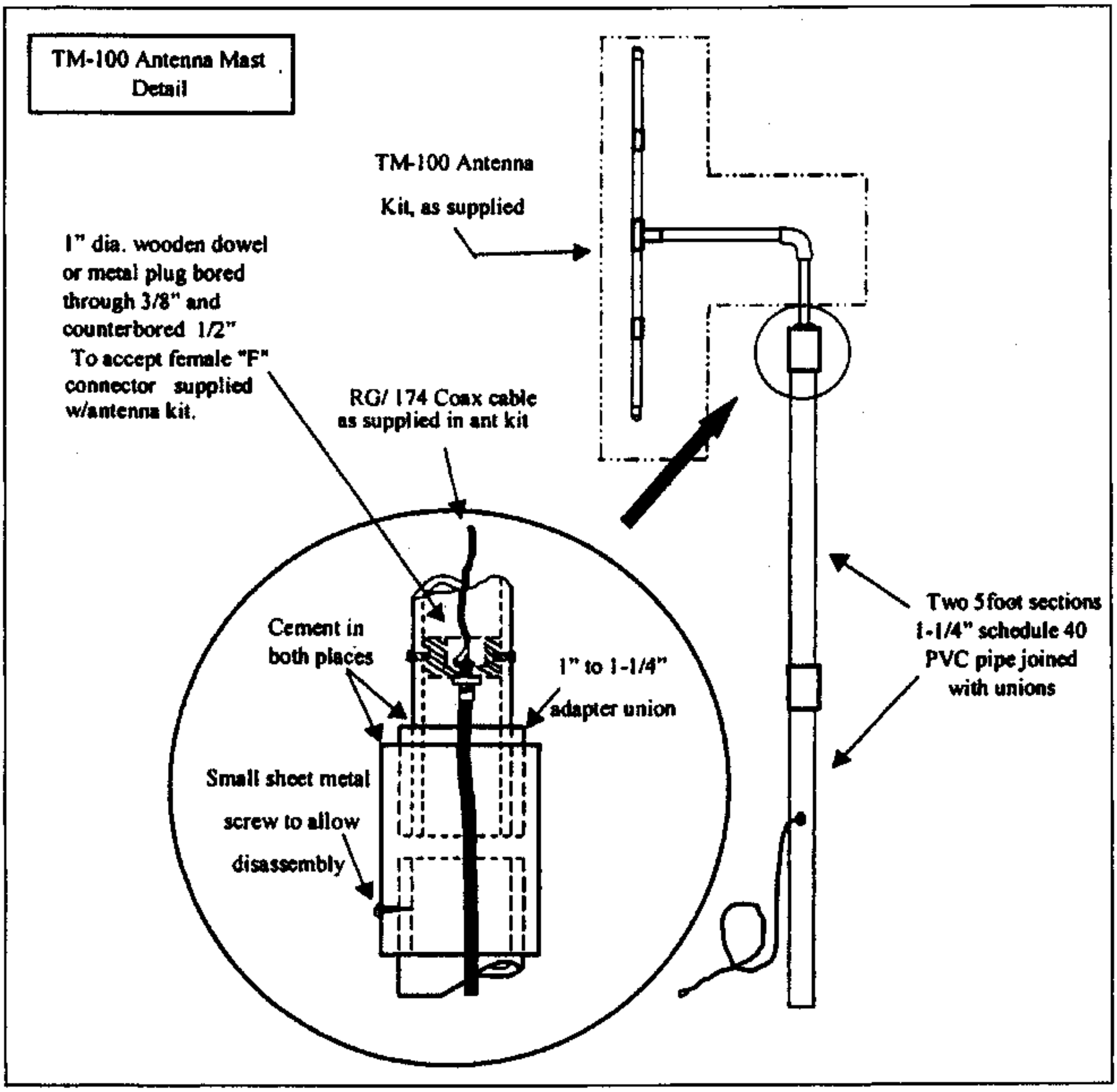
The legalities of Low Power FM

Like many other legal concepts in the display of Fireworks themselves, the unlicensed operation of low power FM becomes the responsibility of the person who utilizes it. If



you cause a problem...You become a problem, and will be dealt within the United States accordingly, by the Federal Communications Commission. As an unlicensed FM broadcaster, you have NO legal rights, and the following is your responsibility:

1. You must select a transmit broadcast frequency that does not interfere in any way with another person's ability to receive a licensed commercial broadcasting station. If you interfere with a licensed broadcaster,

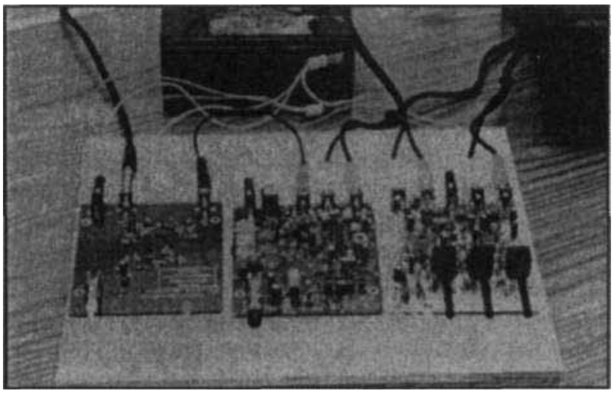


and a complaint is filed, you must immediately correct the problem by moving to another frequency, or terminating your transmission entirely. No exceptions! It is your responsibility to check the FM broadcast band for an unused frequency to transmit on, by possibly using a very sensitive digitally tuned receiver such as a high quality automobile receiver with the antenna extended fully. Again, if a complaint is filed about interference you cause on your selected transmit frequency, you must comply with the FCC regulations and change frequency, or cease your transmission. The manufacturer of these transmitters suggests that a broadcast engineer who perhaps moonlights from a local station, could be called upon to survey the FM band using very sensitive test instruments to assist you to find a vacancy on the FM band. Finding such an unused frequency is usually not a problem in rural areas where fireworks clubs gather, but in highly populated areas where commercial fireworks presentations are many times displayed, this search could be more difficult.

When using a "Scan only" digitally tuned receiver to check for unused channels, watch the frequency display as you scan from one station to another for a jump of 400 kHz. (ideally 600, 800 or 1000 kHz if possible). Set the transmitter frequency to the midpoint between the two stations your receiver has detected, then scan the receiver again to stop on your selected broadcast frequency. Turn off the power to your transmitter, then listen carefully to the new point the receiver has stopped on, to see if that selected frequency is really unused. Depending on the threshold level of scan on your receiver, there could be a nearby station on that spot that your receiver didn't find as it scanned. If there is a station there, repeat the process until you are satisfied that you are on an open channel. 2. You are responsible to maintain the proper legal transmitting power radiating from your unit. Again, if you are unlicensed, and a complaint is filed with the FCC and your station's output is found to exceed legal limits of radiation, you may have more problems than you wish to deal with. You should be cautious when choosing to purchase a power amplifier to boost your output power of your transmitter. Use only enough power to do the job at hand, no more. The Ramsey FM-25 transmitter described has a higher power option to increase the output power of the unit. The manual describes how to use it, but Ramsey Engineers comment in the manual saying, *"For normal operation in the U.S. this option should not be used because it could put you in violation of FCC rules"... "Better to play it safe initially and see what your range is on low power, before you go Hog Wild"*. Use of the LPA-1 Power amplifier mentioned herein will most certainly put you in legally marginal territory as this unit when used in the FM bands of 88-108 MHz. is intended for foreign users or licensed broadcasters who are allowed to transmit at higher power levels. User beware!

The FCC standards for power on unlicensed Low Power FM?

Unlike Citizens Band, or other radio services that are most commonly discussed in terms of the maximum legal transmit power in *watts,* Low Power FM as described in Part 15 of the FCC Rules & Regulations is quantified by *field strength* at a predetermined receiving antenna. The maximum legal power for an unlicensed Low Power FM system in the United States has been reached when a voltage of 250 microvolts from the transmission is induced in an antenna of 1 meter in length, when placed 3 meters from the transmitting antenna. Such measurement requires very sensitive equipment that most people using the units would not otherwise have. This makes it difficult for the user to determine if his unit is in compliance, and changes in the antenna could also affect the performance to a great degree. Again, use caution. You make the decisions, and you must live with the outcomes be they good or bad, as an unlicensed user. From the above information, it is apparent being unlicensed does not translate to being illegal, unless the radiated power from the antenna exceeds that established by the present FCC ruling.



Distances expected from transmissions

The manufacturer provides little data on expected transmission distances since there are so many factors that can affect the transmissions. Antenna type, antenna height, adjacent buildings, geographical contours such as hills and mountains, atmospheric conditions, and transmitted power, are just a few of the many factors that can cause the results of tests to vary considerably. The receiver's sensitivity also plays a very important role in the usable signal received by the listener. The author chose to test the units under the following conditions to obtain useful information:

1. The testing was done in a rural area on a Texas cattle farm consisting of flat pasture land. The area to the south had clusters of trees and some single story homes, as shown

on the site map, while the northern area had little vegetation and few residences. Reduced distances will be noted to the south, and the author suspects the trees, single story dwellings, and metal storage barns along the path affected the range.

2. The Ramsey TM-100 antenna was used in the vertically polarized configuration, with a mast of 10 feet in height. This represented a maximum antenna height of approximately 12.5 feet from ground level, measured from the tip of the radiator when turned upward.

3. The receivers used in the field trials were the following:

I. A Sony WM-FX423 digitally tuned Walkman, typical of the type that uses the headphone cable itself as the FM antenna. New batteries were installed prior to testing.

II. A Sony CFD-50 "Boom Box". This unit is manually tuned and equipped with CD player as well as cassette player, and represents a mid-market portable receiver that many may bring to an event. The FM receiver's external rod antenna was extended fully to 26" for the tests. New batteries were installed in the receiver prior to testing.

III. A Sony XR-C750 digitally tuned automobile radio was used to determine maximum transmit capabilities. This unit represents a higher-end after market radio, installed in an older vehicle, and has perhaps better sensitivity than some models that come factory-installed in an auto or truck. The vehicle antenna was original equipment, and measured 30-inches. Distances below 1,038-feet were obtained using a measuring wheel calibrated in feet, typical of the type used to make fireworks site plans to NFPA specs. Distances above 1,038-feet were taken from the vehicle's odometer and converted to approximate feet.

4. The Ramsey FM-25 transmitter was used with a line level pre-recorded CD music input. The transmitter was battery operated on a freshly charged 12 volt, 7A.H. lead acid gel-cell battery. The CD player was AC operated with an extension cord from a nearby outlet. The STC-1 Audio Processor was not used since its use would have affected the range of the transmissions.

Note: Many full-featured CD players used in component stereo systems consume little current. This one was rated at 18 watts and could have also been operated with a relatively inexpensive 12VDC to 120VAC power inverter, for remote applications as previously suggested.

A. The FM-25A transmitter by itself was first set upon the minimum power option.

B. The FM-25A transmitter and the Ramsey LPA-1 Broadband Power Amplifier were then used to increase the power to the antenna. The FM-25A was set up to low power option, and the LPA-1 was set up on minimum gain (25.3 dB) feedback configuration.

5. The maximum *usable* described distances are those receptions that were not prone to fading, interference, or other noises characteristic of exceeding maximum transmit range capabilities. When fading or other annoying characteristics were first observed, the distance was noted and the test at that condition was halted.

Summary: The distances achieved were beyond the author's expectations. I expected a mile, maybe a little more, but the reception was still excellent at over two miles. In most cases, this would be adequate for any fireworks presentation, under almost any circumstance. The results would vary greatly with many different brands of receivers, but coverage in the immediate firing area would be sufficient for most personal portable receivers carried by pyrotechnicians.

Suggestions for Use of Low Power FM Systems

The following are suggestions given by the manufacturer of these kits, when the apparatus is used in low power unlicensed operations. These suggestions may help you avoid unexpected federal visitors to your location who come with unfriendly aggressive tendencies, should you be a creator of problems when you operate your system in the U.S.

Stay on unoccupied frequencies. Interfere with no one's transmissions. You are also expected to tolerate any interference with your station from others, but you can move your frequency at any time to avoid such interference.

Avoid the use of the frequencies of 88-92 MHz in the U.S., as these FM frequencies are used by numerous low power and medium power college and National Public Radio services. Your transmission is more likely to affect their listeners than the listeners of the more powerful commercial stations above 92 MHz.

Do your best to avoid overpowering your transmitter, for obvious reasons.

Do not use false or made up call signs in your transmissions. Only the FCC can assign these to licensed broadcasters.

