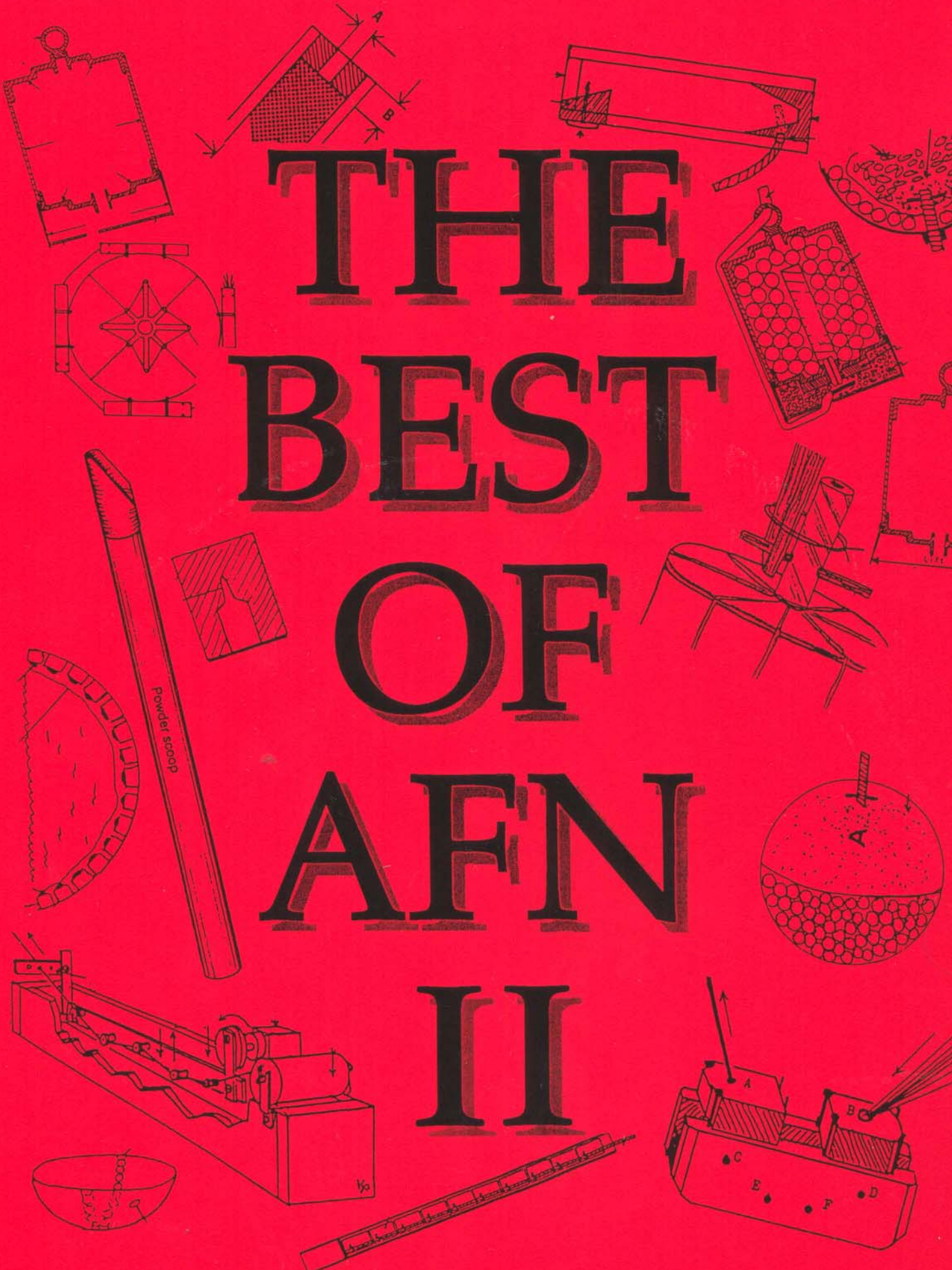


THE
BEST
OF
AFN
II



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AFN

American Fireworks News

THE BEST OF AFN II

Edited by Jack & Dorothy Drewes

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*To George W. Weingart
and Tenny L. Davis*

*those peerless pyros whose books
still form the basis of our education*

WARNING



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

CONTENTS

BASICS, BLACK POWDER, SMALL DEVICES		Gerb Tip	49
		Helpful Hint #3	49
What is a Pyro?	9		
Basic Equipment & Safety	9		
Review of the Basics	10		
Roll Your Own Tubes	11		
Blaster Pastor's Black Match Machine	12		
Black Match Machine	13		
Zippy Stars	14		
Building a Ball Mill	15		
Charcoal	16		
Charcoal Follow-up	18		
Flashlight Holder Aids Displays	19		
Extra Strong Tubes	19		
CIA Black Powder Revisited	20		
Cheap Meal & Rocket Powder	21		
Making Black Powder Lift	22		
Helpful Hint #1	22		
Helpful Hint #2	22		
Real B.P. Please Stand Up	23		
Black Powder on a Budget	24		
Grinding Out Green Powder	25		
Fusee Cones	27		
Titanium Starcrackers	28		
Class C Missiles	30		
Iodine Based Smokes	31		
Big Birds	32		
Class C Repeaters	32		
Buzz Bombs	33		
Flatulent Fireworks	35		
Save Your Old Cakes	36		
Godzilla Powder	36		
Happy Bees Candle	37		
Fire Balloons	37		
Double Voice Crackers	38		
Working With Lampblack	40		
The Burning Mummy	40		
Visco Time Fuse Expedient	41		
Easy Set Piece Building	43		
Tips on Small Set Pieces	44		
Multi-Effect Fountains	45		
Safe Ramming Procedures	46		
Save Those Shells	47		
El Cheapo Fuse Cutting Device	48		
Choked Gerb-Making Technique	48		
A Pyro Wedding	49		
		ROCKETS & ACCESSORIES	
		Basic Skyrocket Construction	50
		Tourbillion Sticks	56
		Fast Rockets in a Hurry	57
		More on Fast Rockets	57
		A Strobing Rocket	58
		Rocket Tips	58
		Rocket Flight Box	59
		Rocket Pellets	59
		Rocket Nose Construction	60
		Stinger Missiles	62
		Multiple-Firing Rocket Rack	64
		STARS	
		Star Formulas	65
		Making Stars	66
		Special Effect Star	66
		Making Cut Stars	67
		1/8" Cut Stars	68
		Stacked Stars	69
		Comets As Rising Tails	69
		Blender Comets	70
		Comet Problems	71
		Comet Composition	71
		The Kamuro Star	72
		A Fierce Yellow Streamer Star	73
		Making Round Stars	74
		Sizzling Colored Comets	76
		Comments on Sizzling Colored Comets	77
		Round Flitter Stars	78
		Lowdown on Gold Flitter	79
		Round Lampblack Stars	82
		Falling Leaf Stars	83
		Crackle Stars	84
		Red Strobe Stars	85
		Micro Stars & Linseed Oil	86
		More on Micro Stars	87
		Sizing Up Your Round Stars	88
		Those Ugly Bumps on Round Stars	90
		Pasta Cores for Round Stars	91
		A New Blue	92

More Blues	93	Dr. Zuffy's Easy Two-Break Shell	137
New Electric Purple	94	Lift Charge Amounts	138
Electric Purple Decomposition	95	Lifting Charges	141
Glitter Crossettes	96	The Crossette Shell	142
Round Stars at Home	97	Tips on Improving Aerial Shells	145
The Dark Side of Pyrotechnics	98	Making Palm Tree Shells	146
Star Testing Device	99	Palm Tree Shell Construction	147
The Cantankerous Crossette	100	Chrysanthemum 6 & 8	150
Homemade Crossette Pump	101	Peppy Shells	151
Simple Crossettes	102	Easy 5" Double Petaled Round Shell	152
Tip of the Month	102	6" Double Petaled Round Shells	154
More on Crossettes	103	An Easy Ring Shell	156
Star Ignition Failure	104	Ring & Character Shell Construction	157
Chart of Fireworks Black Powders	107	Intersector Shell Update	160
		Using Strawboard Casings	161
		Reducing Shell Ignition Failure	162
		Throw Away That Time Fuse	163
		Tamping Stick for Mortars	164
		Push Stick Aids Low Breaks	164
		The Dreaded Dud	165
AERIAL SHELLS		CHEMICALS & SENSITIVITY	
Unconventional Shell Construction	108	What About Flash?	170
Cheap Daylight Shells	109	Things that go "Boom" in the Night	172
2" Displays Shells in a Hurry	109	Chemical Sensitivity	174
The Ascent of Plastic	110	Deathmix	175
RAP* Shell Assembly Techniques	112	Fumed Silica Hazard	176
Whistle Mix Burst	115	Potential Deathmixes	177
An Easy 4" Chrysanthemum Shell	116	Aluminum-Nitrate Reactions	178
Japanese Shell Dissection	117	Spontaneous Combustion	179
The Charcoal Ball Shell	118	More on Spontaneous Ignition	182
Multiple Break Shells	119	Saving Methylene Chloride	183
Pasting Round Shells	121	Auto Ignition Temperature	184
Burst Charges for Round Shells	122	Lead Chemicals	186
Using Bright Aluminum	124	Impact Sensitivity	188
Storage Containers for Stars	124	Dragon Eggs Warning	189
What Are Flash Bags?	125	Notes on Potassium Chlorate	190
Flash Bag Shell Construction	126	Hazards of Blue Star Metals	191
Igniter Flash Bags	129	Armstrong's Mixture	195
Old Lloyd's Igniter Flash	132		
Breaking Paper	133		
Spiking Improves Shells	134		
Shell String	135		
Bowling Ball Shell	135		
Developing Aerial Shell Cases	136		



PREFACE

This is the second book to bear the title THE BEST OF AFN. It contains all the "how-it-is-done" articles that appeared over the years in *American Fireworks News*, *CMPA's Fireworks News*, and even a few from Max Vander Horck's *American Pyrotechnist*. What makes these articles unique and worth producing into a book is that they are the procedures used today by people working in the fireworks trade, or by researchers and experimenters. Taken together, it is an extremely valuable body of information that must be preserved for future pyros.

The pool of knowledge concerning the chemistry of fireworks has advanced enormously since World War II. When you examine books that were available prior to 1945 you will be amazed by the lack of scientific formulations and methods in the procedures employed by the fireworks trade. It was not quite as bad as turn-of-the-century knowledge, when formulations were used that contained as many as ten or fifteen items (including such great stuff as urine). While we still have a great many formulations that are based on experience, we are much more likely to encounter formulations that are based on chemical balance and respect for sensitivity interactions.

As fireworks literature progressed, the first awareness of the error of passing along super-sensitive formulations was felt after the 1947 publishing of George Weingart's *Pyrotechnics*. In a private letter to the late Orville Carlisle, Weingart admitted that he knew some of the cannon cracker formulations in his book were outright dangerous, but he felt they should be published anyway. It is commonly accepted today that potassium and barium chlorates should be avoided whenever substitute oxidizers will suffice. We accept generalizations such as keeping water away from magnesium formulations. And we are learning all the time!

Aluminum-nitrate reactions, keeping water away from aluminum star formulations, extreme care when using lead salts, toxicity dangers with all metal powders - these are some of the facts of fireworks life that we are dealing with today.

If you ever have the opportunity to visit a modern fireworks manufacturing plant you will be amazed by the diversity of personal safety equipment that is in use. You'll see things like electrically grounded floors and workbenches, grounding shoes, 100% cotton clothing, explosion and flash barriers, breathing apparatus, eye protection, face shields, heavy gloves, leather aprons, anti-flash, anti-static coveralls. The employees are trained in safety procedures and how to handle the various chemicals and compositions without poisoning themselves. They are trained in what to do in an emergency. The professional assumes that an incident eventually will happen and works to minimize the damage.

It is not sissy to wear face protection when handling fireworks compositions. It is unwise to think that you are on the cutting edge of research just because you don't wish to follow procedure and do wish to strike out on your own. Just because everybody else is clean, neat and orderly, makes small batches at a time, and follows accepted procedures and practices, it does not make them wimpy and you a genius. Things can happen very fast in chemical and physical reactions.

The information that follows in this book is the best, honest efforts of the many writers who wished to pass on their triumphs and failures in the fireworks field. When reading how they did things, bear in mind that nobody knows everything - omniscience is reserved for God. Some of the writers are well educated and skilled researchers; some are advanced craftsmen. The conditions under which they worked, their level of skill, the complete range of tools and equipment, all of this is different in each case, and most of it is not stated in the individual articles. By publishing the information that follows, we are not encouraging people to manufacture fireworks compositions and devices in their basements or garages. The information is presented as a snapshot of the fireworks world in 1990. Each reader bears the responsibility for his own interpretation of the articles. Development is ongoing. What we know today is the basis for tomorrow's improvements.

Pyro PIPPS

HOT DAMN! WE PUT THE FIRST ONE IN UPSIDE DOWN.



WHAT IS A PYRO?

You talk about pyros who can't pass up a paper tube - this whole thing is insane!

I scrounge for scraps of string, glean gobs of glue, collect cartons of cardboard, pick pieces and piles of paper from the trash and whittle little pieces of wood.

There's no solution for this madness, but in my house, there's a solvent for everything except UFO metal.

You can't find a machine shop in town that I haven't pestered for jelly jars full of chips. In fact, after one auto mechanic found out what I wanted the brake lathe turnings for, he dumped a handful of them on his butane lighter to see what they'd do. And he was just introduced to pyrotechnics!

You can't walk from one end of my garage to the other without spotting boxes, bottles, books and bags, hammers, rammers, sticks and tags. I've got stuff that won't burn, might burn, should burn, will burn and been burned either by accident or design.

My kids want to see more of it, my wife wants to see none of it, I want to see without having purple patches in my field of vision, and my neighbors want to see their lawyers. LORD SAVE ME! PP



BASIC EQUIPMENT & SAFETY

The most used and essential tool is, of course, a "tri-beam" scale. It is imperative that accurate weighing be made when formulas are written in terms of "parts by weight".

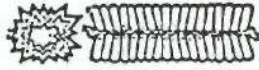
The second most important tools are a pyro's mixing screens. You should build or obtain at least three screens, made of brass or copper, one for oxidizers, another for fuels and the last for compounds. The sides of the frames should be marked this way and used only for each specific purpose. The size depends upon the amount of compounds you use but I have found that about 12-inches square is about right and 20-mesh does a nice job for general purpose work.

Most of my chemicals are kept in 1-quart freezer containers which have the advantage of being light, air tight and cheap. The labels should be on both the top and sides of each container to prevent confusion when two or more chemicals are opened and being used at the same time.

I use scrap computer paper to mix my compounds on and kitchen cup cake papers for weighing. A set of plastic measuring spoons is in constant use.

Now for a few do's and don'ts for the beginner.

1. Do work with small quantities until you are familiar with the compounds.
2. Never grind mixtures or compounds.
3. Never use glass containers for storage (the reasons are obvious).
4. Don't experiment until you have a working knowledge of how chemicals react together and what they are used for.
5. Don't smoke - if you do, give it up or find another hobby.
6. When mixing flash compounds wear protective glasses. It's a good idea to wear them at all times when mixing. GO



REVIEW OF THE BASICS

A general review of basic safety considerations for fireworks makers is perhaps overdue. The newcomer amateur or pro can especially benefit from hard earned experience; mistakes and tragedy should not be relearned in bits and pieces. This only invites history to repeat its tragedies. Nor does space in AFN allow an in-depth and fair study of this vast subject. However, a look at some basics may inspire readers with a thirst for more knowledge and a desire for future existence to do research and ask questions.

It must be borne in mind that any mixture of oxygen and fuel, under the right conditions, may explode if it ignites. It also must be remembered that fireworks mixtures are mixtures of chemically bound oxygen and fuels in solid form. It is therefore the responsibility and duty of all fireworks makers, from the hobby mixer to the industrialist pro, to take all steps to prevent accidental ignition. The second most important duty is to limit exposure by preventative means, should accidental ignition occur. This means limitation of quantities being worked on, and isolation of all other quantities of explosives. It also means to limit the number of workers on an operation to the bare minimum required and to isolate the operation from accidental propagation to all other operations on the premises.

Almost all the ingredients used in fireworks compositions are used as finely divided powders which greatly increases their surface area in the given volume and/or density. For example, a charcoal dust cloud in air exploded violently when ignited. Therefore, all finely divided mixtures of materials should be handled with care. This is especially important with finely divided metals which are hard enough to cause friction, finely divided metals present a hazard to violent explosion when ignited and are susceptible to ignition by static electricity more easily than other mixtures. Steel tools must be avoided in grinding, mixing, charging, pressing, tamping, ramming or other similar loading operations. The almost-as-hard bronze may be used for certain purposes but the much softer brass and lead are safer. Wood and aluminum tools and mallets made of rawhide are safest.

Potassium chlorate, in many ways one of the best fireworks ingredients, may, under certain conditions of temperature and acidity, slowly break down, giving chloric acid or chlorine dioxide, both of which are more active oxidizing agents than potassium chlorate itself. When this happens, potassium chlorate mixtures are extremely hazardous with disastrous results often occurring.

Sensitivity to heat, shock, friction and impact are greatly enhanced by ignition occurring with, in some cases, as little as a flick of the fingernail. Sulfates, sulfides, and sulfur itself may be slowly oxidized to form sulfuric acid, which can then break down to the potassium chlorate into dangerously active chloric acid. Places where plain mixing is done containing sulfur (but no potassium chlorate) must be kept separate from the places where chlorates are mixed. This separation also applies to personnel, clothing, tools and utensils, which should be thoroughly washed between operations. No chlorate should ever be used with ammonium salts because of the chance of forming ammonium chlorate, which violently explodes at the temperature of boiling water (212°F.). All the oxidizing agents, when mixed with finely divided metals, should be handled with extra care and respect.

Carbon (in the form of charcoal, lampblack or carbon black), potassium nitrate and sulfur mixtures seem to be fairly safe to handle, while barium nitrate also seems fairly safe when mixed with finely powdered metals, potassium nitrate and sulfur, finely powdered metals in mixtures with barium and strontium nitrates and potassium perchlorate, even when sulfur is present, seem to be fairly safe mixtures. It is reported, the sensitivity of such mixtures is increased by the addition of powdered charcoal. There is no doubt that charcoal does indeed speed up the burning rate of some mixtures and also lowers the surface ignition temperature of certain mixtures. There is some evidence that in mixtures containing both potassium perchlorate and asphalt gums, after several months the perchlorate is changed into the chlorate with disastrous results. Asphalt gums should never be mixed with chlorates because the asphalt gums contain sulfur or sulfur



acids which break down the chlorates to chloric acid.

The smallest amounts possible should be used when experimenting with new compositions, as the slightest incident can turn a mixture into an explosion.

Magnesium metal powder should be avoided by the inexperienced pyros. This metal must be handled and treated with special coatants before it can be safely mixed with oxidizers to avoid spontaneous combustion. Magnesium does not itself form a protective oxide layer on its surface as aluminum does.

Titanium seems to be relatively safe in regard to spontaneous ignition as it has not been reported to cause such a problem, finely divided titanium powder or dust is a fire and explosion hazard by itself when dry. It is for this reason that titanium dust is packed for shipment wet (with water) in sealed drums. Titanium dust has no useful purpose in fireworks due to its hazardous nature. However, in its granulated form, it is used to make many beautiful (spark) effects. Titanium is an extremely hard metal and as such poses a friction hazard. It especially increases the sensitivity of mixtures containing chlorates or perchlorates. Extra care must be exercised when ramming devices such as whistles, gerbs, fountains, etc, that contain perchlorate and titanium. Ramming of devices containing potassium or barium chlorate should never be attempted, especially if titanium is an ingredient.

During commercial manufacturing, the amount of chemical composition in a building at any one time should be kept as low as possible. The workers should wear nonsparking or conductive shoes. Floors should be conductive as outlined in the National Fire Protection Association (NFPA) publication #99. Cotton clothing should be worn and all metal machinery and moving parts should be well grounded electrically to bleed off static electricity before it can build up a dangerous charge. No matches should be allowed where smoking is permitted to help keep the dangers of smoking under control. Safety training with periodic scheduled safety review meetings with employees and close supervision during working hours are important. WO

ROLL YOUR OWN TUBES

It has always been somewhat of a problem finding (or waiting for U.P.S.) the right size tubes for different applications. I finally started rolling my own. It works for about any size tube, 4 oz. rocket on up, and is very inexpensive.

Using large sheets of chipboard, wall paper paste and the right size dowel, you can make tubes as strong or stronger than commercial types.

Here is an example procedure for a 4 oz. tube:

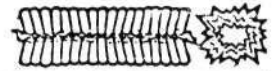
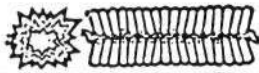
Material required:

- A. Large sheet chipboard (usually obtained from paper supplier by the sheet at 15cent per sheet.)
- B. Wallpaper paste and any old brush.
- C. Dowel 12" 1 x 1/2" o.d..
- D. White glue.
- E. Yardstick.

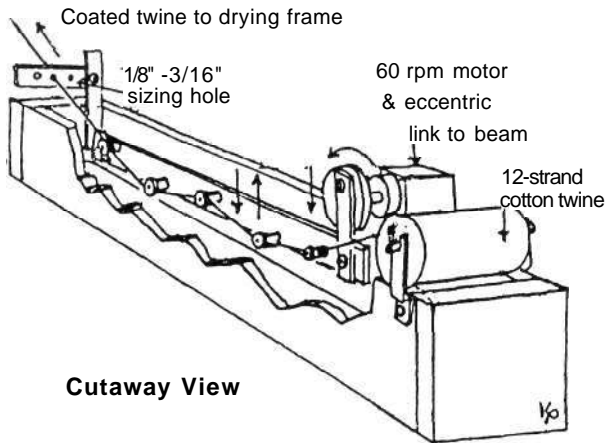
Procedure:

1. I cut chipboard to size (10% x 5"), being sure to make the 10%" cut so to roll with the grain.
2. I mix up the wallpaper paste.
3. I apply liberally (lots) with brush to the cut chipboard strips, about 3 at a time.
4. I start rolling on the 1/2" dowel and use a little white glue at the outside end.
5. Then I press flap down with a flat surface to seal it.
6. I slide off the former, set on end overnight or until good and dry and PRESTO!, Super Tube.