Periodically identify your transmit location and frequency, such as: *"This is 103.3 FM, a broadcast service of The Fireworks Enthusiasts Association, originating from Wilson's Farm, Podunk, Mississippi."* This allows the FCC to get in contact with you more easily if a complaint is made. If FCC officials have to use expensive methods to track you down at an undisclosed location with direction finding equipment, you may be perceived as a "Pirate Station", and the confrontation with such Federal officials could be much more severe, rather than a simple warning. Use common sense courtesy such as this, in your broadcast methods.

Can a Low Power FM Station be licensed?

Yes, but it takes time, money, and use of an attorney is suggested for filing the paperwork as it is complicated. Filing the application costs $2,030. The Federal Communications Commission has provided for licensing as set forth in The Code of Federal Regulations, Title 47, Part 73, and the form used for this is Form 301 A. **Note: The present *minimum* limit of low power *licensed* operation as specified by the FCC, is 100 watts, therefore under present rules, the micro broadcasting systems described in this article cannot be licensed by the FCC.** In Berkeley, CA, an ongoing court case involving the FCC and Radio-Free Berkeley, an unlicensed 50 watt, micro-power broadcasting service that continues to broadcast without a license for a year. The owners have challenged the FCC's practice on non-licensing of the lower power units below 100 watts as being unconstitutional, stating that these rules favor the wealthy, since only they can afford such expensive transmission systems. In 1994 The Canadian Radio-Television and Telecommunications Commission legalized Micro Power broadcasting systems even in metropolitan areas, and the person who wishes to obtain a broadcast license needs only to submit a two-page request to affirm his equipment meets the technical standards to avoid interference. A Canadian manufacturer of low power broadcast systems, Decade Transmitters Inc., a Canadian manufacturer of Low Power FM units, has been given a grantee code by our FCC which allows them to mass market two of their low power FM transmitters in the U.S. Decade mentions that our "FCC is receiving numerous requests on a daily basis concerning the use of Low power FM transmitters on 88-108 MHz for indoor applications, and is studying the possibility of discharging the users of the requirement to hold a broadcasting license for such applications".

Further information on licensing and FCC Rules

If you have a personal computer on the Internet, and want to know more about Low Power FM and its licensing, as well as obtain FCC documents, you can download much more information in PDF files from the Ramsey website at:

http://www.ramseyelectronics.com

You can obtain the complete set of FCC documents pertaining to CFR 47 Parts 2 and 15 and the FCC forms, at their website:

http://fcc.gov/Bureaus/Engineering_Technology.

If you decide to download the complete rules of part 15, take a break, have a coffee, and have plenty of paper in your printer. There are almost 70 pages.

Suppliers of Low Power FM Systems

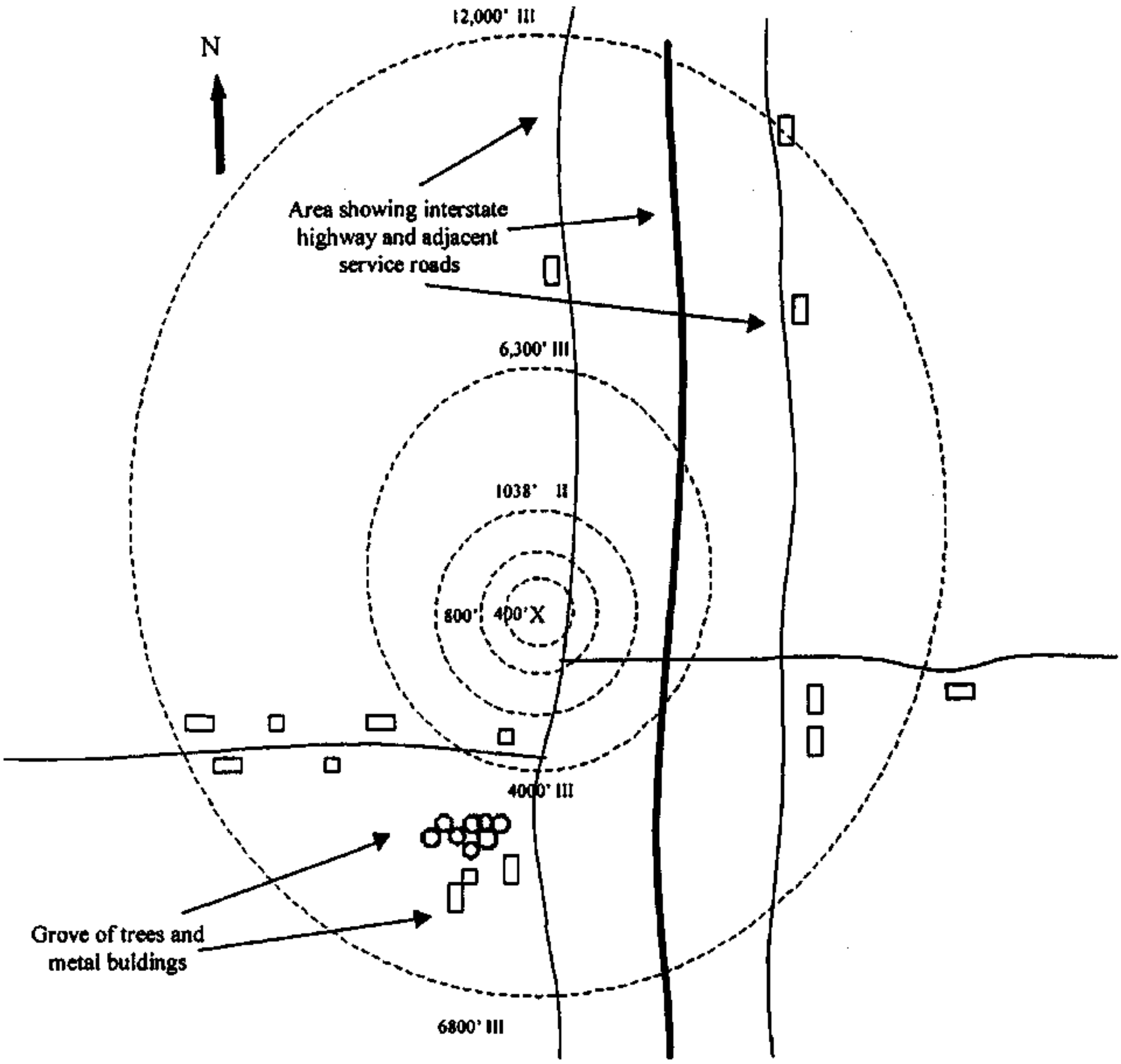
Ramsey Electronics Inc.
793 Canning Parkway
Victor, NY 14564
(716) 924-4560
(Ask for catalog)

See results and site layout on next page.

Results of Low Power FM Field Tests

Condition	Receiver	Maximum Usable Distance/Notes
FM-25A standalone	Walkman	400 feet / Line of sight
FM-25A standalone	Boom Box	1,038 feet / Line of sight
FM-25Aw/LPA-l	Walkman	800 feet / Line of sight
FM-25Aw/LPA-l	Boom Box	5,300 feet / Line of sight
FM-25Aw/LPA-l	Auto Receiver	6,800 feet/Separated by grove of trees and single-story structures
FM-25Aw/LPA-l	Auto Receiver	12000 feet / Line of sight

Field Test Sight Layout



THE EXPLOSION OF A BALL MILLING JAR

By Lloyd E. Sponenburgh

THE SOUND OP THE OTHER SHOE

Ever since I wrote the original articles on how to build a ball mill (AFN November 1995), I wondered how destructive an event it would be if a mill of my design were to explode while milling black powder. It was like waiting for the sound of the other shoe dropping - would it be catastrophic or just a mild explosion?

For three 'pyro seasons' I have been trying to arrange a test of an exploding mill. Finally, with the help of the Florida Pyrotechnics Arts Guild and its very professional safety committee, we were able to create a test.

I had read other pyrotechnicians' accounts of mill explosions. From their stories, I generalized that such an explosion would be a pretty gentle and unimpressive thing. But my mill had that 'rocket engine'of a milling jar on it. And I didn't know - I just didn't know...

For those who are unfamiliar with the mill I'm discussing, a short redux is in order. My ball mill uses an 8-inch long piece of Schedule 3035 PVC pipe with an end cap on one end, and a reducing coupling on the other to form the milling jar. The small end of the reducer is sealed shut with a rubber plumber's 'test cap'. The jar's empty capacity is one gallon. It holds one half-gallon of milling media - in this case, twenty-nine pounds of 3/4" diameter lead balls - and one quart of material to be milled.

For the test we proposed, the material to be milled was black powder. One quart of finely milled powder weighs about six hundred grams (about 1-1/3 pounds).

To record the forces of the test, we built a 'witness box' of 1/2" CDX plywood 18"W x 24"H x 48"L. We assembled the box with 1 1/4" drywall screws; one every eight inches. The mill jar was positioned inside the box, suspended approximately in the middle of the enclosure on a lightweight PVC pedestal. The jar was about the same distance from the walls of the witness box as it would be from the walls of the finished ball mill enclosure with the lid of the ball mill closed.

We intended the witness box to display any damage that might occur from flying pieces of the jar or from flying milling balls. Indentations or holes in the plywood would manifest the flight of any shrapnel. We soon nicknamed the box "the coffin". It turned out to be an aptly chosen name.

Some of us feared that milling balls would be hurled with great velocity from the exploding jar. I personally believed that the rubber test cap would 'balloon', then fail, and the jar would be projected like a rocket endwise in the test box, with the contents of the jar ejecting endwise in the opposite direction. I presumed that based on my perception of the slowness of burning of finely powdered meal, as opposed to the energetic burn rate of good, grained powder.

We all got our individual surprises. As you'll see later, we should have feared dangers greater than we invented.

With the help of an automatic shovel (a tractor-mounted back hoe) we quickly fashioned a pit to isolate and contain the explosion. We dug the pit about three feet deep, three feet wide, and six feet long; shallow, but a suitable size for a grave!

We placed the bottom plate of the witness box flat on the bottom of the pit. We charged the jar with twenty-nine pounds of 3/4" diameter lead balls and six hundred grams of well milled meal powder. I milled the meal *in that jar and with that media* for three hours before the test. We used the common 75-15-10 mixture with commercial air-float charcoal and vulcanizing grade sulfur. (Note - *this is not nearly so energetic a mix as some black powder made with 'custom' home-made charcoals, like willow or buckthorn, and not <u>anything like</u> as energetic as commercial grained powder!)*

A ***<u>shielded</u>*** Davey electric igniter (Part # SA-2001) was placed approximately centered end-to-end in the jar and lying on the surface of the pile of media, then the jar was sealed with the rubber test cap. The e-match leads were thin enough to allow the rubber cap to seal the Iar as well as if they had not been present. The Jar was then *carefully, slowly turned* until the mass of material inside was 'sloped' or piled up one side of the jar, as it would be during normal ball mill operation.

This particular, ***potentially dangerous*** *concession to accuracy is why a shielded e-match was used. If any milling balls were to fall upon the match while the jar was being turned, we didn't want them to ignite the match by impact The plastic shield on the match prevents any but extremely vigorous impacts from igniting it accidentally from friction or impact*

Additionally, we ***practiced*** *with an open jar, and no powder or e-match until we were confident of how far we could turn the jar before balls began to cascade. We did not allow any balls to fall, but merely 'piled them up' on one side of the jar.*

Once we conditioned the jar for the test, we poised it upon its perch in the center of the witness box and closed the box. A shunted length of shooting wire was spliced to the e-match leads, and we spooled out two hundred feet of wire to the viewing site. An FPAG member kindly loaned us an "authentic blasting box" with which to perform our ceremony of destruction.

Our safety crew made radio calls around the range announcing the test about to happen. Shouts of "look out" and "look up" were heard here and there about the field. We counted down together, and I twisted the crank on the blaster.

For the tiniest (probably only mental) fraction of a second I thought, "Nothing's happened." No sooner had I thought it than I was greeted by a gut-thumping ***BOOM*** much deeper and more 'throaty' than a mortar's muzzle blast - and we saw a wide, tall column of smoke rising from the test pit. Atop this forty-foot white pillar rode the intact top of the witness box, as prettily as if the smoke had been a fountain of water!

There were wide eyes, grins, and knowing nods among the viewers; this was *neat stuff*!

Our crew was already trekking back to the test pit when the witness box lid finally touched down. It had flown higher than fifty feet, and landed about fifty feet from the test site.