No more looking in trash cans and begging local merchants, hoping to get the right size. I can make any size tube with the right size former. I am thinking of trying a 24 x 3" i.d. mortar tube next. Making 1 1/2" i.d. mortar tubes is a snap. I use a Dial Saw made by SKIL (#73400) to cut any holes from 1-1/8" to 2 1/2" in a block of wood for the base and I have a solid mortar. Then I use a smaller size dowel for making the shells,



THE BLASTER PASTOR'S MARVELOUS BLACK MATCH MACHINE



Cutaway View

So much black match is used in the construction and assembly of firework devices that a means of producing it cheaply and quickly is very helpful. Now our perennially innovative "blaster pastor" B.B. has combined a few odds and ends from his junkbox to construct a real assembly-line setup that will produce and wind for drying 500-feet of blackmatch at a time. The box for coating and impregnating the cotton twine (unwaxed variety, of course) has a length of two-by-four as its base, with the sides and end-pieces attached with screws and finishing nails and all seams caulked with G.E. Silicone Seal.

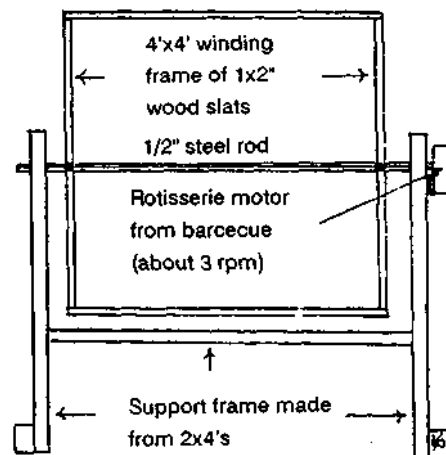
The unique feature of the machine is the "walking beam", pivoted at the far end and moved up and down once a second by the revolving disc and connecting rod at the other. The twine is led from the 1,000-foot reel (about \$13.50) over and under the alternate spools along the beam and out through one of the sizing holes as shown. The spools are turned from 1/2" aluminum rod to form a groove with flanges on each, and the one at each end has a transverse hole bored through it. The twine is fed through the hole to keep it aligned.

The box is then filled with his favorite black powder match coating "soup" to cover the beam, spools and twine, so, of course, all parts it contacts should be of aluminum or other non-rusting material, including the nuts and bolts holding the spools, and the wood should be coated with marine varnish or waterproof resin.

The coated twine is led over to the drying-frame and attached at one corner. The rotisserie motor is turned on, slowly turning the wooden frame bolted to the steel rod and pulling further twine through the coating machine. Both parts of the system should be well aligned with each other and firmly anchored. The two bottom 2x4's of the frame seen only from the front in the drawing, must be long enough to hold it firmly upright against the pull as it winds in the match.

B.B. is already considering such improvements as feeding the twine from more than one reel to form a better-impregnated multi-strand match, and some sort of automated moving guide to space the turns on the frame.

Note: B.B. adds a postscript in a letter received just before closing. He says: "I made two modifications which may improve the speed and make the coating better. First, when starting the 12-ply string thru, I've divided it into four strands of three that should be run thru a plastic block with four holes instead of one large hole. Then the string will follow onto the spindles as before. Second, I've placed a small 1" pulley on the end of the bar before it goes thru the sizing process and gets wound on the rack. Again, it's still experimental and that's what's so intriguing about something like this." MPVH

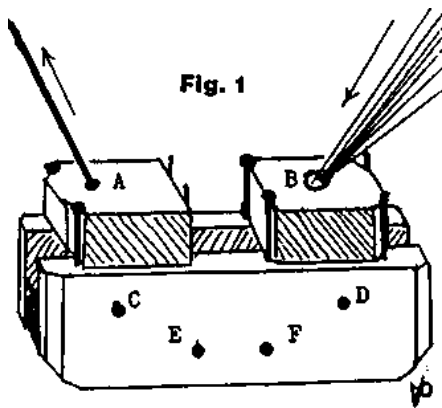




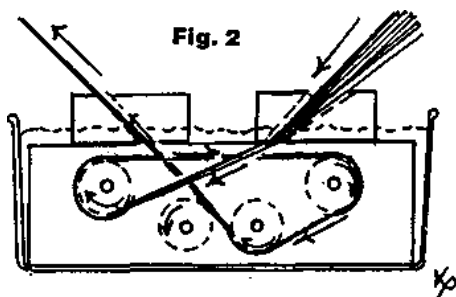
A BLACK-MATCH MACHINE

The idea for this machine was conceived after a tour of a fireworks plant. Their black-match machine was so beautifully simple that I tried using some of the principles in a version of my own. This is the result.

Figures 1 and 2 show the construction, in perspective and side-view cross-section and are rather self-explanatory, except for the following details.



The entire machine was made of hardwood and doweling and a few nails, to fit into a plastic container (not shown in fig. 1). The one I used was 3 1/2" wide, 5" long and 2 1/2" deep, one of the plastic freezer containers readily available. Fig. 2 shows how it fits into the container so that the composition surrounds the rollers. The dotted line represents the top level of the wet composition at the beginning of operations.



For the rollers, indicated by C, D, E & F in fig. 1, I used 3" lengths of 3/4" dowel with 5/16" holes bored through them length-wise and supported by slightly longer 1/4" dowels run through them and set into the frame as shown. Alignment of the frame is assured by a piece of wood fastened

in each end, slightly longer than the rollers, so that they may turn freely.

The two blocks A & B are loosely held in place on top of the frame by nails as shown in fig. 1, to facilitate threading and cleaning, and are removable. They may be made of wood, plexiglass, or hard rubber for durability, as may the entire machine if desired.

Note that in the drawings, the string that forms the core of the match enters the hole B at the right, which should be about 3/8" diameter (not critical), runs over and through the rollers and wet composition, and emerges through hole A, which is just slightly larger than the finished match, in this case a 1/8" hole. Note also that the holes are slanted in the direction of travel over the rollers, as shown in fig. 2.

OPERATION: I begin with seven rolls of thin cotton string (not the waxed variety), arranged on a rack to the right of the machine so as to unwind easily. These are not shown in the drawings. I knot the ends together and pass them down through hole B, around the rollers as shown, and up through hole A. This can best be done while the framework is dry and clean. Now I fill the plastic container half-full of wet composition, place the machine in it, and add enough composition to thoroughly cover the rollers, as in fig. 2. Now I grasp the knot extending from hole A and pull. By entering as seven individual strands and passing over the rollers, the string ends up evenly coated with composition within and without and of even diameter as it emerges from hole A. This is greatly preferable to coating a single strand.

DRYING: The black cord which emerges is the finished match. It needs only to dry. As far as I know, my system for drying is unique. I use two 3-foot lengths of 2x4, into each of which I drive 17 large nails to a depth of about one inch, about 2" apart and in a straight line.

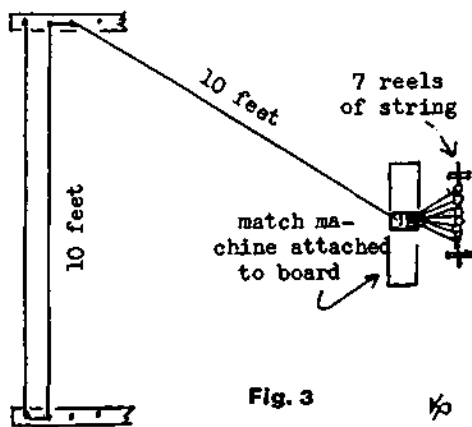
These are arranged in an equilateral triangle with the match machine as shown in fig. 3, and all are fixed in this position by holding down with bricks or other devices. This is very impor-



THE BEST OF AFN II



tant. Trying to work with poorly anchored equipment can be most frustrating. With the arrangement shown, I can make 170 feet of black match in about ten minutes. (For clarity, fig. 3 is not drawn to scale, but shows only the first two strands of match looped around the nails.) The beauty of this setup is the equilateral triangle formed by the two 2x4's and the machine. This means that when I walk from the machine to an opposing nail, the length of match is automatically right.



I pull some of the cord out of the machine and walk to the farthest nail, hooking the knotted end to it. I bring the wet match down to the first nail in the opposite 2x4, around the second nail there, and back up to the first 2x4 as shown, until I have 17 strands of match hooked up for drying. I knot the terminal end and attach it to the last nail. The match emerging from the machine is also knotted for ease in starting the next batch.

I allow the match to dry about two days before using. I then cut it into 2, 3, or 5 foot lengths. It is, of course, **EXTREMELY FLAMMABLE** and I store the match in fireproof containers away from heat or flame.

COMPOSITION: With home-made black powder, this machine will make excellent candle match, burning fairly slowly, and if coiled, enough heat to ignite stubborn mixtures. With commercial powder (4Fg, for example) it will have enough power to eject a parachute, and quickmatch made by enclosing it in a paper tube about 1/4" diameter will ignite a set-piece almost instantly. In both

cases, I add about one to two percent of dextrin or starch to the powder for adhesion to the cord. A representative formula for home-made powder would be: potassium nitrate, 15 parts; charcoal, 3 parts, and sulfur, 2 parts (by weight), with all ingredients powdered as fine as possible before mixing. I add water very slowly, with constant stirring, until a mixture is obtained that will adhere to the string and give a smooth coating as it emerges from hole A. The machine here described will then produce an excellent black match, suitable for many uses. AF

ZIPPER STARS

An intriguing effect can be achieved by binding star mixtures with a high grade nitrocellulose lacquer. I have achieved the best results with DuPont High Grade (ave. 13.35%N) Nitrocellulose, although a lower grade would probably work and might be more readily obtainable.

I mix the NC powder with a half-and-half ether-and-alcohol solution to make a thick lacquer about the consistency of molasses, or I sometimes use acetone alone as the solvent. I then gradually blend with dry star composition until a thick paste is obtained.

I pack this paste wet into thin-walled paper tubes, nominally about 1/2" diameter by 1" long, with my fingers or a spatula, with 1/2" length of stiff black match inserted nearly its full length into the composition before it dries. I dry the stars until quite hard, which may take a full week at room temperature.

When fired from a Roman candle (fused end facing the propelling charge) these stars will, at mid-flight, frequently veer off at (literally) right angles to the initial trajectory. The effect is particularly startling with comet type mixes. The erratic rocket effect is also spectacular when the stars are fired en masse from a mine. I have not tried these in a shell (there may be some detonation hazard from the high NC content). BR



BUILDING A BALL MILL

Ball milling of chemicals is a proven method of finely powdering or incorporating compositions. I have figured out a way of using old phonograph turntables to make operating ball mills in a very simple, straight forward method.

PARTS

1. A used turntable with a good drive that doesn't slip.
2. A pint jar, with lid.
3. Wood or whatever to make axle frame.
4. Wood or metal dowel, 3/8".
5. A wheel, smaller in diameter than the turntable, of light-weight, non-slip material.
6. Contact cement.
7. A few nuts and bolts.
8. Glass marbles to fill jar about 3/4 full.

CONSTRUCTION

I purloined my kid's Erector Set. The parts are excellent for all kinds of pyro work. All of the parts for this project, except the turntable, jar and dowel came from my son's set.

The axle frame is smaller and simpler than the diagram shows. It need be made from material only 1 1/2" wide and thick enough not to be flimsy. It should be mounted on the turntable base so that the axle dowel will be on center line with the turntable spindle and it should be mounted to the turntable base with slotted ports so that it can be adjusted to the correct height when construction is completed. The holes to receive the axle dowel should be drilled after everything is assembled and should be slightly larger than the diameter of the dowel.

It is possible to make the drive wheel out of any handy material as long as a non-slip surface is put on it because the jar, which it drives, has a tendency to slip, especially at the start.

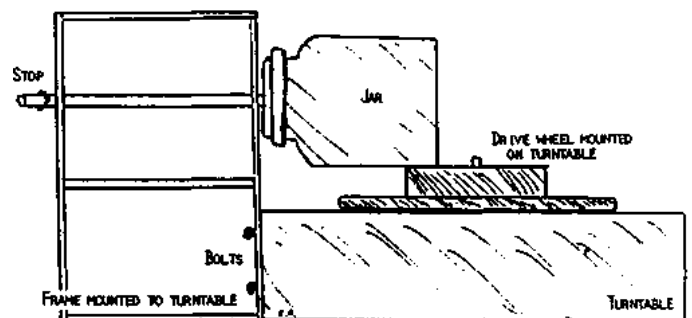
To mount the dowel on the lid of the jar it is necessary to first mount a circle, cut out of wood, to the lid of the jar with contact cement, first I drill a hole in the wood circle, smack in the center, then glue in the dowel. Then I carefully center the circle on the lid top and glue it with contact cement. If these operations are not done carefully, the jar will wobble.

When all the parts are constructed, I adjust the frame so that the slots are centered, that is, I will be able to move the frame either up or down. I screw the jar lid (with dowel in place) onto the jar and place in position on the turntable as shown in the diagram. I mark the spots to drill the axle dowel holes. After drilling, I slide the dowel thru them, then adjust the frame so the weight of the jar will rest on the drive wheel. It may be necessary to put washers on the dowel to keep the lid from rubbing against the frame and maybe put something on the end of the dowel to keep it from riding out of the frame.

COMMENTS

I have used mills like this for three years. They serve my needs very well. The turntable motors are shaded 4 pole type and have no brushes to spark. I have found them capable of milling black powder that is very near to commercial quality.

A pint jar is limited to about 100 gram batches. My procedure is to use the standard mix of 75-15-10 and add 5 grams dextrin. I make sure the potassium nitrate is not lumpy. I put all the stuff in the jar with the marbles, make sure there is a good seal on the lid and then mount it on the turntable. I turn it on, using 78 rpm speed and let it run from 3 to 4 hours. When the powder coats the jar no further milling is useful. I have found that powder produced like this is useful for many purposes, either as meal or damped and granulated by pushing thru a screen. For really fine powder, I mill, damp, dry and remill for a total of three operations. At this point, except for hardness, I think it approaches commercial powder when made into grains. Anon Pyro





CHARCOAL

When studying fireworks formulations, readers will frequently find charcoal represented by the symbol C, for carbon. Readers will be excused from deducing from this that charcoal and carbon are the same animal, but experienced fireworkers know that it is far from the truth.

Charcoal is a complex organic substance containing moisture, ash, carbon, hydrogen, oxygen and a variety of volatiles. All of these materials have vital use in fireworks as anyone will attest who has attempted to use elemental carbon in place of complicated charcoal in his fireworks formulations. Shimizu (*Fireworks, The Art, Science & Technique*) described the charcoal chemical symbol as $C_{20}H_7O$.

U.S.Navy chemist J. E. Rose (*The Role of Charcoal in the Combustion of Black Powder*) found that the performance of black powder was profoundly affected by its charcoal, the characteristics of which were determined by the raw material from which it was produced, and by the temperature of and degree of carbonization. There is no doubt that volatile materials play an important role in charcoal's value in black powder and Rose summed it up this way: "High volatile content carbons lowered the activation energy and reduced ignition temperature of black powder". Further, he found that "The source of the charcoal is an important factor in determining charcoal physical and chemical properties and corresponding ballistics of black powder made with charcoal. Preparation conditions, which include temperature and time duration of charring process, influence the physical and chemical properties of charcoal produced".

Commercially available charcoal in the U.S., the product of hardwood base material, does not offer the optimum product for fireworks use. Charcoal made of pine, the most easily obtained wood in the U.S., is viewed with disgust, while Weingart, Lancaster and Conkling agree that willow is the most desired wood for charcoal to be used in black powder.

Charcoal is the type of fireworks material that can be produced by the user, although the process is laborious and messy. Meticulous

fireworkers with a source of willow wood might find that they can tailor the process to produce a very superior charcoal for their own use, and might even be able to offer the product to other fireworks manufacturers who themselves have given up trying to find suitable charcoal.

The production process is a straightforward matter but the producer must understand what must be done and perform the operations at the correct time. The wood is put into a container and set on fire. At about $300^{\circ}C$. a heat generating reaction begins as a result of the breaking down of the tars in the wood. This tar - water, acids and oils - is driven off as gas. It is this process that the operator uses to determine each step.

A former method of producing substantial quantities of charcoal required digging a pit in the ground, stacking up wood and covering the pit and pile with mud. After the process, the entire mess was destroyed and the charcoal recovered. Alas, charcoal mixed with mud, sand and rocks is useless for fireworks, but there is another way that can produce superior charcoal well suited for fireworks. All that is required is a 55-gal. drum! One drum is capable of producing about 50 lbs. of charcoal a day, and two hard working men might handle 6 to 8 drums per day.

The wood must be debarked but can be dry or green. Wood that has been dried a month in advance is best. The pieces should be no larger than 4" in diameter and no longer than the drum.

The drum is made by first removing the bottom, then two holes 6" square each are cut into the top. At the same time, the plugs are removed from the two top bung holes, leaving four holes in the top of the drum, and no bottom. Now the drum is turned over and placed on two pipes or logs so that the four holes are now on the bottom and elevated from the ground. These holes will supply the air needed for initial combustion.

Wood is now placed in the drum and packed as tightly as possible, with smaller pieces shoved into the spaces between the larger pieces. The wood is stacked vertically. Some space is left in the center which will be filled with leaves and

THE BEST OF AFN II

twigs. When the drum is as full as possible, the fire is started.

Now operator skill determines if the resulting product is charcoal or ashes. The idea is to get a fire burning, then adjust the air supply so that only white smoke comes out of the drum. If black smoke or no smoke at all is seen, the air supply must be adjusted. There are four steps the operator can or must take to make this work:

1) The piece of steel cut out from the bottom (now top) of the drum is placed back in the opening and adjusted to keep a steady flow of thick, white smoke.

2) When this is insufficient, the drum is rocked to reposition the wood inside. It is usually necessary to rock the drum every 15 to 30 minutes. The drum is blazing hot and the operator must devise a method of rocking it without endangering himself.

3) If all is proceeding well, in 30 to 60 minutes it will be impossible to continue the thick, white smoke with Steps 1 and 2. At that time, the drum is lifted off its supports and placed on the ground. This cuts off the flow of air through the four bottom holes.

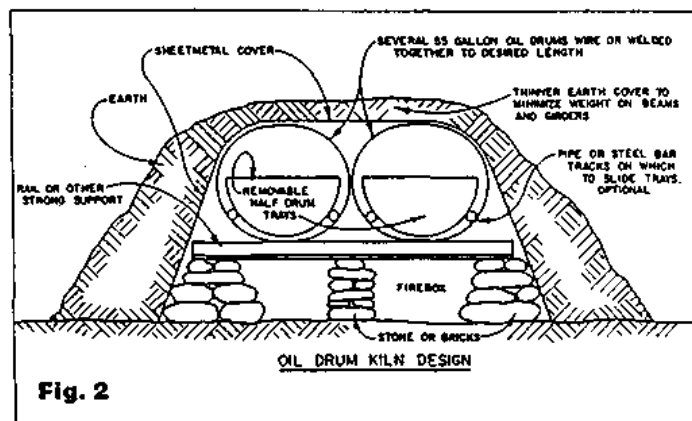
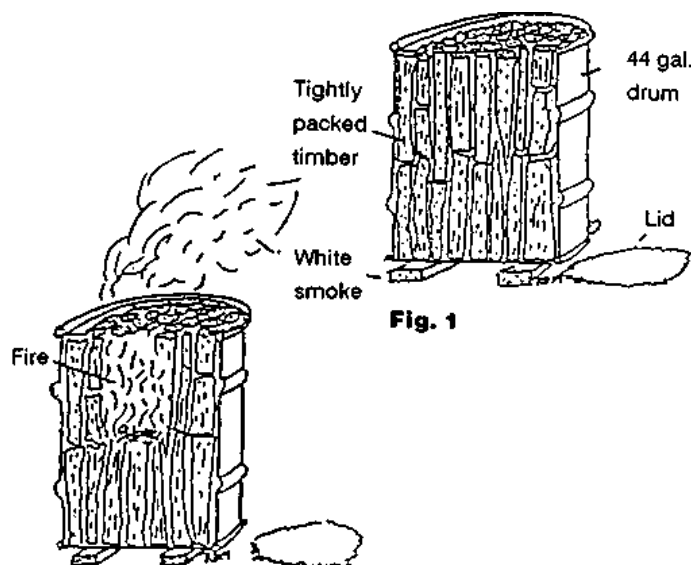
4) After 90 minutes, more wood is added to the drum. These should be short pieces especially saved for the purpose. During the run, the operator will refill two or three times and at the end, the drum will be full of charcoal. The extra wood also helps to cut down the amount of air as the charcoal settles in the drum. The time to add more wood is found when Steps 1, 2 and 3 are not enough to keep a steady flow of white smoke coming out.

After approximately 5 1/2" hours of white smoke, the operator should have a drum filled with red hot charcoal. Now the most difficult part of the process occurs. The drum must be sealed tightly to put the fire out and let the charcoal cool. The cutout top is placed back in the hole, then, holding this in place with a stick, the drum is tipped onto its side and finally completely upside down. Mud is packed around the base edges to seal out the air, then the four holes in the top are plugged. The drum is then left undisturbed until

it is cool, which will be at least overnight. This entire upending and sealing process is fraught with great danger to the operators and extreme care must be exercised to avoid severe burns.

When cool, the drum is emptied and the charcoal examined. The lumps should be uniformly black inside and out. Brown charcoal or unconverted wood pieces should be saved for the next batch. Only perfectly formed charcoal should be removed for use.

An improvement of the single drum method is shown in the drawing. Although this method requires mounding over of the process with earth, yields of up to 30% have been claimed, and the tars driven off can be collected by piping. This ambitious project hardly seems profitable for fireworkers, but readers who wish additional information about making charcoal by the retort method may obtain a 24-page how-to-do-it report shown in the AFN catalog. JD



CHARCOAL FOLLOW-UP

I was excited by the article on making charcoal, but was a little let down when I saw the complexity and scale. Seemed more like something for the person in business. Which is OK. But - there really are easier ways if you just want to make a little.