As soon as we saw the devastation in the pit, we ***knew*** we had a duty to inform others of what could happen. If we did nothing else, we had to get out the word that milling black powder indoors or near dwellings was ***a bad idea!***

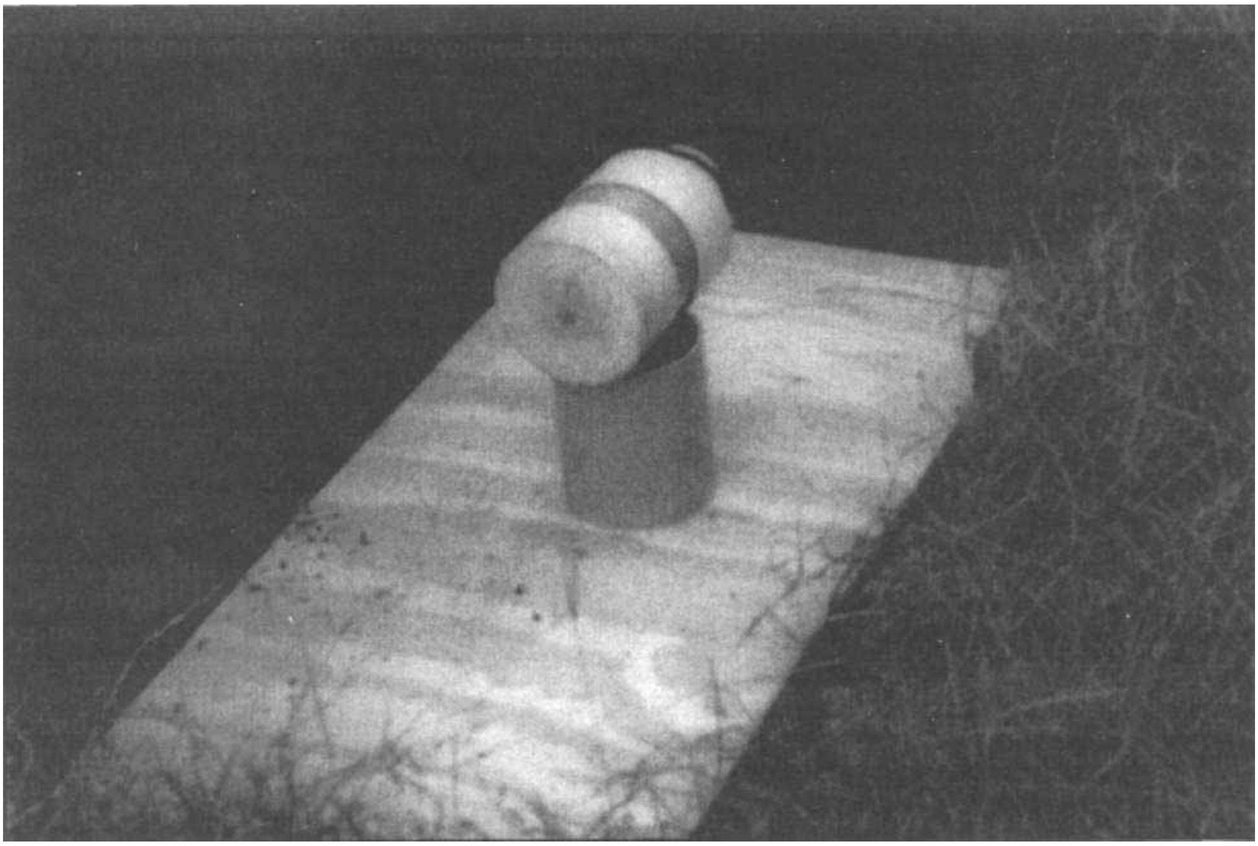
The explosion had completely shattered the mill jar. I was partly exonerated in my opinion about the jar taking flight, because the base (end cap) of the jar had flown the length of the box with enough velocity to imprint the PVC pipe company's logo and end-cap nomenclature on the end plate of the witness box.

However, the jar must have been in the act of shattering to bits at that very instant it struck and passed through the end plate, because no piece of the jar (or the thicker and stronger fittings) larger than a few square inches was found anywhere. No visible 'strike' of the intact jar was seen in the dirt walls of the pit just outside the box. Pieces of PVC were embedded in the pit walls. The guys who had bet the jar would explode violently were correct.

The biggest surprise was that the lead milling media did not fly far from the blast. We recovered just over 60% of the milling balls. The ball recovered furthest from the pit was only fifteen feet from the explosion's center. It's reasonable to assume that some balls went further, but they did not travel with much speed. Even those balls that impacted the soft clay walls of the pit left only shallow impressions. I think that the lead milling media would not pose a serious risk as projectiles in such an explosion. I think that lighter media like ceramic or glass *would* be a hazard.

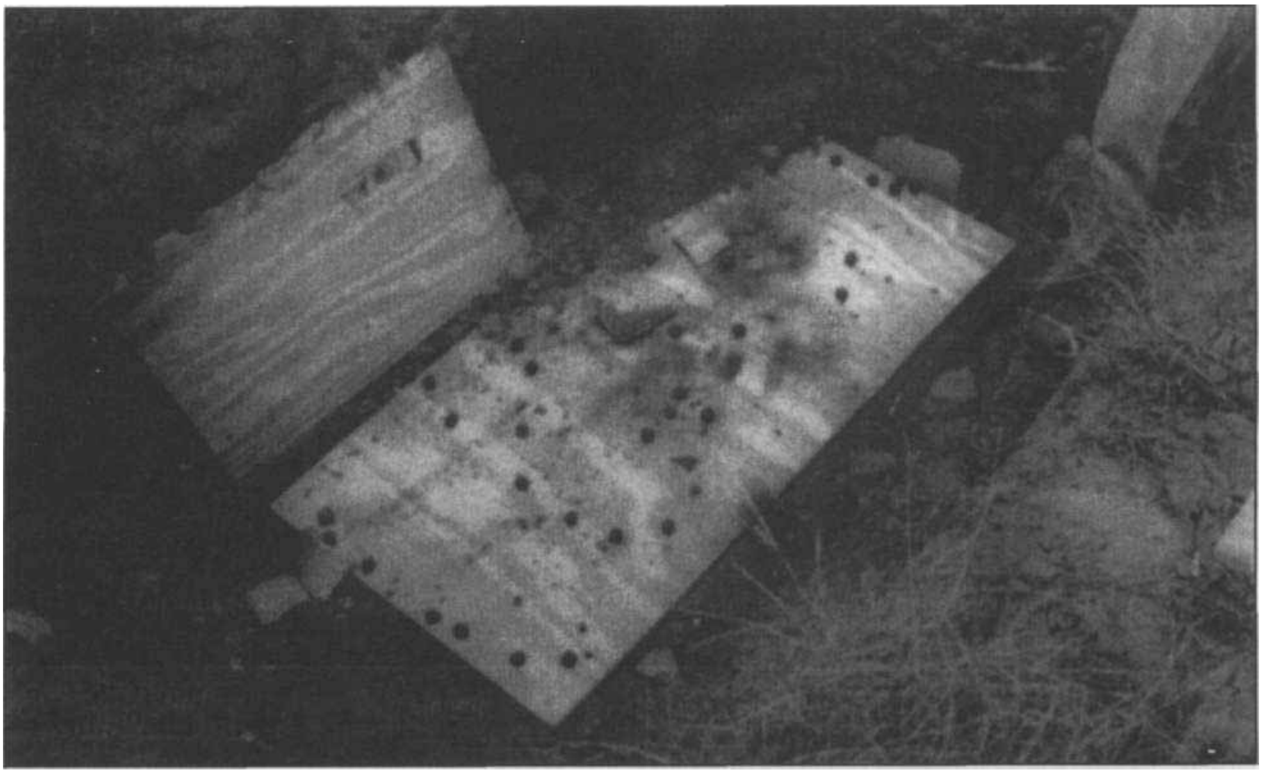
But there is a *serious* risk of shrapnel from the milling jar. The day of the test, we found pieces of PVC over seventy-five feet from the pit. Remember that they had to travel up *and* out to get out of the test pit. During subsequent trash cleanup, pieces of plastic were found over one hundred feet away.

Every piece of plastic was razor-edged! Most pieces had knife-like points. Pieces of



The milling jar on its support before closing the witness box.

The explosion, with the lid of the witness box in flight.



Evidence of a cataclysm in the pit.

PVC were embedded deeply in the test pit walls. The plywood witness box - made of tough Southern Yellow Pine plywood - was deeply gouged and cut where the plastic struck.

We didn't include a roasting chicken in our test, like the CPSC does when it wants to show the newspapers how dangerous M-80's are. But we were convinced that the plastic shards would have easily penetrated a person's abdominal wall. They certainly would have shredded and maimed the hands or face of anyone unlucky enough to have been close to the exploding jar.

The test was a sobering reminder that this art of ours can be dangerous if we don't control it. The rule of fireworking to "minimize, isolate, and contain" applies as much to milling black powder it does to mixing flash.

What did we learn? Personally, I learned that six hundred grams of black powder is *a lot of explosive.* I use a lot of black powder, so I guess it never impressed me that much before. It does now.

• ***Never mill more material at one time than you must.***

We learned that, while PVC makes a cheap and effective milling vessel, it can be very dangerous if a mill explodes. We confirmed what we have been teaching all along:

• ***Never mill pyrotechnic mixtures indoors or near a dwelling.***

• **ALWAYS** ***start and stop your mill remotely.***

• ***If possible, place your mill in a strong, separate building or bunker.***

I hold the same opinions about a 'less dangerous' milling vessel, like a rubber tumbler. The shrapnel hazard might be reduced, but the force of the explosion we saw was great. A person's being near it would have been a bad idea. Caps, clamps, and closure hardware could become projectiles as dangerous as the PVC fragments we saw. Treat any milling vessel as a potential bomb.

Our test confirmed what we already knew intuitively and from industrial history — milling black powder is dangerous. If you mill your own powder, mill in a safe, remote location no less than one hundred feet from any occupied buildings. Start and stop your mill from a safe distance. LES

QUICK MATCH: ITS CONSTRUCTION AND MANNER OF FUNCTIONING

By KX. & B.J. Kosanke

PART 1 OF 8 PARTS

During the last few years, we have occasionally investigated some questions about quick match. We plan a series of short articles based on this work, reporting on: methods used to slow its burn rate, the effect of humidity on its performance, the reasons for its failure to function properly, and some suggestions for possible improvement. However, before presenting those things, this first article will set the stage by discussing the manner of construction and functioning of quick match.

Typically quick match consists of black match in a thin loose fitting sheath of paper; generally the paper sheath is called the "match pipe" and sometimes quick match is called "piped match". See Figure 1 for the appearance of black match and quick match. The match pipe may be pre-made and a length of black match slipped into it. However, while this works well for making short lengths of quick match, such as needed for shell leaders, longer lengths, such as needed for fusing lancework, would need to be spliced together. As an alternative, and probably the most common method used commercially, the match pipe can be formed in a continuous process around a very long length of black match. Traditionally, the match pipe included an inner wrap of thin wax impregnated paper for moisture protection of the black match core. More recently, some manufacturers have used plastic laminated paper or other similar means to provide an increased level of moisture protection.

Black match consists of a collection of thin strings, most commonly cotton, that have been coated with a slurry of Black Powder and binder in water. Manufacturers may use commercial meal Black Powder, a mixture of commercial powder and rough (hand made) powder, or rough powder alone. The individual strings are typically pulled over a number of rollers immersed in the slurry, then brought together as a bundle and pulled through a funnel shaped orifice to remove the excess Black Powder mixture. The wet black match is usually wound on a frame for drying before it is used to make quick match. However, some oriental manufacturers apparently use wet, or at least damp, black match to make their quick match. One variation in making black match is to apply a dusting of meal powder to the black match while the match is still wet. This so-called "dusted" match is reputed to ignite easier and burn faster when made into quick match.

Black match typically burns at approximately one inch per second. The same black match, when sheathed to make quick match, typically burns roughly 100 times faster, at 10 to 20 feet per second. One hears three common explanations for the accelerated burning of black match when wrapped to make quick match, specifically:

1) The black match burn rate increases because of its being starved for oxygen under the paper wrap.

2) The increase in black match burn rate is the result of burning under increased pressure because of the paper wrap.

3) The burn rate increase is the result of a transition from parallel burning to propagative burning induced by the presence of the paper wrap.

In large part, the first explanation can be dismissed on theoretical grounds; there is no scientific basis for pyrotechnic burning accelerating because of the lack of oxygen. Black Powder is not dependent on atmospheric oxygen for burning. More over, atmospheric oxygen is a more energetically favored source of oxygen than potassium nitrate, and if anything, its availability can only serve to facilitate burning rate. However, the main reason for rejecting this explanation is that it is contrary to common experience. For example, consider a case where a thin trail of fine (mixed particle size) commercial Black Powder is burned on a flat surface. The rate of burning will be at least several inches per second. When this same powder is tightly wrapped with threads to make visco fuse or when compacted into a casing as a rocket motor, its burn rate falls to less than .5-in./sec. This slowing is contrary to the prediction of accelerated burning when Black Powder is starved for oxygen by encasing it.