Anyone lucky enough to have a fairly large wood or coal burning stove, or even a large fireplace, can make charcoal any time the fire is going. I get a "bakery can", the kind bakeries, donut shops, and institutional food consumers get jelly and pie fillings in. I'm sure this is being supplanted by plastic containers, but the metal cans are still around. I make sure it will fit in the hearth with a good bed of coals under it. Usually the lids fit annoyingly tight on these cans, so sealing them is no problem. I punch a small (1/8") hole in the lid, not too close to the edge. That's the extent of preparation. Next I fill the can as completely as possible with the wood of my choice. Since hardwood charcoal is pretty easy to come by, I'm always looking for willow, black alder, poplar, or possibly pine or vine. In any case, I want sticks, free of bark, no thicker than a finger, if possible. I push the lid on, being sure that no sticks are keeping the lid from closing complete. Now it's ready.

If I have a good hot fire going, I try to get it down to red coals, with no chunks of burning firewood sticking up. Then I simply roll the can into the fire, positioning it quickly before it heats up. A pair of work gloves, 'Tough Pig' or the like, are good for this. I usually close the doors and adjust the draft to the max until I can hear the vapor jetting out through the hole in the lid. If the distillation seems to be proceeding too rapidly, I can then open the doors, and let the intruding cool air moderate the temperature, but I have never had to do this. I do have to roll the can over, and perhaps shake it once or twice. The burning gases issuing from the vent hole will undergo all the usual changes associated with charcoal making. I simply wait until the flame goes out, or is only appearing intermittently at longer intervals. At this point the coal is highly calcined, and retains very little volatile matter, and I really don't want brown charcoal. The can will get "red hot" and may dent, but will not burn through.

At this point I must prepare to *Get The Can Outside - Quick!* I usually stack a pad of wet newspapers on the deck, and since I do this in the winter, cool temperatures prevail anyway. I make a couple of "potholders" from more thick, wet newspapers, but not so much that I can't grab the can. I get the doors open - house and stove - and, using my gloves, poker, whatever, roll the can out to the front of the stove opening, grab it in the newspaper, and jog it on outside, being sure to NOT drop it on the carpeting! This cannot be overstated! I let it set outside until cool. Usually only a slight coal tar odor will linger indoors, and the newspapers will be only slightly scorched the first couple of layers down.

I leave the lid on until the can is completely cool, otherwise the coal will ignite shortly after it is exposed to the air. When it is cool, the initial small size of the sticks makes further reduction fairly easy. A hand-cranked food processor is fine for grinding down small amounts.

If interested in pine or hemp coal for Japanese formulas, I can always scavenge the limbs off a discarded Christmas tree, sometimes still available even into late winter, or try grape vine prunings, usually available in the spring and fall. While hemp grows wild in many places, there is some risk in gathering it, as one's intentions may be misinterpreted by the authorities. I might try sunflower or corn stalks, as these are large, pithy, fibrous plants, much like hemp, as well as the aforementioned grapevines.

I have made charcoal this way from apple and pear wood, just to try it, and also made an interesting 'flake' by roasting the coarse chips made by a chain saw. I admit I have not yet done a whole lot with it, but I have plenty of material to work with. I have even roasted iron filings in a frying pan this way, indoors, and went so far as to smelt my own antimony regulas from the sulfide. (Haven't gotten around to pulverizing it yet).

Even without a woodstove, fear not! The best rocket tail I ever got was from charcoal picked up from a bonfire that had burned at an outdoor party the previous night. I poured it into a trash



bag, stuck in a piece of ceramic drain pipe, tied the bag shut around the pipe, set it in a washtub or trash can, and pounded until the bag wore through. Then I screened out the fine stuff. I can often pick up nice hardwood charcoal at state parks on a Sunday evening when all the picnickers' campfires are nicely ashed over and the twigs are glowing beneath. This is one way I can take something left over from a pleasant evening, and bring it to life again to entertain at a later date. It's the easy way if you want to make your own.

JHB

FLASHLIGHT HOLDER AIDS DISPLAYS

Here is a safety tip that AFN readers may find useful.

I fire my Class C displays with a self igniting propane torch. Problem is there is no light to see what I'm doing, as would not be the case if I used a fusee.

My solution: I bought an elbow pad! I wear it on my free wrist. It's simple to place a flashlight between the pad and my arm. The flashlight stays in place and I can direct the light where it's needed, and my hand is still free. LF

EXTRA STRONG TUBES

I got sick and tired of being hit in the leg by flying end caps from my salutes. I also wanted a stronger tube for my weaker flash powder formulas. I got down to business by buying a few rolls of 3" wide, 80-lb. Kraft paper with wettable glue on the back. Wholesale packing or box suppliers have the best prices (under \$2. per 100-ft. roll).

Next I got out a funny looking tool from my leather crafting set (a nail will do). I carefully poke into the middle of the tube's wall from one end so that half of the tube's wall is left as I push it over. Try to think of it this way: look at any standard 1 1/2" cracker; see how the end walls have been pushed in on themselves? Well if not, dissect a cracker and you can see how it's done. I continue pushing in the rest of the wall so that the cracker's end is indented about 3/8". Now I pour epoxy or polyester resin into the indentation and let it harden. In this way, the glued end is as strong as the tube and won't pop out.

I fill the tube one-half to two-thirds full, depending on the formula. I insert a fuse, leaving 2" out for safety. I then fold in the case sides on the top as I did on the bottom. Standing the salute on end, I carefully pour resin into the top indentation.

The finished case is very strong and I can practically guarantee that the ends will not pop out. I suppose that the case could be rolled as thick as wanted but there are limitations on how much of the ends can be pushed in. MB



CIA BLACK POWDER REVISITED

With the sale of the booklet *CIA Field Expedient Preparation of Black Powders* many pyros rushed out to their local stores and purchased potato ricers, and isopropyl alcohol by the gallon. Soon after the little woman had left the house, they proceeded to produce the damnedest mess seen in a pyro's kitchen in quite a while, along with black powder of varying qualities.

However, all is not lost as H.W. Voigt and D.S. Downs at the Seventh International Pyrotechnics Seminar presented a paper dealing with black powder igniter pills produced in part with black powder obtained using a modification of the CIA method. This paper contained several interesting revelations, the first being an early attempt at producing black powder using a "salting out" method (aka, the precipitation method) by one Edward Greene (USP 160,053) of New York, January 25, 1875! Greene's method consisted of mixing the sulfur and charcoal in a saturated solution of potassium nitrate, as close to the boiling point of water as practical, and then removing the excess water by connecting the mixing vessel to a vacuum, with constant stirring. (The boiling point of water at 760mm of mercury (atmospheric pressure) is 100°C. However, if the pressure is lowered to say 100mm of mercury, the boiling point of water is lowered to only 52°C. Therefore, a great deal of water can be removed rapidly (flash evaporation) resulting in the "salting out" of the potassium nitrate.) No doubt due to the difficulties in producing the required vacuum, and for other more technical reasons, this method was never used.

The second revelation is the fact that although generally credited to the CIA, the production of black powder through the use of alcohol as a dehydrating agent was developed at Frankford Arsenal, by T. J. Hennessy. ("Field Expedient Preparation of Black Powders", Frankford Arsenal Memorandum Report M67-16-1, Feb. 1967.) The method they use differed from the "CIA" process in a number of important ways: Whereas the CIA method added alcohol to a mixture of sulfur, charcoal, and potassium nitrate in hot water, Voigt and Downs method mixes the sulfur and activated carbon black (in place of charcoal) in alcohol, along with two other in-

gredients, and then to the mixture is added the potassium nitrate dissolved in hot water.

The details provided by them are as follows:

45 grams of potassium nitrate was dissolved in 45 ml. of water at about 75°C. 2.5 grams of potassium nitrate were added to compensate for loss in the filtrate. (A loss of less than 6% as compared with a loss of over 18% for the CIA method.)

6.24 grams of commercial flowers of sulfur (most pyros do NOT use flowers of sulfur due to the possibility of its containing free acid, so normal pyro grade sulfur should be used) and 8.76 grams of activated carbon black (not lampblack) were suspended with vigorous agitation in a solution of 0.135 gram of polyvinyl pyrrolidone (a dispersing agent - try wetting sulfur some time!) and 0.6 grams of mercaptan terminated polyacrylic liquid polymer (B.F. Goodrich Co. Hycar MTA - a binding agent, don't worry, you can leave it out) in 135 ml. of 95% ethanol. (Isopropyl alcohol is cheaper and just as good.)

The alcoholic suspension of the fuel components was cooled to 15 C, after which the hot aqueous KNO_3 solution was introduced gradually with vigorous agitation whereby the KNO_3 was precipitated in the form of very fine particles intimately mixed with fuel components. The resulting product was then washed with alcohol and dried.

The process was also tried: 1) using channel carbon black, and NO Hycar MTA; 2) using wood charcoal that was ball milled, and NO Hycar MTA; 3) using maple wood charcoal, colloidal sulfur, and NO Hycar MTA; 4) and using a 50/50 mixture of maple wood charcoal, and carbon black power, WITH Hycar MTA. All of these methods produced black powder equal to the standard DuPont (Goex?) black powder when tested in a "Closed Bomb".

I would be remiss if I failed to mention that powder is listed as an explosive in 18 USC section 841(c), and anyone making it would be, in effect, manufacturing an explosive material. DH



CHEAP MEAL & ROCKET POWDER

On the following pages there is an article explaining the advantages in cost savings using fertilizer grade potassium nitrate (KNO_3). Being one who likes to stretch a nickel as far as possible I asked some pyro friends, who had been around awhile, about it. The answers were mostly negative, labeling it as junk. Not easily discouraged (you can't be with this hobby) I located a large quantity of fertilizer grade KNO_3 at a local chemical dealer for about 190 per pound in 100 pound sacks. A customer had canceled his order and they were left with about 100 sacks of the stuff. If you want a sack, you'd better hurry as they have only 99 left.

After many trials, errors and helpful hints from as far away as Maine, I finally came up with a very useful meal powder that can be used for almost anything including fountains, comets, crossettes and rockets, all at a fraction of the cost of technical grade potassium nitrate.

-HERE'S HOW I MADE IT-

To make the basic meal powder I needed: the fertilizer; airfloat charcoal; sulfur; water; isopropyl alcohol; 1 qt. pot; piece of old sheet; coarse mesh screen (window will do).

My technique is:

A. Mix together:

Fertilizer grade KNO_3	375 gm
Air float charcoal	75
Sulfur (fine mesh)	50

B. I pour mix into 1 qt. pot (or old electric skillet if you can steal one) and add 1/2 cup of water, then mix up thoroughly.

C. I heat the mix over low flame or better, a hot plate, to a simmer with constant stirring. A fine mist is given off and crust will form on top of the mix.

D. I remove mix from heat and take outside (very important!). After about 5 minutes I slowly pour in 1/2 cup alcohol. The mix will bubble and give off a lot of fumes for a short while after the alcohol is added.

E. I let cool then remove the excess liquid by placing the mix in the cloth and squeezing.

F. I screen the meal powder thru the window screen. This granulates it and speeds up the drying enormously. If the granulating is difficult, that is, if the stuff is sticking greatly to the screen it means I didn't squeeze it in the cloth enough so I dump it back in and squeeze out more liquid. When going right, the little granules that fall thru the screen look like tiny worms on the catch paper underneath. I then place the batch in the sun to dry, and then pass it thru a 20 mesh screen. That's it.