The second explanation for high burn rates of quick match has a potential theoretical basis to support it; burn rate generally increases in response to increasing ambient pressure. This is expressed in the burn rate or Vieille equation:[1]

$$R = AP^B,$$

where

R is linear burn rate,

P is ambient pressure, and

A and *B* are constants.

For Black Powder, burn rate increases with pressure as shown in Figure 2 (based on the constants given by Shidlovskiy[1]). Two things should be noted in Figure 2: first, ambient pressure must rise to approximately 265 psia for the burn rate of Black Powder to double; and second, that the effectiveness of rising pressure to increase burn rate lessens with increasing pressure. Obviously, the pressure increase needed to even double the burn rate for black match is much greater than could ever possibly be contained by the paper match pipe, let alone the horrendous pressure increase needed for a 100 fold increase in burn rate. Accordingly, this second possible explanation must also be rejected.

The third explanation for the accelerated burn rate of quick match is that it is a transition from parallel to propagative burning. This explanation was articulated by Shimizu,[2] without specifically using the terms parallel to propagative burn type transition. (For a more complete discussion of these terms, see reference 3.) Shimizu uses the analogy of a candle flame. When a barrier obstructs a candle flame, see Figure 3, the flame tends to spread out along the barrier. He likens the unobstructed candle flame to the burning of black match. When the black match has burned to the beginning of the match pipe, the pipe at least temporarily obstructs the flame. Some of the flame is deflected out the end of the match pipe, but some flame is also deflected into the "fire path" between the pipe and black match. This flame entering the match pipe causes the ignition of an additional amount of Black Powder on the surface of the black match. Because more black match has ignited, additional flame is produced. Some of this flame exits the match pipe, but some penetrates deeper into the pipe, igniting still more black match and producing still more flame. The process continues accelerating as the flame races through the fire path between the black match and match pipe. The pressure inside the pipe increases, but very much less than would be required to explain even a small fraction of the increased burning rate. Nonetheless, the increase in pressure has important ramifications. The acceleration of burning increases to the point where the internal pressure exceeds the strength of the pipe, at which time it ruptures and further acceleration of burning ceases.

In addition to there being a sound physical basis for believing Shimizu's explanation, he conducted some supporting experiments in which the paper match pipe was replaced with metal tubes. As expected, burn rate increased beyond that found for paper-piped quick match, because of the higher pressures tolerated by the metal tubes before rupturing. Further, the studies we have conducted on quick match support or are consistent with Shimizu's explanation.

With Shimizu's explanation as the basis for understanding the manner of functioning of quick match, the next article will report on methods that can be used to slow the burning of quick match.

References

1) Shidlovskiy, *Principles of Pyrotechnics,* 3rd ed. [Translated from Russian] (1964) p 111.

2) Shimizu, *Fireworks, From a Physical Standpoint Parti.* [Translated from German]: Pyrotechnica Publications (1981) p 12-16.

3) L. & B. J. Kosanke, "Parallel and Propagative Burning", *Pyrotechnics Guild International Bulletin,* No. 79 (1992) p 18-26.

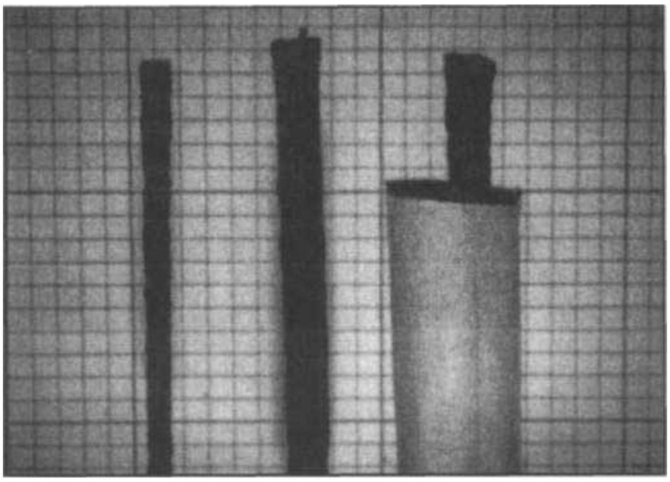


Figure 1. TUXD examples of black match (left) and an example of quick match (right).

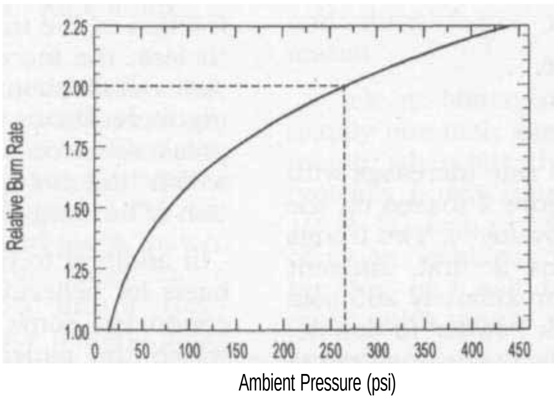


Figure 2. Graph of Black Powder burn rate as a Junction of ambient pressure.

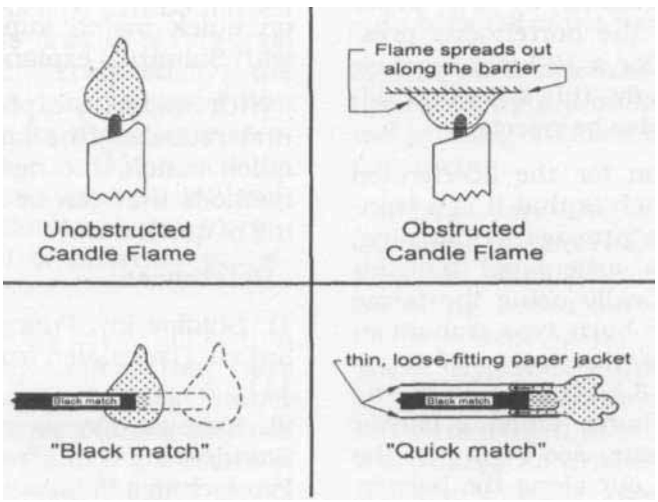


Figure 3. The analogous burning of a candle and black match in the presence of an obstruction.

QUICK MATCH: METHODS OF SLOWING ITS BURNING

K. L. & B. J. Kosanke

PART 2 OF 8 PARTS

In the first article in this series, the method of construction and manner of functioning of quick match was discussed. There it was reported that while black match typically burns at a rate of about one inch per second, quick match typically burns roughly 10 to 20 feet per second. There are times, however, when this is faster than desired for quick match, such as when used to fire a small finale. The techniques used to control (slow) its speed of burning is the subject of the current article.

Recall from the initial article that the reason quick match burns rapidly is that fire (burning gas) races down the "fire path" between the black match and the loose fitting match pipe. Therein lies the answer to slowing its rate of burning. Whenever the fire path in quick match is tightly closed, its burning must temporarily transition from propagative burning (fast) to parallel burning (slow). Ofca calls such delays "choke delays".[1]

There are a number of similar methods used to close the fire path of quick match. Probably the most common is simply to tie a string (or light cord) very tightly around the quick match at the point where a momentary slowing is desired. The string collapses the paper match pipe, compressing it tightly against the black match. Accordingly, the quick match burning propagates rapidly along its fire path until the point where it is tightly closed by the string. At that point it must burn slowly, layer by parallel layer under the string and compressed match pipe. Then, when the fire path re-opens, the burning again propagates rapidly. For this method of slowing to work, the fire path must be totally closed. Otherwise some fire will race through any small gap between the black match and match pipe, and there will be much less slowing of the burning.

Several common methods to close the quick match fire path are illustrated in Figures 1 and 2. Instead of tying a string tightly around quick match, other items such as a plastic electrical cable tie can be used. Another method is simply to tie the quick match itself into a tight knot. If a longer delay is desired, more than one tie can be made around the quick match, or a long continuous wrap of string can be used, or the quick match can be tightly tied in the shape of an "S" with string.

The approximate length of delay for these methods was determined by videotaping the burning of quick match sections and counting the number of 1/60 second video fields, while watching in slow motion. Each 16-inch long test section of quick match had an additional 4 inches of black match exposed on the end for ignition. Timing started with the first indication of burning inside the match pipe (i.e., when the flame from the burning black match became distorted by the paper match pipe). Timing stopped at the first sign of fire or significant sparks projecting from the other end of the quick match section. The quick match used in these tests was produced by Valet Manufacturing.[2] The test sections had been stored for more than a month at 75 °F and 35% relative humidity.

The results of tests for the quick match slowing methods are reported in Table 1. In each case the longest, shortest, and average times of three separate tests are reported. The relative unpredictability of these slowing methods can be seen by comparing the longest and shortest burn times for each method. In part this must be the result of variations in the length of tightly compressed match pipe around the black match. The variability was probably exacerbated to some extent by the low relative humidity, causing the pipe paper to be relatively stiff and unyielding.

The subject of humidity will be specifically addressed in a future article; however, one effect is the amount of delay commonly achieved using the various quick match slowing methods. For quick match that has been subjected to high humidity for a few days, the delays reported in Table 1 can be twice as long. Another factor affecting the amount of delay achieved using the various methods is the quality of the quick match. That which is fiercely burning, with a heavy or dusted black match and a thick match pipe, will be the most difficult to slow.

To some extent, an operator may be able to control the speed of a finale during the chaining operation. See Figure 3 for a short finale chain with paper wraps (often called "buckets", and made from coin wrappers) and which are used for attaching the leaders of shells in the chain. Also see Figure 4 for a cut away illustration of one bucket. At the chain end of each bucket (left in Figure 4), if the string is tied VERY tightly, a brief delay will be introduced (such as suggested in Table 1). Whereas, if the buckets are only tied tight enough to hold the fusing together, there will be significantly less delay.

When long delays are desired, it is possible to add a length of time fuse such as illustrated in Figure 5. Here a length of time fuse has been cut, punched and cross-matched (usually with thin black match). It is the length of fuse between the cross-matched points that determines the amount of delay. The piece of time fuse is inserted into a thin-walled paper tube, made with two or three turns of Kraft paper. The time fuse is tied into place near both of its ends. To install the delay element, first the quick match is cut in two and its black match exposed by tearing back the match pipe roughly one inch. Then the two ends of quick match are inserted into the two ends of the delay element and tied securely. It is important that the string ties around the time fuse be quite tight to keep fire from passing under the strings and skipping around the time fuse.

As one gains experience with a particular supplier's quick match and the methods of slowing quick match burning, it should be possible to control its burn rate to accomplish most needs, providing a high degree of timing precision is not required. In the next installment in this series of articles on quick match, the effects of powder loss from the black match will be discussed.

References
1) B. Ofca, "Ignition: Materials, Problems and Solutions", *Technique in Fire,* Vol. 8 (1995).
2) Val-Et Manufacturing, Inc., RR #1, Box 1117, Factoryville, PA 18419, L&BJK

Table 1. Quick Match Delay Times.

Condition	Burn Times (s/60)[a]			Average[b] Delay Times(s)
	Longest	Shortest	Average	
Unaltered	21	17	19	0.0
Single string tie	45	21	33	0.2
Quick match knot	52	30	44	0.4
"S" tie	79	26	48	0.5
Cable tie	100	24	47	0.5
1/2" string wrap	109	42	65	0.8

(a) Burn times are in NTSC video fields, each 1/60 of a second.
(b) Given the observed large variations in burn times, the reported averages (in seconds) must be seen as only approximate values and are reported to the nearest 0.1 second.

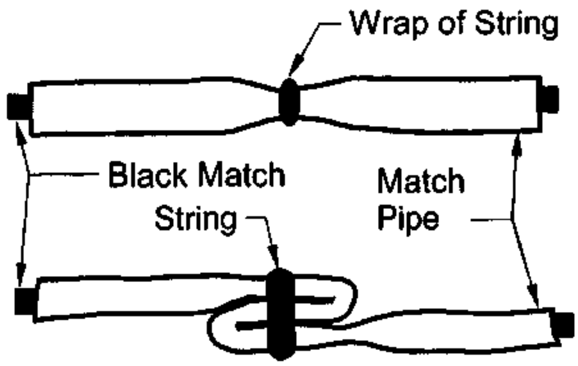


Figure 1. Some common methods used to slow the burn rate of quick match.

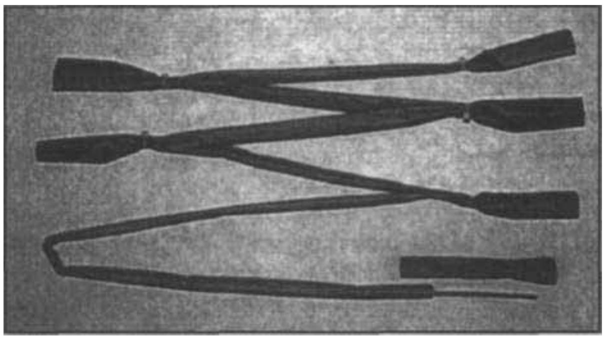


Figure 3. Photo of "Finale Chain" shown with "buckets" for attaching shell leaders.

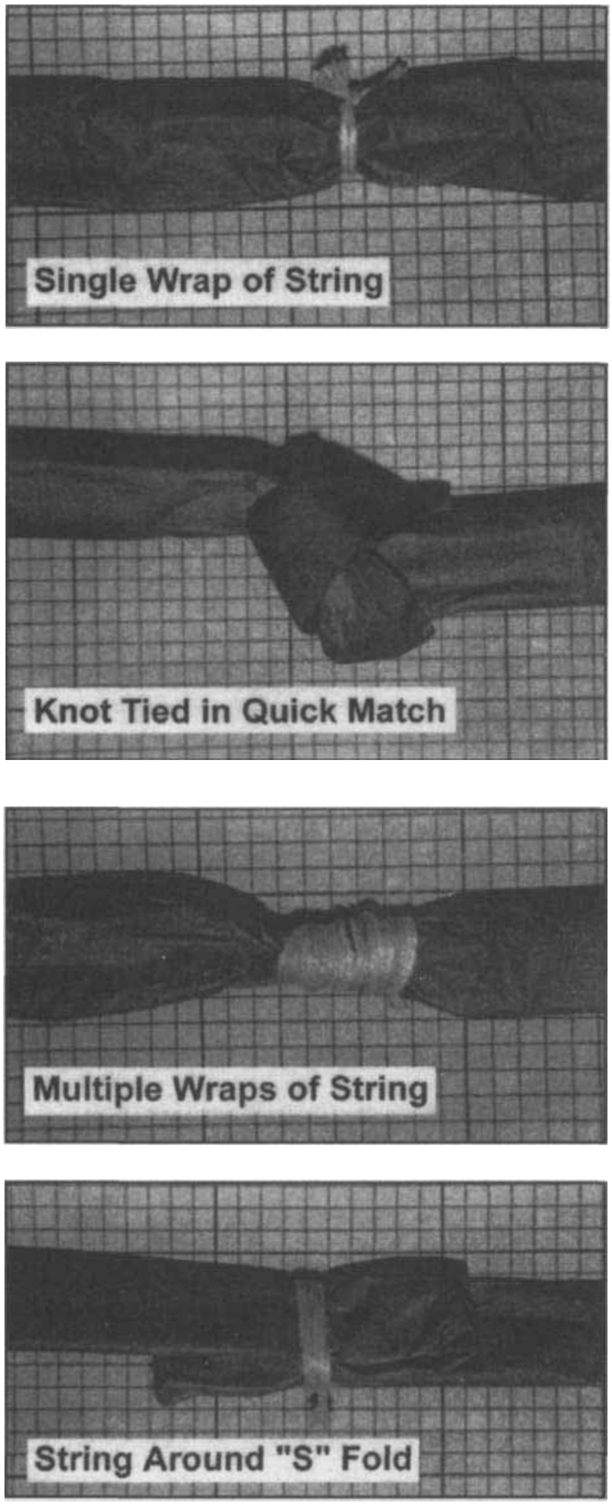


Figure 2. Photos of common methods used to slow the burning of quick match.

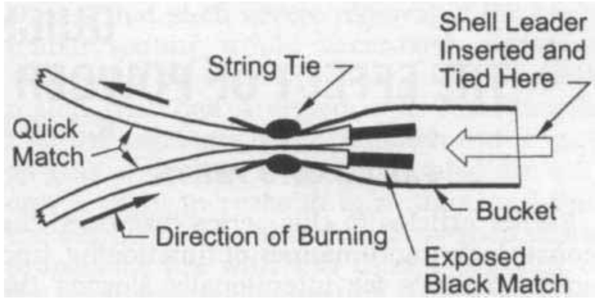


Figure 4. Cut away illustration of one "bucket" in a finale chain

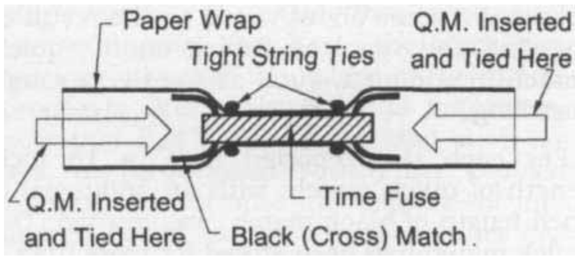


Figure 5. Cut away illustration of the method for attaching a length of time fuse to quick match (Q. M.).

QUICK MATCH: THE EFFECT OF POWDER LOSS ON ITS PERFORMANCE

K. L. & B. J. Kosanke

PART 3 OF 8 PARTS

Earlier articles in this series discussed the construction and manner of functioning, and some methods for intentionally slowing the burning of quick match. The current article presents information on the effect of powder loss from the black match core of the quick match. One example of how such powder loss might come about would be the result of extreme and repeated flexing on the quick match in one area, such as from very rough handling.

For each test reported here, a 16 inch length of quick match, with an additional 4 inch length of black match, was burned. The quick match had been stored for more than a month at approximately 35% relative humidity. For each condition examined, three separate test burns were performed. Each burn test was recorded using a video camcorder. In each test, the end of the exposed black match was ignited, and burn times were determined from a field by field play back of the video tape. The burn times reported were from the first indication of burning entering the match pipe until the first flame or a significant number of sparks were seen exiting the other end of the quick match segment.

The first test samples were prepared using quick match from Val-Et Manufacturing[1]. Damage to the black match coating was introduced by repeatedly drawing approximately 2 inches of its length (near the middle of the quick match segment) over a 0.25 inch radius mandrill. After each pass, the direction of the bending was changed by rotating the quick match by approximately 90°. The process was continued until the paper match pipe was so distressed that its tearing was imminent. (Note that this amount of damage is more than would be expected even from the very roughest handling of aerial shell leaders.) At this point, the length of quick match was held vertically and repeatedly tapped to cause as much as possible of the loosened black match coating to fall out of the match pipe. On average, approximately 0.3 g of powder was removed from each quick match segment. A second set of test samples were similarly prepared, except that approximately 6 inches of its length was damaged by being drawn over the mandrill. In this case, approximately 0.7 g of powder was removed. The results from these tests are shown in Table 1, along with burn times for undamaged quick match segments.

Because the observed differences in burn time were small, one cannot be quantitatively certain of these results. Nonetheless it does seem that the damaged quick match segments actually burned a little faster. It is certain, however, that the damage did not cause the segments to burn significantly slower. This despite the damage being severe and the loosened powder being removed. In these tests, it seems obvious that more than sufficient powder remained attached to the black match for it to function well. If there actually was a burn rate increase, it is likely that it was the result of the introduction of effective additional fire paths between the strings in the black match, or an increase in the ease of ignition of the black match coating because that remaining had been broken into small pieces.

In another series of tests, this time using quick match manufactured by Primo Fireworks[2], the effect of even more extreme black match powder loss was studied. In this case, quick match segments were prepared in which there was a complete loss of black match coating for approximately 2 and 6 inches. This was accomplished by first sliding the length of black match out of the match pipe. The black match coating was then removed from a length of the match, by first crumbling off a much as practical, and then by washing the strings. Care was taken to prevent water from contacting the rest of the black match and to limit the migration of water into the black match through the strings. The lengths of black match were then dried at approximately 70°F and 35% relative humidity for a week, before being re-inserted into the match pipe. The burn testing proceeded as described above, with the results also reported in Table 1.

Table 1. Burn Time of Test Segments of Quick Match Suffering Serious Powder Loss.

Condition	Bum Times (s/60)<a)			Average(b)
	Longest	Shortest	Average	Difference
Undamaged[c]	21	17	19	0%
2" Damaged	16	15	16	-15%
6" Damaged	17	13	15	-20%
Undamaged[d]	24	19	21	0%
2" Washed	26	20	24	15%
6" Washed	37	34	36	70%

a) Bum times are in NTSC video fields, each 1/60 of a second.
b) Given the observed variations in burn times, the reported average percentage differences must only be seen as approximate and are reported to the nearest 5%.
c) Val-Et's quick match.
d) Primo's quick match.

While there was a slowing of the burning, under the conditions of the tests, it is apparent that the flame front successfully jumped the lengths of string with no coating. However, it is expected that having open ends to the match pipe aided in the propagation of flame over the uncoated sections of the black match.I[3]' Accordingly, it should not be assumed that such severe removal of the black match coating would necessarily result in successful propagation in a length of quick match that has a closed end. Nonetheless, that the segments of quick match with 2 inch lengths of washed string propagated fire with only a slight increase in burn time, and that the segments with 6 inches of washed string propagated fire with less than a doubling of the burn time are interesting observations.

The results from these two series of tests seem to be convincing evidence that for otherwise excellent quality quick match, as a single factor, it is unlikely that even the most severe physical damage to the black match coating will cause the failure of the match to propagate fire. However, it is important to note that this is not to say that such damage, in conjunction with other problems, does not contribute to failures of quick match. Absorbed moisture is another factor affecting the performance of quick match. In the next installment in this series the effect of humidity (absorbed moisture) on the performance of quick match will be investigated.

References

1) Val-Et Manufacturing, Inc., RR #1, Box 1117, Factoryville, PA 18419, USA.

2) Primo Fireworks is no longer in operation.

3) Shimizu, *Fireworks from a Physical Standpoint, Part 1*, [Translated from German] Reprinted by Pyrotechnica Publications (1981), p. 14.

QUICK MATCH: THE EFFECT OF HUMIDITY ON ITS PERFORMANCE

K. L. & B. J. Kosanke

PART 4 OF 8 PARTS

Earlier articles in this series on quick match discussed its manner of functioning, some methods for slowing its burn rate, and the effect of powder loss from its black match. The current article presents information on the effect of humidity (absorbed moisture) on the burning of quick match.

For each test in this series, a 16- inch length of quick match, with an additional 4-inch length of black match exposed, was burned. In preparation for the testing, the quick match had been stored for more than a month at approximately 35% relative humidity. For each condition examined, three separate test burns were performed, each recorded using a video camcorder. In each test, the end of the exposed black match was ignited, and burn times were determined from a field by field play back of the video tape. The reported burn times were from the first indication of burning entering the match pipe until the first flame or a significant number of sparks were seen exiting the other end of the quick match segment.

The constant humidity chambers (hygrostats) used in this study were simply constructed using plastic containers approximately 14xl0x6-inches, purchased from a discount store. These boxes were chosen because their lids fit well and the seal could be made fairly tight by placing weights on the lids. Two smaller containers were placed inside each plastic box. Each container was filled with saturated aqueous solutions of either ammonium nitrate, sucrose (table sugar) or potassium sulfate. At the temperature of the lab, the theoretical relative humidity maintained by these solutions should have been approximately 66%, 85% and 97%, respectively.[1,2] (For more complete information on this method of producing constant relative humidity environments, see reference 3.) The quick match segments to be subjected to the various humidities were placed into the chambers for the desired lengths of time.

The relative humidity in the lab during the period of the measurements was only about 35%. Because the chamber lids were removed to load and remove the samples, and because the lids on the chambers did not provide a perfect seal, the relative humidities maintained inside the chambers were less than their theoretical values and they varied somewhat during the course of each day. The relative humidities actually maintained within the chambers were determined using a digital hygrometer (Davis Instruments, model 4080). Those values were approximately 64%, 78% and 90% for the three chambers.

Absorbed moisture has the potential to reduce the burn rate of quick match because thermal energy is consumed in heating and vaporizing the moisture, without contributing any energy to the pyrotechnic reaction. (See reference 4 for a more complete discussion of the factors that affect burn rate.) A brief series of tests was conducted to determine the effect of exposure to higher humidities on the burn rate of unaltered quick match, and the approximate length of time of exposure to reach a steady state condition. The tests were run using Val-Et Manufacturing[5] quick match and the data are reported in Table 1. As can be seen, the range of values for the same conditions is quite wide as compared with the effects being measured (i.e., statistical precision is limited). Nonetheless some things are certain under the conditions of these tests. In all cases the quick match segments successfully propagated fire. However, exposure to higher levels of humidity significantly slows the burning of quick match, and greater slowing was produced as the level of humidity exposure was increased. Also, for these short open ended segments, the effect of the exposure apparently reaches a steady state within about 5 days.