This meal powder is great for a number of uses, as mentioned before. For example, here's a 4 oz. and 8 oz. rocket mix that really gets them up.

<u>4oz.:</u>	Meal	100 parts by weight
	Charcoal	15

<u>8oz.:</u>	Meal	100
	Charcoal	25

A 36 mesh charcoal gives the rockets a nice tail. If rockets blow, add more charcoal; if too slow, then decrease charcoal.

One of the advantages (besides the cost) of this meal is that it is clean compared to the technical grade and doesn't fly all over the area when being rammed.

I have tried this meal with some of Weingart's formulations; it makes a beautiful silver comet and I see no reason why about 50 grams will not lift a 3" shell up 300 feet. Anon



MAKING BLACK POWDER LIFT

The time has come to mention something about this largely ignored topic. Most pyros I hear from tell me that they use 2FA black powder to lift their round shells. Pyros who cannot obtain 2FA will most often use 2Fg (sporting rifle powder) for lift. 2Fg is a most efficient black powder lift for round shells as it often takes twice as much 2FA to achieve the same lift height.

I use about 20 gm of 2Fg to lift a 3" round shell, 26 gm to lift a 4", and 45 gm to lift a 5" shell. The much larger particle size of 2FA causes the black powder grains to burn longer than 2Fg. This translates to a waste of lift energy as the shell will leave the mortar before the 2FA is completely burned. For cylinder shells and particularly multi-break cylinder shells, 2FA is a good choice as it gives a gentler lift than 2Fg. The use of 2FA will greatly reduce the incidence of flowerpotting of cylinder shells. Round shells being lighter than an equivalent diameter canister shell and possessing greater structural integrity can withstand the powerful kick of 2Fg. Fine grained black powder like 2Fg becomes less appropriate for round shells as the diameter increases. Shells 6" or larger should be lifted with larger grains, such as 1Fg or 2FA.

2Fg grain powder is available at gun shops but is expensive, often costing as much as \$8.00/lb. It is possible to avoid the expense by making lift from ball milled black powder. I use a 6 lb. rock tumbler with a rubber liner to make up 500 gm batches of black powder. For grinding media I strongly recommend the ceramic tumbling media offered by Rich Wolter's Pyro Tools. This media is superior to lead balls in that it does a more efficient grinding job and the media stays clean. One package of grinding ceramic media is the correct amount for 500 gm of composition.

Tumbling black powder always carries the risk of explosion, especially in dry climates, so I DO NOT ball mill anywhere near my work bench, but in an isolated place. I never ball mill compositions containing metals or any other ingredients than the black powder components with or without dextrin: (potassium nitrate 75%/charcoal 15%/sulfur 10%). I want to eliminate any chance of getting any traces of chlorates or

perchlorates contaminating the tumbler. The addition of small amounts of water to the tumbling mix will greatly reduce the explosion risk but if too much water is added the composition will get pounded stuck to the wall and will not mix. I use a couple of sprays of water from a sprayer/mister.

I use fertilizer grade KNO_3 in the granular form which is quite cheap at around 300 a lb. After tumbling or milling for 24 - 48 hours I dump the 500 gm load of black powder in a cake pan and add 85 gm or ml of water. I cover the pan and shake with a circular motion for one minute. The damp black powder is passed through a 10 - 12 mesh screen into a shallow cardboard tray and allowed to dry for 2 days in the shade. Then I pass the dried granules quickly through a somewhat coarser screen to break up any lumps. It is important to remove the fine particles which can make up as much as 10% of the total weight of granulated product. The fines are removed by shaking the granules on the top of a 50 mesh screen. The fines are collected and rewet with the next batch. The resulting product is not as powerful as commercial grain but will be quite serviceable. It is important to make the black powder grains the same way each time so that there is consistency in lift power. I have found that it takes from 70-85 gm to lift a 4 inch round shell to the optimum height. If the particle size is larger than 12-50 mesh, it will take correspondingly more. DB

HELPFUL HINT #1

When making pulverone, use 3x3 hardware cloth instead of 4x4. It is faster and makes a better granule size for most uses. The 3x3 can be difficult to find, but keep looking. HF

HELPFUL HINT #2

#2: One typical problem with pulverone is proper wetness. Too wet and it's difficult to work with. Too dry and it crumbles, causing too much waste. Suggestion - over wet (22%) the meal, make patties like hamburgers, let them dry for hours/days/weeks until they have a firm crust, then granulate. HF



WILL THE REAL BLACK POWDER PLEASE STAND UP

For the last several centuries the two terms Gunpowder and Black Powder have been used to refer to a specific material that can only come from the gunpowder mills. It is material of well known hazards suitable for use in firearms and specifically tailored for that use. Those same mills produce a lesser grade referred to as Black Powder - Blasting, which is still used to quarry building stone.

Anyone who has prepared a mix of 15-3-2, the raw stock for the processing mills that make true gunpowder, has noted the greenish color of the mixture. Raw materials for any process of manufacture are often called "green", such as "green flax" or "green tow" which is a nasty brown color. In the English language raw, unseasoned, unprocessed, crude anything is referred to as "green". It is not right to consider green 15-3-2 as suitable for gunnery. Only the uneducated would call such a mixture "Black Powder" as it is clearly green in color and "green" of processing, and clearly does not perform like the others. Stick a fuse into an opened can of gunpowder and light the fuse. The result is a low power explosion. Fill a similar can with green 15-3-2 and you have a crude fountain. There is a difference.

Pyros preferring the Italian tradition make green mix and call it pulverone; the industry calls it junk mix because it is so cheap. Well it is useful and not junk at all. Even if you use the Waltham Abbey proportions of 15-3-2 for your green mix and ball mill the stuff it is still not gunpowder but simply the same as the feed stock that went into the gunpowder mills - and still does.

The pyrotechnist soon learns that processing the green mixes this way or that makes them perform specifically this or that task better or more easily. I have always taught pyros to control hazard at all times, as well as possible. The best way to do this is often to start with a green mix of whatever kind and use processing to speed up or enliven the performance only enough to do the job at hand.

The soft granulated green mix D.B. describes is going to cost less than one tenth the money real black powder costs. Therefore, one can use a good bit more of it and still save money, but best of all, a gallon container of this material, even though it is much "hotter" than most of our mixes, presents only about half to seventy percent of the hazard that a similar container of real black powder would constitute. A gallon of 4Fg in a plastic jar will make an explosion, with a fireball about 10 ft. in diameter, gasses leaving above the speed of sound in air making the soft "Boom" or "Whoom" type sound that defines an explosion, producing a shock wave in air. The plastic bottle is riven to shreds about an inch in size. The grains of the powder would be driven about 1/20 to 1/8 of an inch into exposed skin about four feet from the container, unprotected eyes would be severely damaged, the burns would take weeks to heal.

The experiments I ran on my own homemade lift indicated that there was much less damage to be expected from the same gallon jar full of this green powder. To begin with, the density of the grains and the powder was much lower, so only about sixty percent as much chemicals (by weight) were present. I side fused both bottles with visco fuse. The green mix was processed as Shimizu describes, the proportions were Waltham Abbey 15-3-2. The grain size of the soft granulated mix was 10 mesh to 14 mesh. The bottle flew about ten feet like a short burn rocket; the burn made a rocket-like whoosh sound, no shock wave in air, no explosion. Most of the bottle was found intact. Not all of the remaining walls of the bottle showed signs of fire or burning. The side of the bottle where the fuse entered had been burned away, the perimeter was still molten. Actually, I had expected far worse. The bottle had opened up a gaping hole in the side and dumped the contents in air where it burned without consequence.

As "witness plates" I had hung wet sheets of 20 lb. bond paper near the bottles, one layer, two



layers, four and eight. The black powder drove grains through the four layer material but not through eight layers. The green mix deposited solids on all but penetrated more. Heat transfer is the most serious burn-producing mechanism in such accidents as were intended to be mimicked here. The burns from both would be serious. The burns from the green mix would probably not require skin grafts; the others would. The black powder would have produced blindness by projected intrusions, the green mix by spot burns. Safety goggles would have saved the eyes in both cases.

Three times in the past I have been burned by such "flare ups" as the green mix produced. They produce ugly looking burns that hurt like the dickens. The skin turns purple, slides off and two months later you need a photograph of the injury to prove that it occurred. I have also had "black powder tattoos" similar to the effects I would expect from the gallon of real black powder. They hurt worse, some slightly, and the black charcoal in the powder gives a tattoo effect that lasts up to two years.

The experiment confirmed the superior safety value of homemade lift. In general, it is always smart to use the least violent burning mixture that will suffice. By actual accidents, the green lift does not produce the serious projectile wounds that gunpowder does.

The green powder lift used above is all I have used for years to lift shells. It does very well for shells larger than five, seems best for fives, will work for fours and if enough is used, it will lift threes. For anything smaller I would recommend black powder instead. LSO

BLACK POWDER ON A BUDGET

If you're a pyro like me, you'll go through a couple hundred pounds of the basic substance every year. My three-foot-high fountains last year consumed many pounds of b.p. I know that there must be an alternative to the costly, hard to come by potassium nitrate (KNO_3), charcoal and sulfur.

Checking at the local commercial fertilizer dealer, I found 100-mesh potassium nitrate in 50-lb. sacks for \$11. each or 220 per pound. That price beats the heck out of the \$2 - \$4 per pound I had been paying. I could tell no difference in final "effect" when using the fertilizer grade as opposed to the technical grade stuff.

While at the dealer, I also spotted some 80-lb. sacks of 86% finely powdered sulfur. Its cost was around 60 per pound! I was concerned that the sulfur would not be pure enough for use in b.p. Upon testing it in my cannon, I was very impressed. No noticeable difference!

Now, what about charcoal? Well, you may laugh, but I use charcoal brickettes. To begin with, I get out an old five-gallon bucket. I throw in about 2 1/2 lbs. of brickettes. While standing over the bucket, I would repeatedly drop an 8-lb. sledge down into the bucket. After the brickettes are fairly well powdered, I would then sift the powder through various sized screens. For really fine powder, I would shake the powder through cheese cloth. Needless to say, the entire charcoal operation is extremely messy. But for only 220 per lb., it's worth it.

It was several years ago that I began making bargain black powder and the price of KNO_3 , sulfur and charcoal has gone up only a few pennies per pound. Still a bargain. The regular pyro chemical suppliers have nothing to worry about. The cheap b.p. will only increase the demand for the more expensive, special-effect chemicals. MB



GRINDING OUT GREEN POWDER

I promised to continue discussing the old mainstay, charcoal, sulfur and nitrate comps, that have had important roles in fireworks for a couple of millennia.

Most fireworks books say sieve the ingredients together after powdering separately. The resulting fluffy mess is almost useless. It fluid flows between ram and case and when you strike the ram a blow it shoots air-propelled mess everywhere. The particle sizes of the commercially sold ingredients are, in the case of nitrate, invariably too large, charcoal the same, and sulfur usually the same.