Thus far in this series of articles, three potential risk factors for the proper performance of quick match have been investigated (closure of the fire path, loss of powder coating, and exposure to high humidity). While these do affect quick match performance, for the conditions examined in this study, none were observed to result in its failure to propagate. In the next article, the effect of some combinations of these risk factors will be reported, and will be seen to produce more deleterious effects.

References

1) *CRC Handbook of Chemistry and Physics,* CRC Press (1995) 15-25.

2) Haarmann, personal communication (ca. 1990).

3) "Standard Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions", *American Society for Testing and Materials,* E 104-85(1991).

4) K.L. & B. J. Kosanke, "Control of Pyrotechnic Burn Rate", *Proceedings of the Second International Symposium on Fireworks,* Vancouver, BC (1994) p 241.

5) Val-Et Manufacturing, Inc., RR#1, Box 1117, Factoryville, PA 18419, USA.

Table 1. Burn Times of Unaltered Quick Match Segments Exposed to High Humidity.

Relative Humidity	Burn Times (s/60)[a]			Average[b] Difference (%)
	Longest	Shortest	Average	
	21	17	19	= 0%
64%, 2 days	22	17	20	10%
64%, 5 days	30	14	24	30%
64%, 7 days	28	16	23	20%
78%, 2 days	37	22	31	60%
78%, 5 days	32	22	29	50%
78%, 7 days	34	21	28	50%
90%, 2 days	39	28	34	80%
90%, 5 days	50	29	40	110%
90%, 7 days	48	31	41	120%

(a) Burn times are in NTSC video fields, each 1/60 of a second.

(b) Given the observed very wide variations in burn times, the reported percentage differences must only be seen as very approximate and are reported only to the nearest 10%.

QUICK MATCH: THE EFFECT OF COMBINED FACTORS ON ITS PERFORMANCE

K. L. & B. J. Kosanke

PART 5 OP 8 PARTS

In earlier articles in this series on quick match, methods for slowing its burn rate (fire path closure), and the effects of powder loss and humidity exposure were reported. In some respects, these are all potential risk factors for the proper performance of quick match. The current article presents information on the effects of some combinations of these risk factors.

For each test, a 16-inch length of quick match, with an additional 4-inch (10.0 cm) length of black match exposed, was burned. In preparation for the testing, the quick match had been stored for more than a month at approximately 35% relative humidity. For each condition examined, three separate test burns were performed. Each burn test was recorded on video tape, and burn times were determined from a field by field play back of the tape. Except where indicated, all quick match was from Val-Et manufacturing.[1]

The constant humidity chambers were simple plastic containers, inside of which two smaller containers with aqueous solutions for humidity control had been placed. The quick match segments to be subjected to the various humidities were placed into the chambers for the desired lengths of time. The relative humidities maintained inside the chambers were determined to be approximately 64% and 78%. (For more complete information on this method of producing constant relative humidity environments, see the previous article in this series and reference 1.) In all cases, unless otherwise noted, the quick match humidity exposure was for at least 5 days.

In the second article in this series, the success of some of the methods used to intentionally slow the burn rate of quick match were reported. Two of the techniques were reexamined for quick match that had been exposed to high humidity. The first technique was to tie a knot in the quick match itself. This was chosen because it had been felt that the stiffness of the low humidity quick match segments had made tying a tight knot difficult, and thus possibly less effective than it might typically have been. The second technique was to tie a string tightly around the quick match. This was chosen because it is probably the most commonly used method. Burn times from the original tests (dry quick match) and for the moderate humidity tests are presented in Table 1 ("Knot in Quick M." and "String Tied").

In the current study, it was found that these two slowing methods produced greater delays when combined with exposure to high humidity. This was not surprising; exposure to such humidity was previously shown to increase quick match burn times by about 50%. The additional slowing produced by tying the humidity exposed quick match into a knot was approximately 40%, essentially that which would have been predicted. However, to the contrary, the extreme increase in burn time, approximately 300% (>1.5 s), observed for the string tie method was surprising. This is approximately six times the magnitude of the effect that might have been expected from combining the separate effects. This observation is especially significant because such string ties are commonly used (in securing shell leaders to cylindrical aerial shells, to bags of lift powder, and to finale chain buckets) and because such humidity exposure is not uncommon. It seems clear that short delay hangfires can be produced by nothing more than prolonged exposure to moderately high humidity and tight string ties around shell leaders.

In the third article in this series, the effect of the loss of some or all of the black match coating was investigated. In one series of tests, the black match coating was loosened from six inches near the middle of the quick match segment. This was accomplished by repeatedly drawing the quick match over a mandrill, followed by removal of the loosened powder. The results of the original tests, and the results for identically prepared segments conditioned in the humidity chambers, are reported in Table 1 (labeled as "Damaged"). As expected, there was an increase in the burn times of the segments. However, the amount of increase for the humidity exposed segments was nearly twice that expected for the humidity exposure alone.

Also in the third article, the complete loss of short lengths of black match coating was investigated. To accomplish this total loss of powder from a portion of its length, the black match was removed from the match pipe, some of the coating was removed by physically crushing the black match, and then the strings in that area were thoroughly washed and then dried for a week. For the additional testing reported here, the quick match segments that were prepared as before, but were then conditioned by placing them into the humidity chambers. The results for these tests are also reported in Table 1 (labeled as "Washed"). Exposure to high humidity increased the burn times of the segments, and again the increase in burn time was approximately twice that expected for the humidity exposure (not even including the one time that propagation was unsuccessful).

In another series of tests, the combined effect of having the segments suffer the loss of some coating (method described previously), tightly tying a string around in the area where the powder coating was damaged, and subjecting the segments to high humidity was studied. The results are in Table 1 (labeled as "Dam., S. Tied"). For these, the burn time for dry undamaged segments with a string tied tightly around them was chosen for reference. Reported in a previous article, when the only factor was partial black match powder loss, there actually was an average 15% decrease in the burn time. However, in the current study, the burn time for the combination of the string tie and coating loss did not decrease, rather it increased by 40%. When the effect of moderately high humidity was included, the effect was more extreme (>200%), with some propagation failures.

Finally reported in Table 1 (as "Wash-ed, S. Tied") are results for another test, where-in segments with 2-inch washed sections were tested after tightly tying a string around the quick match in the area of the washed section. Under these extreme conditions, it is not surprising that there was a consistent failure to propagate.

Under the conditions of tests reported in earlier articles in this series, it would seem that high quality quick match can generally suffer any of the individual performance risk factors (closure of the fire path, powder loss, or high humidity) without a serious loss of performance. However, combinations of the risk factors apparently act synergistically to cause much greater losses of performance, sometimes including a total failure of quick match to propagate fire. Of course, one reason this is significant is the hazards posed when aerial shells hangfire or misfire. The next article in this series will examine this in greater detail and will recommend some things that can be done to reduce the chances of malfunctions.

References

1) Val-Et Manufacturing, Inc., RR #1, Box 1117, Factoryville, PA 18419, USA.

2) "Standard Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions", *American Society for Testing and Materials,* E 104 - 85 (1991).

3) Primo Fireworks is no longer in operation.

Table 1. Burn Times of Quick Match in Various Conditions and Exposure to High Humidity.

Condition and Humidity	Burn Times (s/60)[a]			Average[b] Difference (%)
	Longest	Shortest	Average	
Knot in Quick M., 35%	52	30	44	≈0%
Knot in Quick M., 78%	87	41	62	40%
String Tied, 35%	45	21	33	≈0%
String Tied, 78%	162	103	137	320%
6" Damaged, 35%	17	13	15	≈0%
6" Damaged, 64%	30	18	22	50%
6" Damaged, 78%	32	25	27	80%
2" Washed, 35%	26	20	24	≈0%
2" Washed, 78%	74	36	50	110%
6" Washed, 35%	37	34	36	≈0%
6" Washed, 78%	∞[c]	68	71[d]	100%[d]
String Tied, 35%	45	21	33	≈0%
2" Dam., S. Tied, 35%[e]	65	30	45	40%
2" Dam., S. Tied, 64%, 2 D.	69	34	52	60%
2" Dam., S. Tied, 64%	∞[c]	44	107[d]	220%[d]
2" Dam., S. Tied, 78%, 2 D.	∞[c]	89	115[d]	250%[d]
2" Dam., S. Tied, 78%	∞[c]	∞	∞	∞
2" Washed, S. Tied, 35%	∞[c]	∞	∞	∞

(a) Burn times are in NTSC video fields, each 1/60 of a second.

(b) Given the observed large variations in burn times, the reported average percentage differences must only be seen as very approximate, and are only reported to the nearest 10%.

(c) The infinity symbol, oo, was used to indicate that the buming did not propagate to the end of the segment.

(d) The average difference in burn times was calculated using only the results from the two tests in which the buming successfully propagated to the end of the segment.

(e) Two inches of damaged black match in the quick match, around which a string is tightly tied, exposed to 35% relative humidity. (Note that listings also indicate when there were only two days of exposure at the higher humidities.)

QUICK MATCH: HANGFIRES AND MISFIRES

K. L. & B. J. Kosanke

PART 6 OF 8 PARTS

Probably the most notable malfunctions of quick match, especially when used as aerial shell leaders, are hangfires and misfires.

Hang fire - A fuse ... which continues to glow or bum slowly instead of burning at its normal speed. Such a fuse may suddenly resume burning at its normal rate after a long delay. ...If the hangfire goes completely out (is extinguished), it is termed a misfire.[1]

An aerial shell hangfire is hazardous because of its unpredictability. The shell could fire at any time, up to a limit reputed to be about 30 minutes. An aerial shell misfire is a problem because of the necessity to eventually unload the mortar. It is not the purpose of this article to discuss how these malfunctions should be handled once they occur, but rather some things that might be done by the shell manufacturer and display operator to reduce the likelihood of their occurrence.

In earlier articles in this series, the effect of individual performance risk factors (fire path closure, powder loss, and high humidity) were examined for high quality quick match. Under the conditions of these tests, no single risk factor was observed to cause the failure of the quick match. However, in the previous article in this series, the effect of some combinations of risk factors was sufficient to cause malfunctions. If these results are generally applicable, a solution to hangfires and misfires is to eliminate situations where multiple risk factors could occur. Of course, the most reliable way to accomplish this is to avoid even the individual risk factors as much as practical.

In the normal course of its use, it is necessary to make connections to lengths of quick match; for example, when attaching shell leaders to the top of cylindrical shells or to plastic bags of lift powder, and when chain-fusing aerial shells. It is typical to use string or other ties around the quick match when this is done. The strength of the attachment (that which keeps the connection from pulling apart) is often a result of the tightness of the string tie. It was demonstrated previously that a tight tie at a point where there is serious damage to the coating on the black match can cause a malfunction (especially when the quick match has also been exposed to high humidity). However, there are measures that can be taken to limit this potential problem.

Some manufacturers insert a short length of black match into the end of the quick match where a tie will be made. This accomplishes two things. Assuming the inserted black match is in good condition, it is assured that at least that piece of black match will have a good powder coating where the tie will be made. Also, with two side-by-side pieces of black match, it is nearly assured that even a tight tie will not completely close the fire path between them.

Some manufacturers do not rely on tight ties to hold quick match to finale chain buckets or to top-fused aerial shells. Rather they use a combination of a moderately snug tie (a less than completely tight tie) and a small amount of white glue or wheat paste applied to the paper at the point of connection. In addition to reducing the likelihood of completely closing the fire path of the quick match, this provides a strong and reliable connection (not likely to be pulled apart accidentally). Note that a strong coupling can have important safety ramifications. An undetected partial slippage of the shell leader from its point of connection to a top-fused shell can increase the chances of a hangfire or misfire. Similarly, when a finale chain pulls apart while firing, it may cease firing, typically causing someone to approach and reignite the chain.

During the summer months, exposure to high humidity may be inescapable. With high quality materials and manufacturing techniques, this alone may be unlikely to cause malfunctions. However, exposure to high humidity has seriously deleterious effects when combined with other quick match performance risk factors. Thus, at a minimum, nothing should be done to exacerbate the situation. Magazines should be kept as dry as practical, particularly if the aerial shells are not of the highest quality. At the display site too, measures should be taken to limit exposure to high humidity. For example, boxes of aerial shells should not be placed directly on the ground for long periods of time, and most certainly they should not be placed directly on the ground and then covered with a tarp.

The testing that was performed for these articles used only high quality quick match. Thus the results reported in these articles can not be assumed to apply to lower quality material. For example, it was observed that even moderately severe damage to the powder coating on the black match, in the absence of exposure to high humidity, did not result in propagation failures. It is likely that this is a result of one characteristic of high quality quick match, that its black match is made using multiple strands of string, each of which is well coated with composition before being drawn together to form the black match. To the contrary, in recent years some of the aerial shells imported from China have used a single coarse cord for the black match, which is only coated on its outside, and to which there is rather poor adhesion of the powder. It would not be expected that this product would be as forgiving with respect to rough handling, especially in conjunction with any other risk factors.

In addition to those things a shell manufacturer and display operator might do to help reduce the likelihood of hangiires and misfires, there may be some things that the quick match manufacturer might do to make their product less susceptible to these problems. Some of these will be discussed in the next article.

References

1) *The Illustrated Dictionary of Pyrotechnics*, Journal of Pyrotechnics (1995) p 59 and 79.

QUICK MATCH: MOISTURE ABSORPTION BY ITS COMPONENTS

K.L. & B.J. Kosanke

PART 7 OF 8 PARTS

In earlier articles in this series, the effect of exposure to high humidity on the performance of quick match (as a single risk factor and in conjunction with other factors) was investigated. It was observed that moisture absorption as a result of humidity exposure can seriously affect the performance of quick match. Accordingly, it seemed appropriate to examine the moisture absorption problem more closely by testing the materials used to make quick match. The current article is a report on that investigation.

The constant humidity chambers used in this study were simple plastic boxes, inside of which two smaller containers with aqueous solutions for humidity control were placed. The solutions used for humidity control were saturated solutions of ammonium nitrate, sodium chloride, sucrose, potassium nitrate, barium chlorate, and potassium sulfate. At the temperature of the lab (~ 65 °F), the theoretical relative humidities for these solutions would be approximately 66, 75, 86, 93, 94, and 97% relative humidity, respectively.[1-2] (For a more complete information on this method of producing constant humidity environments, see reference 3.) However, because the seals of the lids on the chambers were not perfect, and because the lids were removed daily to load and remove samples, the average humidities were less than the theoretical values. Actual relative humidities were determined using a digital electronic hygrometer (Davis Instruments Model 4080), and were found to average approximately 64, 72, 78, 86, 88, and 90% relative humidity, respectively.

The test samples for this study were either lengths of black match harvested from various manufacturers' quick match and the individual materials used in making quick match. All test samples weighed about 5 grams, were first dried for 24 hours at approximately 175 °F, were weighed and placed into the constant humidity chambers. The samples were weighed daily to monitor their absorption of moisture as functions of time. For most materials, there was very little absorption after one day and no further absorption after 2 days. However, the total time of exposure in the humidity chambers was always at least 4 days. In a few cases, e.g., where the samples liquefied, absorption continued for several days and time of exposure was extended appropriately. Once data collection was completed at one humidity, the sample was placed into the next higher relative humidity chamber.

The samples of black match were harvested from leaders from aerial shells that happened to be available for use in 1994, and some of the shells were then already several years old. Certainly it cannot be assumed that the black match samples used in this study are representative of what that manufacturer may be using on all of their products or are using today. The percentage weight gains for various relative humidities are presented in Table 1. As can be seen, most samples gained between 5 and 7% at the highest relative humidity examined. Note that the Mantsuna black match gained less than half that of any other samples. (The reason for this will be discussed later in this article.) The average black match sample weight gain as a function of relative humidity, is graphed in Figure 1. Notice that the weights gained increase more rapidly for relative humidities approaching 90%. At a relative humidity of approximately 93%, the potassium nitrate in the composition would become deliquescent (would liquefy by drawing moisture from the air).

The weight gain results for materials used in the manufacture of quick match are presented in the Table 2. Both the Goex [4] Black Powder and the rough mixed ingredients, gained essentially the same amount of moisture. Given that the mixture of air float charcoal and sulfur constitute one fourth of Black Powder, they account for about half of the moisture absorbed by the samples of Black Powder and rough powder. High purity (Analytic Reagent grade) potassium nitrate was not observed to gain any moisture. The lower grades of potassium nitrate provided commercially in bulk, that with anti-cake and the agricultural grade material, did absorb moisture. Based on the absorption of the ingredients in the rough powder, it might be expected that its total absorption should have been 3.0% (1.2% + 1.8%) rather than the 2.6%. This difference could simply be a reflection of the limited precision of the measurements. However, it is also possible that it is because the rough powder had been made previously, almost certainly with materials from different production lots.

In manufacturing black match, dextrin (a binder) is usually added to the Black Powder or rough powder. In this study, six other binders were examined to determine whether they would absorb less moisture. The other binders were gum Arabic (more commonly used in the past in fireworks), sodium carboxymethylcellulose (CMC) (also a thixotropic agent, and occasionally used in manufacturing black match), polyvinyl alcohol (PVA) (occasionally used in fireworks), hydroxyethylcellulose (HEC), and two forms of soluble glutinous rice starch (SGRS) (commonly used in the Orient). If the goal is to make black match that is less sensitive to high humidity, it would seem that PVA might be considered as an alternative to dextrin.

In Table 2, note that the cotton string which is used in most high quality black match is another important contributor to moisture absorption. As a contrast, notice that string made from synthetic (plastic) material, does not absorb moisture. This string appears identical to cotton string (but is noticeably stronger). It can be identified by placing it near a flame, where it first melts before it bums with a sooty flame. The use of such non-cotton string may pose a problem regarding difficulty in wetting the string during the black match coating process. However, the use of a small amount of surfactant in the slurry of composition should solve that problem. Recall that the sample of black match from Mantsuna absorbed less than half the moisture of the other samples. This black match is made using such non-cotton (plastic) string, and demonstrates that high quality match can be made using it. In addition to high humidity resistance, another important potential advantage of using the non-cotton string is that it does not smolder, or burn somewhat like a punk, as does cotton string. Of course, the reason this could be important is that it probably significantly reduces the likelihood of hang-fires occurring.

Except for the binders, Kraft paper was found to be the most significant absorber of moisture. However, that is expected to have only a minor effect on the performance of quick match with an unconstricted match pipe. This is because, unlike the string in black match, the paper is not in intimate contact with the pyrotechnic coating. Accordingly, when the black match composition burns, the moisture containing paper match pipe should not be as effective in consuming the thermal energy being produced. However, when string ties are made around the match pipe, there will be tight contact between the paper and black match. In that case, the damp paper could have a greater effect. For example, recall the much greater delay reported in an earlier article when a string was tied around a quick match segment and exposed to high humidity.

One reason for securing finale chains to the mortar racks is that it is reputed to be possible for the leaders of the firing shells to pull apart the fusing to unfired shells. This is predicated on the assumption that the strings in the black match retain their physical strength for a short time after the burning of the quick match. The next article in this series is a report of a brief investigation of the length of time, after the quick match burns, that the strings in black match retain their physical strength.

References

1) CRC Handbook of Chemistry and Physics, CRC Press. **15-25** (1995).

2) D. Haarmann, personal communication, ca. 1990.

3) "Standard Practice for Maintaining Constant Relative Humidity by Means of Aqueous Solutions," *American Society for Testing and Materials,* E 104 - 85 (1991).

4) Goex, Inc., Mick Fahringer, PO Box 659. Doyline, LA 71023-0659. USA.

5) Service Chemical. Inc.. 2651 Perm Ave. Hatfield, PA 19440, USA.

6) Skylighter, Inc., PO Box 480. Round Hill. VA 22141. USA.

Table 1. Percentage Weight Gain of Various Sources of Black Match Exposed to Different Relative Humidities.

	Percentage Sample Weight Gain at Humidities					
Source (a)	64%	72%	78%	86%	88%	90%
Mantsuna	1.3	1.3	1.4	1.5	2.1	2.5
Wandar	2.1	2.4	3.3	3.5	4.1	5.2
Angel Brand	1.9	2.1	3.1	4.1	…	5.4
Temple of Heaven	2.5	2.9	3.0	3.7	5.2	5.6
Primo (dusted)	2.7	3.0	3.9	4.8	5.1	5.8
Horse Brand	3.1	3.3	4.8	4.9	5.4	5.8
Onda	2.6	2.8	4.0	5.1	---	6.2
Yung Feng	3.1	3.3	4.8	5.6	6.0	6.7
Val-Et	3.1	3.3	4.3	5.0	5.3	7.1
Primo (undusted)	3.0	3.6	4.1	4.7	5.7	7.1
Average Gains	2.5	2.8	3.7	4.3	4.9	5.7

(a) All quick match samples dated to approximately 1992.

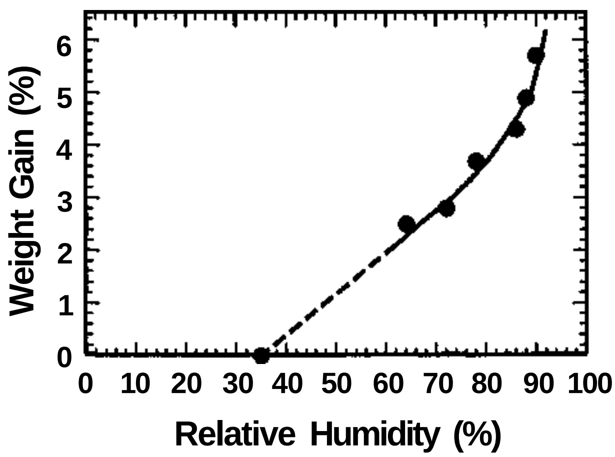


Figure 1. Average percentage weight gain as a function of relative humidity exposure.

Table 2. Percentage Weight Gain of Various Materials Used to Make Quick Match When Exposed to Different Relative Humidities for Five Days.

	Percentage Sample Weight Gain at Humidities					
Material	64%	72%	78%	86%	88%	90%
Goex Meal Powder	1.2	1.2	1.2	2.1	2.3	2.8
Hand Mixed Meal	1.0	1.0	1.2	2.1	2.1	2.6
Charcoal + Sulfur[(a)]	3.4	3.6	3.8	4.2	4.3	4.8
Potassium Nitrate, AR[(b)]	0.0	0.0	0.0	0.0	0.0	.0.0
Potassium Nitrate w/AC[(c)]	0.0	0.0	0.2	0.9	1.3	1.8
Potassium Nitrate, K-P[(d)]	0.2	0.2	0.3	1.5	2.1	2.2
Dextrin	8.9	11.2	14.0	22.3	(e)	(f)
Gum Arabic	11.8	13.9	15.7	16.8	(e)	(f)
CMC[(9)]	21.5	26.5	35.5	52.7	(e)	(f)
PVA[(h)]	5.7	7.9	10.4	16.8	(e)	18.5
HEC[(i,j)]	12	17	26	38	(l)	(l)
SGRS Quick[(j,k)]	11	13	16	20	(l)	(l)
SGRS Waxy[(j,k)]	12	14	16	19	(l)	(l)
Cotton String	5.4	5.9	7.2	9.5	10.0	10.8
Synthetic String[(l)]	0.0	0.0	0.0	0.0	(e)	0.0
30# Kraft Paper	6.7	7.8	10.3	13.2	(e)	15.1

(a) Airfloat charcoal and sulfur in a weight ratio of three to two. Supplied by Service Chemical.[5]

(b) Potassium nitrate Analytic Reagent grade.

(c) Potassium nitrate with anticake, as supplied by Service Chemical.[5]

(d) Potassium nitrate, K-Power, agricultural grade.

(e) Data not taken for this relative humidity.

(f) Sample liquefied.

(g) Sodium carboxymethylcellulose, a thixotropic agent and water soluble binder.

(h) Polyvinyl alcohol, a water soluble binder.

(i) The relative humidities used for this sample differed slightly from those of the other data in this table. The reported percentage weight gain was adjusted slightly by the authors in an attempt to correct for this difference.

(j) Hydroxyethylcellulose, a water-soluble, thixotropic binder.

(k) Soluble Glutinous Rice Starch, supplied in two varieties, "Quick" and "Waxy" by Skylighter.[6]

(1) Samples not tested at these humidities.

(m) The synthetic string had the physical appearance of cotton string. Unfortunately, the type of plastic used to manufacture the string is not known.

QUICK MATCH: SURVIVAL TIME FOR STRINGS IN BLACK MATCH

K. L. & B. J. Kosanke

PART 8 OP 8 PARTS

One reason given for the practice of securing finale chain fusing to mortar racks is that as shells fire, their still attached shell leaders can sometimes pull apart the fusing to yet unfired shells later in the chain. The only way this can occur is if there is sufficient physical strength remaining in the paper match pipe or in the string of the black match, for a short time after the burning of quick match. This article reports on a brief study to determine how long after quick match burns does the string in its black match retain significant physical strength.