If you add water to the mix until you can just mold the batch into a lump, then sieve this out on drying trays and sun dry, you form soft, very easily crushed grains that are much easier and cleaner to ram. They powder so easily they are good for virtually nothing else. You can crush a handful of these grains by closing your hand on them, with light pressure. The resulting dust is more dense than the simple mix, and cleaner to handle; it burns a little faster.

Mixtures for port fires, lances, other torch-like goods and rammed items can be made conveniently with comps treated in this manner. The ingredients are held together in microscopic clumps that are likely to retain their degree of mixing on handling better than simply dry sieved mixtures.

If you use boiling water and add enough to make a mudball that shines with a wet surface where you pat it, and sieve this onto drying trays, it will form harder, more dense grains. Under some drying conditions there will be a slight increase in burning speed from the above, but usually a decrease in speed is observed. This degree of wetting is called capillary wetting. Since hot water was used and more of it, more of the potassium nitrate or other solubles dissolved. When the water was removed, the material recrystallized. The size and location of the crystals are entirely

controlled by the drying conditions. It is often the case that poor regulation of the drying causes such large crystals to form that the mix actually burns more slowly than the simple dry mix or the first procedure which has the ten dollar title of "penduncular wetting". The grains are a little more difficult to powder in the hand. The grains so produced are very convenient to handle for ramming, and even funnel and wire ramming will result in moderate compaction. For larger drivers, rockets, gerbs and fountains this is often a good mix and soft granulation process. If you intend to ball mill the mixture this makes a good feed stock for ball mills after drying. The chrysanthemum comps for round stars often improve if they are soft granulated this way and crushed to powder when dry.

Any binder added to either of the above processed mixes will considerably slow the burn rate of the comps. It will also considerably harden the grains. In the case of star comps that will later be used for coating on round stars, the comps may be crushed to fine powder before they are completely dry, at which time binder as dust is added and drying continued. Or if binder was added to the dry mix before water was added, the grains must be crushed while slightly damp.

Chinese writings of about 600 AD describe another process which I often prefer to either of the above. The sulfur and charcoal are blended together and placed in a bowl. The nitrate is dissolved in the minimum of boiling water. Since the solution is saturated with a salt, the boiling point is raised considerably, in the case of potassium nitrate to about 115° C. This you will note, is above the melting point of sulfur. Since the water present is the material of greatest heat capacity and the steam leaving is superheated, some melting of sulfur into the porous charcoal occurs as the hot liquid is added to the charcoal sulfur mix. The faster the wet mix is stirred, the finer the crystals of nitrate will be as they are deposited. The faster the mess is allowed to cool,

the faster the crystals will deposit. The key to this process is speed. The faster you mix, and then cool, the faster the powder will burn. As soon as the material is uniformly blended, it is spread on a cool surface. In ancient China, they poured it onto marble slabs. The more often the material is stirred while cooling, the faster the powder. They used a huge stone roller quickly passed back and forth over the cooling mass.

As soon as the material is uniformly mixed, it can be sieve granulated and dried. Wooden tools are used to handle the hot mass as it is capable of producing severe steam burns to the hands. With practice the hot grains can be made very uniform and may be tumbled while hot to round them a bit and let them collect all the smaller dust as they tumble and cool. Properly made and dried, these grains will serve as lift for shells. They are not as fast or as powerful as real gunpowder, but if you use enough, they get the job done.

This and all other home brew substitutes for real gunpowder that I have seen are erratic in performance. Unlike real gunpowder, the burn rate of the more porous substitutes is highly pressure sensitive. The speed of burning increases with pressure. The flame spread rate is much lower than real gunpowder. It is important to insert extra pieces of black match in the last few inches of leader pipe, at the lift, so the home brew green will receive quite a blast of fire and pressure and begin to try to cough up that shell. It also helps to make the lift bag strong on the sides and weakest on the bottom. It should be well attached to the shell so it forms an obturating cup that seals in the gasses produced. This is easily accomplished by rolling the shell and leader along a strip of paper that has been pasted about half an inch along the upper long edge. This is rolled up at a slight angle to the axis of the shell. The angle is adjusted so that the innermost layer of the lift bag is pasted to the base of the shell and the spiral wrapping allows the pasted paper to stick to the shell and not to the previous layer of the lift bag. The lift is loaded and the layers of the lift bag are folded over the lift one at a time. When the shell fires, the paper will expand

against the base of the pipe until it seals. With this spiral paper bore seal it is possible to lift shells with very poor "powder" indeed.

Concrete is made with sand and gravel; even sand grains can strike sparks, so one should resist the temptation to use cement surfaces as a marble slab substitute. I use wooden spatulas and wear gloves. One good substitute for the marble slab is a sheet of roaster-thickness aluminum foil over a cookie sheet, or pizza pan that contains a solid slab of ice. Remember the nitrate solution should contain the absolute minimum of water. I start with a cup of distilled water to 500 grams of potassium nitrate and boil down until a film of crystals forms on the surface. I will never have to cuss lumps of nitrate again.

I will always remember how amazed I was at the difference between the microscopic appearance of my first attempts at fireworks powders, and the materials I recovered from Japanese fireworks. I was eight years old and felt so overwhelmed at the difficulty of making my materials function as well as theirs. Mine had particles of nitrate that looked like rock salt at 400 power. I could not see most of theirs. My charcoal looked like coffee grounds and larger boulders. Their stuff was like tiny black fibers. I could easily see clumps of yellow lumps I knew were sulfur. I could not see the their sulfur. I decided to add a drop of water to each and see what that looked like. To dry out the slides I later heated both with my alcohol lamp. Discovery! Eureka! I could make much of the nitrate in my mix disappear into the charcoal grains much like theirs with hot water. Two weeks later my bottle rockets flew, but not as well as the Japanese bottle rockets. I was about seventeen when I caught up with the performance of the good ones. The formula for my favorite bottle rockets was by a childhood analysis:

Charcoal	36
Sulfur	8
Pot. nitrate	56

LSO

FUSEE CONES

Have you ever wondered about putting to use all of those partially burned red flares (fusees) littering up our roadways? Some might pass up this "free" source of pyro material, thinking it too unbalanced (or mundane) a composition to use. But with some manipulation and modification, this is how I came up with a variety of effects.

(The following is a "rough" explanation only, for my possible usage of fusee composition in pyrotechnic devices. The author assumes no responsibility in offering this information. Readers should ascertain for themselves as to characteristics and suitability of any pyrotechnic composition.)

This is how I make a "Pink Electric" effect cone. I gather a number of discarded fusees and split them open with a razor, then crush the composition to a uniform powder and sift through a window screen size sieve to separate out the sawdust. My area is quite a wet place so I dry the mixture for a few days near the water heater.

Next, I obtain some empty textile cones from one of the many garment factories around town. I press a piece of masking tape onto the small end of each cone. A small batch of plaster of Paris is mixed up and I pour it into the cones to a depth of about 3/4". It is necessary to immediately tap the cone several times against a hard surface to settle the plaster and dislodge any bubbles. The cones are set aside to harden an hour or so and then drilled through to make the nozzle. I use a 3/8" bit in a drill press for an 8" tall cone.

I weigh out each item, place in a plastic bag and mix by gently kneading it until a uniform color is achieved. Then, acetone is added to the bag contents. The correct quantity is determined when (with kneading) I have achieved a dough-like consistency inside the bag. The Parlon and smokeless powder make the mix extremely cohesive (sticky, if over-wet) and I knead in the bag for several minutes to allow permeation by the solvent. At this point, the mass can be turned out onto a protected surface (solvent damage) and cut into stars or pressed into the cone with a dowel. The composition must be as dry as possible but still allow manipulation. (If mix is too damp, shrinkage may occur in the cone while drying, resulting in an explosion upon ignition. Acetone is a fire and explosion hazard as well as being moderately toxic.)

When cone is filled to the desired level, and allowed to dry out for several days, cardboard disks can be pressed and glued in. I have used plaster of Paris as a plug but would not recommend this in practice. (This type of composition can be very water resistant.)

I fill the nozzle with a drossy glitter mix to insure ignition. Performance of this device is a medium dense flitter spray 6"-9" high with a pink primary flame at the cone itself. Nozzle becomes quite eroded due to high temperatures (metals); chipboard walls often burn through on larger cones if untreated. Percentages can, of course, be altered. Smokeless powder can be omitted but spray will not be as high. PE

COMPOSITION

Fusee base (screened & dried)	56.3%
Magnalium (20-60 mesh)	14.1%
Magnesium (100-200 mesh)	7.0%
Titanium (20-60 mesh)	5.6%
Parlon	8.5%
Smokeless Rifle powder (single base)	8.5%

TITANIUM STARCRACKERS

Last Fourth of July I went searching for decent firecrackers that have an attractive flash at night. As you all know, toy firecrackers in this country are limited to fifty milligrams of powder. What I really wanted were some good 180 milligram crackers. Most of the samples I bought were so anemic that only an infrared camera would have noted the light output. I did find one brand that had used a trace of coarse aluminum flake and these did produce a nice "spray" of microscopic sparks that gave off visible light.

I wanted my four and five-year-old sons to have a safe little firework they could make, load and shoot "all by ourselves". We glued short pieces of dowel into short pieces of used Roman candle cases and provided a fuse hole. Using a spent .22 rimfire case for a charging measure (with a wire soldered on for a handle), and firecracker's fuse, the boys had cute little "guns" that "shot real fireworks", with a *ftpt* sound and recoil so low I let the two-year-old shoot them. His aim was a little dangerous until a swat on the pants got his attention. I had cut the fuses off a string of firecrackers by holding the crackers down with a ruler-like board and holding a razor blade knife at an angle as if to cut into and "under" each cracker. The sharp knife cut away the braided line of fuses, which were used later for the "guns".

The boys finger-molded a blob of priming paste on each fuse end and dunked the wet blob in a shot glass containing a teaspoon of rifle powder. The loads shot nearly across the street if fired horizontally. About noon of each day since, the boys have started begging, "Can we go out to the property tonight and shoot our firecracker guns". Obviously, this calls for Stage Two of the lessons in things pyro.

I made a small star pump-like device that allows a firecracker to be inserted, leaving a cavity 9/32-inch diameter and 1/4" deep. I wet the fused

ends of the crackers with a simple prime by dipping a small bundle of them in a thin layer of wet slurry on a plate, load each into the pump and form a star of almost any mix compatible with potassium nitrate-sulfur-charcoal prime, and let dry. These shoot further at night. They are a very nice little fireworks for under two cents a shot. The five-year-old suggested "shoot a bunch all at once", so we will build his first comet rack tomorrow. One thing I should mention, don't let children pump lampblack stars. The composition may be wet and safe enough for children, but the mess is unbelievable. A black mess of this magnitude can cause exploding wife-mother phenomenon.