There is a solid basis for believing that the black match strings must survive for a short time after quick match burns. In the burning of quick match, a flame front races down the fire path formed between its black match core and its paper match pipe. In this process, a small amount of time is required for the black match coating to be consumed and the strings in the black match to be exposed. Accordingly, the strings are not immediately subjected to high temperatures, and they must retain a significant portion of their strength for a brief time after the quick match flame front has passed.

The apparatus used to make these measurements is illustrated in Figure 1.

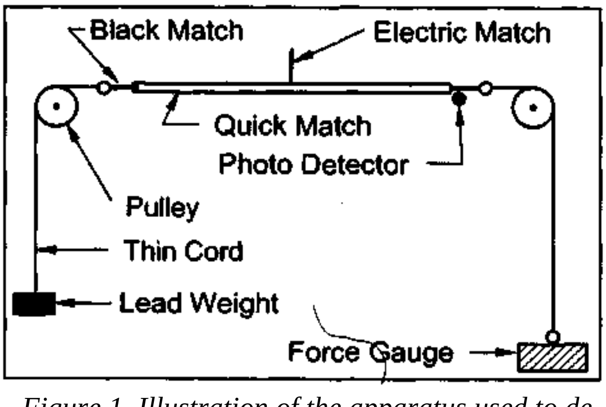


Figure 1. Illustration of the apparatus used to determine black match string failure times.

In the center is a 16-inch length of quick match, with approximately 2-inches of black match protruding from each end. Small loops were formed on the ends of the black match to attach thin cords used to apply tension to the black match. The thin cords were each run over small pulleys, one cord was attached to a piezoelectric force gauge, and the other cord was attached to a suspended lead weight of approximately 2 pounds. Accordingly, as long as the black match strings in the quick match remained intact, there was approximately a 2-pound tension being applied to the force gauge. The means of igniting the quick match was an electric match inserted through the match pipe at. the approximate center of the quick match segment. At one end of the match pipe, a cadmium sulfide photo detector was mounted, for the purpose of detecting when the flame front exited the match pipe. (Note that is not clear whether the detector responded to visible light from the flame or infrared light from hot gases slightly ahead of the flame front.)

A digital oscilloscope was used for timing the events during the tests. The oscilloscope was triggered by the application of current to the electric match. (The level of electric current had previously been determined to be sufficient to cause the firing of the electric match in less than 1 ms.) The output from the photo detector and force gauge was recorded by the oscilloscope. The time for each event was read from the oscilloscope traces knowing the horizontal sweep rate.

For these determinations three measurements were made for each of three humidity exposure conditions. The quick match used in these tests was manufactured by Primo Fireworks[l] and had been stored for more than a month at 35% relative humidity. After being made up as test segments, three were conditioned for 5 days by being placed into a large plastic container maintaining approximately 78% relative humidity. (The method of producing the constant humidity environments was described in earlier articles in this series.) Three other segments were placed into a 64% relative humidity chamber for 5 days, and three continued to be exposed to 35% relative humidity. The results are presented in Table 1.

For the segments conditioned at 35% relative humidity, The black match strings held the weight for approximately 1/3 second after firing the electric match. In this case, the average time difference between detecting fire exiting the match pipe and the strings failing was approximately 1/4 second. Consistent with what was found in earlier testing, exposure to higher humidity increased the burn time of the quick match (in this case there was an approximate doubling of burn time resulting from exposure to 78% relative humidity). Exposure to higher humidity also increased the time before the strings failed; for 78% relative humidity the strings failed after about 1/2 second. However, each time, the net result was that the strings failed approximately 1/4 second after detecting fire exiting the match pipe.

Based on the measured times for aerial shells to exit the mortar, [3] the survival time of the black match strings after the burning of quick match might occasionally be sufficient to infrequently allow firing shells to pull apart the fusing of other shells. However, a proper discussion of this question is more complex than it might at first appear and is beyond the scope of this article.

Caution

The information about quick match performance presented in this series of articles is substantially more complete than has appeared elsewhere in print. Nonetheless, there is much more that should be researched and reported about quick match and its occasional malfunctions (hang-fires and misfires). Great care should be taken in drawing any conclusions from this series of articles. The results reported are reasonably accurate but may only be correct for the materials and conditions of these studies.

Acknowledgments

The authors gratefully acknowledge the suggestions and technical editing assistance of Bill Ofca and Garry Hanson in the preparation of this series of eight articles.

References

1) Primo Fireworks is no longer in operation.

2) K.L. & B.J. Kosanke, "Hypothesis Explaining Muzzle Breaks", *2nd International Symposium on Fireworks* (1994).

Table 1. Black Match String Break Times as a Function of Humidity Exposure.

Measurement and Humidity	Times (s)			Average Difference (s)
	Longest	Shortest	Average	
First Light, 35%	0.16	0.07	0.13	—
String Break, 35%	0.41	0.28	0.35	0.22
First Light, 64%	0.28	0.10	0.20	—
String Break, 64%	0.52	0.39	0.46	0.26
First Light, 78%	0.30	0.22	0.27	—
String Break, 78%	0.56	0.48	0.51	0.24

KL&BJK

OF PYROGEEKS AND CREATION

By Kurt W. LaRue

And God said, Let there be light: and there was light
And God saw the light that it was good ...

Genesis 1: 3 and 4

The pyro cursed the oppressive humidity as another drop of sweat fell into the fine, gray powder he was mixing on the workbench in his tiny, windowless shed. After cleaning up the mess he continued his work, his arms and face coated with black and silver dust, his hands covered with dried glue and his throat burning from the noxious particles that had gotten past his respirator.

As he pasted, pounded and patted, the tan paper cylinder filled with odd smelling chemicals took shape and was nearly finished. One last clove hitch would complete it and he winced as the strong, thin twine bit into his hand, adding a little smear of blood to the mix of stains on his fingers.

It seemed like forever but the sky finally faded to semi-darkness. He hurried to the shed to retrieve the precious cylinder and, cradling it like a baby, made his way to the open field and waiting mortar. After sliding the shell carefully down the pipe he pulled the safety cap off the leader. With a trembling hand he struck a match, lit the fuse and made a hasty retreat. A brief eternity passed until he heard the *swoosh* of burning quickmatch and the satisfying thump of his creation being hurled into the twilight sky. With a golden trail of sparks it tumbled higher and higher until at last - it disappeared! His momentary elation turned to stunned bewilderment. It's a dud! What happened? All that work... His confusion was short lived, however, for at that moment a flash of amber light shattered the dusk. Rays of brilliant, deep electric cobalt streaked outward, then vanished as suddenly as they has appeared. He held his breath and counted silently: one, two, three - a blinding burst of silver-white illuminated the heavens and a powerful shock wave reverberated a shout of success across the valley. He felt as if he were floating higher than the wisps of smoke drifting quietly in the air.

Does this story strike a cord of recognition?

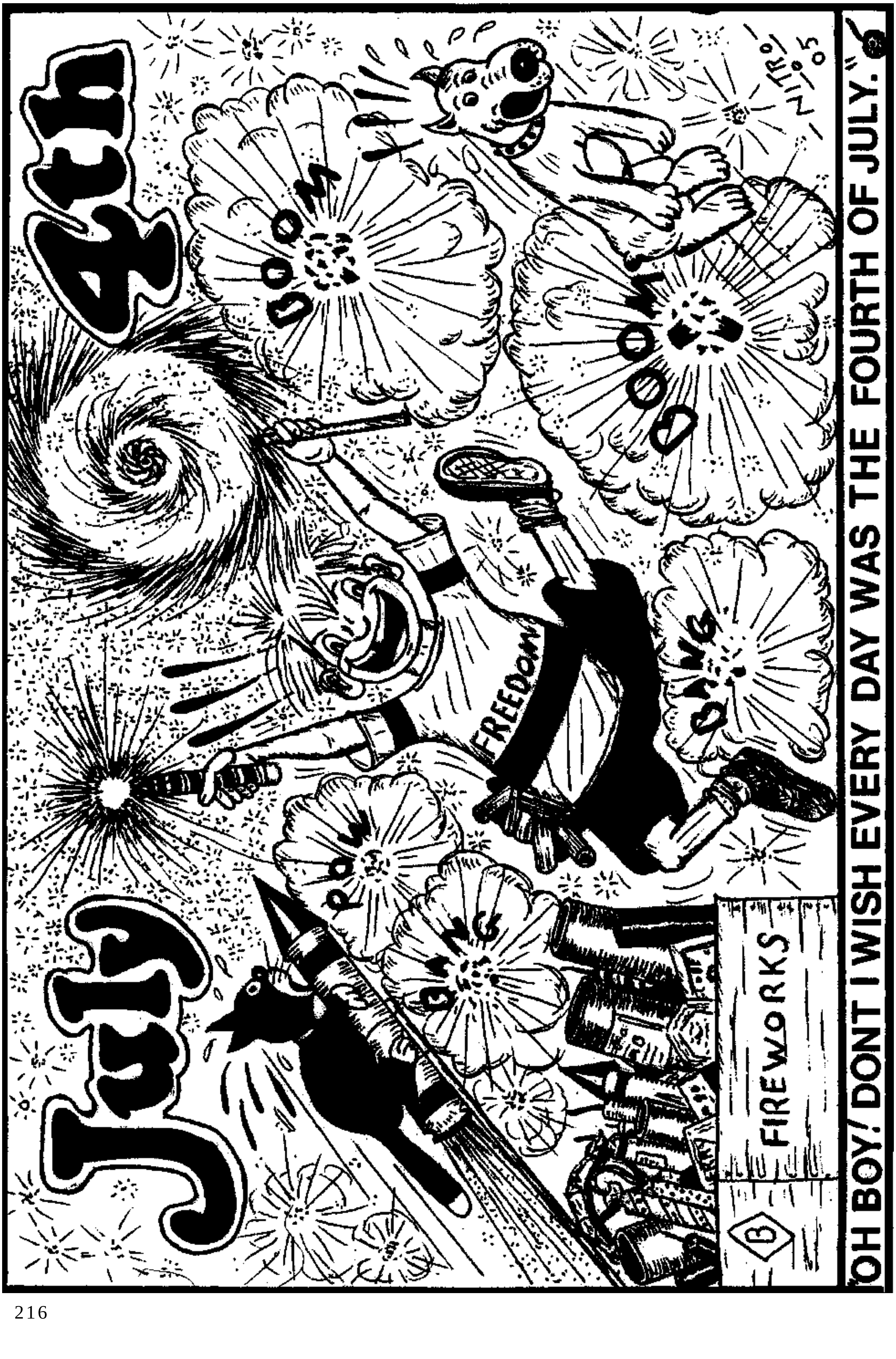
What is it that compels certain individuals to abandon sanity, tempt fate and defy reason? Some form of derangement must grip them and turn them into "pyrogeeks". Perhaps "smelling the smoke" triggers some latent genetic flaw, causing an irresistible urge to mix up batches of toxic and explosive compounds that stain the skin like a sailor's tattoo. Many even risk domestic discord and untold legal nightmares in the pursuit of things pyrotechnic. How many hard-earned dollars are spent on information alone? Pyros purchase every scrap of literature they can find, from entry level how-to articles to college level, theory-laden tomes, in the hopes of gleaning one more bit of pyro wisdom - like a prospector searching for that golden sparkle in his pan.

We are pyros. There are many reasons for doing what we do. For some it may be a need to show off with a "look what I can do" attitude, and for others it may be an addiction to the adrenaline rush of unleashing so much kinetic energy. A few might be lured by the dream of financial gain, though most of us rummage through trash bins for supplies.

I believe there is a more fundamental purpose to our endeavors. We are artists at heart with a need to create, and our chosen medium is light, the first element of creation. Using multifarious materials from the ordinary to the exotic to recreate this first element, we are, in a sense, identifying with the "Master Pyro" as co-creators, producing our own tiny echoes of the Big Bang. The art we fashion can transport onlookers from the grind of daily life to a state of sheer, child-like joy and amazement as they witness the fruits of our labor blossom into brilliant, thunderous life, then fade, again and again. Who could watch the eyes of a spellbound spectator widen with wonder and doubt that there is meaning in what we do, and what greater reward could any craftsman receive?

Upon seeing our first feeble attempt at pyrotechnic glory flash, bang or sparkle, we realize that we have passed the test. We are initiated into that brotherhood and sisterhood of the Greenman, the artists of flame, the co-creators of light.

We are pyros. KWL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