Back to fireworks. I bought a piece of 5/32" music wire at a hobby store, cut it in half with a grinder, ground smooth the ends with a slight taper. I bought a package of cheap 16 or 20 pound copy paper and found the "felt" or "machine" side of the paper. This side reflects light with less glare. I placed the paper felt side up on the rolling bench and wiped quickly with a very wet sponge. The felt side of paper absorbs water more readily. The water will soak into the paper almost as fast as you can wipe. The sheet will curl and this helps roll a neat tube. I took the wet top sheet off the stack, placed it wet side (felt) down, laid the wire about a quarter of an inch from the edge of the paper, started a loose roll, and rolled the tube and mandrel wire several times with hand pressure until the paper was tight on the wire. I pasted the edges of the paper by unrolling about an inch of paper, rolled back up by hand, then used a board to further tighten the roll. A piece of the tubing used to make the above star pump should easily fall down the tube with at least 1/64-inch clearance. I back rolled the pasted tube once or twice to loosen it on the rod. While the tube is still wet, it should feel like damp leather and like damp leather, easily take a tool impression. I cut the tube into measured lengths; paper 11-inches long will make 7.33 tubes 1 1/2" long.



THE BEST OF AFN II



The old 1-11/16" firecrackers of my youth had this 5/32" bore and they were 9/16" external diameter. The still water-damp tubes are very likely to have flat collapsed ends, so I pinched them to open them and inserted a tapered tool to expand them to fully open. The whole trick of making firecrackers is to keep the tubes damp. As soon as I finished opening a tube, I placed it in a plastic bag or jar, anything to keep the paper damp.

I prefer to crimp one end before restoring it to round. This takes a little practice, but it does save a step. Crimping one end like a firecracker is easy with a tool made of steel wire one half the thickness of the tube wall, or in this case, about 1/32". A short piece of dowel or wood scrap with about half an inch of music wire or broken-off sewing needle works fine. Crimping one end will mess up the other, so it should be opened up and made circular after crimping.

I then make a small bundle of the tubes, open-end up, and sprinkle flash over them until they are full. I rap the bundle on the table to settle the flash, and then crimp in a fuse. Twenty to forty mesh titanium will make the finished article really nice. About 20% additional should work with good flash.

We have made only a few firecrackers here. If larger numbers were being made, it would be wise to allow the flash powder to stand for about thirty minutes before fusing and crimping. This dampness of the flash would greatly reduce the friction and impact sensitivity of the flash powder. An ounce or so of titanium flash can sizzle a fellow and the burns can take a week to heal. Eye injury is likely to be permanent with titanium flash. I always wear eye protection.

If we were making hundreds of crackers the half pound of flash required could cause lethal

damage and would surely cause serious loss of body parts or functions if it went off in one mass. It is necessary to understand the risks and divide up the hazard.

The fuse I like is firecracker type, or blackmatch. I cut it off flush with the case top. While the firecracker is still damp and pliable, I pump the star material on the fuse end. This makes a nice firework for less than one cent that puts commercial Class C to shame. Shot from the same little guns, these are harmless and beautiful. A match box full of titanium starcrackers is a nice little display for the backyard, and it is nicely noisy. The titanium crackers are an eye hazard at six feet from the explosion. The titanium will make burning splinter-like wounds if they go off in your hand, so I don't take chances. A few such crackers in a weak box will pop one at a time. A case in a magazine could detonate.

A dozen of these makes a nice little 1-3/8 inch mine shot and they can be used in small shells. In that case, I would use very bright star comps such as silver waves. Four layers in a 4" shell is about right. Short fat crackers with star heads work better for shells. The audience thinks it a slightly skimpy break, until the "stars" explode and then they yell in surprise.

Short fat cracker stars should be mopped with white glue on the exposed crimp for use in large mines or shells. For the shell crackers, I use the Kraft paper sold in one foot wide rolls at paint stores. I use 1/4" bore, 1 1/4" length to make 7/16" starcrackers.

The small Ti starcrackers make a nice "finale" for comet racks with a wheel between them, especially if the racks are tilted to cross their fire above the wheel.

For quick and easy crackers, I like to use the damp paper trick. LSO



CLASS C MISSILES

For some time now, many of you have wanted Triple G to stock assembly line type parts for making a complete missile. We have now done that. This article will show how to best, and most easily, utilize the materials needed.

MATERIALS: Engine tube - GMC; Body tube - STD; Nose cone - Triple G; Tail fin set - Triple G. Also needed will be certain chemicals, clay, glue, rammer, etc.

ENGINE: Although the engine described here is a black powder version, engines this size are by no means limited to just black powder mixes. Whistle mixes and certain potassium perchlorate mixes may be suitable, with somewhat more care being exercised during ramming.

FORMULA: Potassium nitrate fine powder, 6 parts; Charcoal dust (~ 325 mesh) 1 part; Sulfur, 1 part, all by weight.

This propellant can be hand mixed or carefully ball milled, but I mix it the same every time for consistent results.

Once the propellant is well mixed, the engine is made as follows: I take the 7/16" i.d. tube and place it on a solid work table. The tube can be rammed in a support block of wood or aluminum but that is not necessary. I funnel in a level 1/2 teaspoonful of clay (I prefer Bentonite) and I hit the 7/16" rammer 4 - 5 blows with a mallet. A cooking measuring spoon can be used to great advantage and the rammer can be made from a metal curtain rod or hex-head bolt by cutting off the threaded part with a hacksaw and filing smooth, but should be at least 3" long. Next, 1/2 tsp. of the 6-1-1 comp. is funneled in on top of the clay and is consolidated with 6 - 8 blows of the mallet. This is repeated 2 to 5 times. Three or four increments is a good starting point. A two-stage effect can be made by consolidating 2 increments of plain comp and then two of other comp.

Preferably with a drill press, (but a hand drill will do) I drill a hole thru the clay plug with a 1/8" diameter bit. A good starting place for the 6-1-1 mix is a 1/8" vent. I adjust upward or down, depending on the mix. A spindle could be used

but it cannot be adjusted in forming the nozzle hole. It is easier to adjust the hole size to meet the needs of the comp, until finding the size hole that best works.

IMPORTANT: After there is a correct hole size for the nozzle and I have a smooth, steady performance from the engines, I write it all down and save it for future reference! I won't remember what I did 6 months from now, so I write it down.

ASSEMBLY: I take a finished engine and round off the top end by pressing with my hand against a hard surface while rotating it. I smooth out the inside of the body tube by rotating a pencil or dowel around the inside end. I insert the end of the engine (not nozzle end) into the body tube, grab the body tube 3" or so from that end with both hands for support and push body tube onto engine against a wall or table. The engine can be lightly tapped into place with a mallet. The engine tube was designed to fit tightly in the body tube to eliminate gluing and for a more secure fit. (How many readers have had glue or tape loosen up after your device heated up?) A piece of PVC pipe about 7/8" i.d. can be used for a body tube support.

Note: If a stick is to be used as a stabilization for flight, the engine should be pushed flush into the body tube. If the plastic fins are to be used, 7/8" of engine should be left remaining outside.

FINISHING: The stick or plastic fins I now attach in the appropriate manner. Heading for the rocket is poured into the body tube. (I test my rockets first before putting in the heading.) Then the nose cone is lightly glued in place. A piece of fuse is placed into the nozzle and it is ready for the works.

HEADING: Only experimentation can determine how much heading the rocket can carry. These little things can carry quite a bit but will not lift anything like 3" shells. Be realistic. A little flash or grain powder with some stars, crackers, whatever, will do nicely. The more weight - the less altitude. MG



IODINE BASED SMOKES

Modern colored smoke generation is based on the use of aniline dyes. The technique is established. It works and consistently produces beautiful colored smoke. But before the formulations were established, some curious attempts were made to generate colored smoke with other materials - some rather strange. The seven that follow are based on iodine.

I got them from C. B. Allen, who got them from Hitt Fireworks Co. in Washington. I suppose they date back to the 1920's.

C. B. Allen was a scholarly fireworks man with an itchy foot who worked in fireworks factories all over the country, gathering and spreading formulae, lore, and techniques with a free hand. I came to know him when I worked at Bernie Wells' old Atlas Fireworks plant in Rialto, California, and C. B. would periodically grace the firm with his presence.

As a cautionary note, Attilio Izzo (Pirotecnica E Fuochi Artificiali), says that during World War I some iodine smoke mixtures were tried, but that humidity tended to make them self-igniting and their use was abandoned. I have no first-hand experience with these mixtures and offer them only as historic oddities of interest to lovers of pyrotechnic arcana, and I urge that they be approached with the darkest suspicion.

FOR HISTORIC PURPOSES ONLY

COLORED SMOKE - HITT FORMULAE

Red:

20 parts Potassium Chlorate
12 parts Lactose
20 parts Iodine
36 parts Paratona Red
(Best if burned from bottom)

Pink:

30 parts Potassium Chlorate
20 parts Lactose
20 parts Copper Iodide or
Cadmium Iodide
15 parts Iodine

Violet

30 parts Potassium Chlorate
20 parts Lactose
20 parts Iodine

Yellow:

30 parts Potassium Chlorate
20 parts Lactose
15 parts Litharge
7 parts Iodine

Yellow-Green:

30 parts Potassium Chlorate
20 parts Lactose
25 parts Quicksilver Sulfide
10 parts Cobalt Oxide
5 parts Iodine

Red:

30 parts Potassium Chlorate
15 parts Lactose
40 parts Ammonium Iodide
25 parts Iodine

Purple:

30 parts Potassium Chlorate
15 parts Lactose
40 parts Ammonium Iodide
25 parts Iodine
10 parts Magnesium (powder)

CM

BIG BIRDS

After making a few dozen 4-oz. helicopters I thought to myself that there must be a simpler way to make a flying buzz bomb or helicopter. Why not make a large "Colorful Bird"?

Most things I make seem to be plagued with problems but my "Big Birds" took right off - literally. I've made 1/2" i.d., 3/4" i.d. and 1" i.d. Big Birds. My favorite is the 3/4" one because it uses only a moderate amount of comp. but it takes off with such intensity, it is surprising! I put a bit of flash powder on top so they end with a report.

To make these large birds, I start with a thick walled tube 1 1/2" to 2 1/2" long, depending on the inside diameter of the tube. A 1/8" i.d. tube should be 2" long. I ram very hard a 5/16" clay plug solid on one end. Next I drill a 1/8" hole in the side of the tube at a 45° angle so the tube will spin. I put a piece of green fuse in now. I then firmly ram whistle comp to within 1/2" of the top of the tube. I hand drill a 1/4" hole in the clay end of the tube until reaching the comp. Next I put a pinch of flash powder on top and put a cap on with glue. The bird is finished!

Fortunately or unfortunately, depending on how you look at it, the birds often have a mind of their own. They can go in practically any direction! They usually go straight up after briefly spinning on the ground. I've fused some together and loaded them in a candle tube. What an effect! One other wild effect would be to launch a bunch off all at once. Whatever you do with them, I'm sure you will love these "Big Birds". MB

CLASSC REPEATERS

Things needed:

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

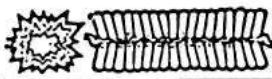
Step 1: First I determine how long to cut the visco because the fuse is what makes the project work. I take the desired number of casings and multiply by 3/4", then add 6". Then I measure the fuse to that length and cut it at a 45° angle.

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

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

Step 4: When dry, I lay the string of casings on the bench, muzzle end toward me. I stand the casings up one at a time for loading. I place the funnel in the end and measure 1/2-teaspoon of black powder into the scoop. Then I measure 1/4-tspn of titanium fines and mix with the black powder. Then I dump this into the casing. Now I add small stars or whatever I wish to produce the desired effect. I have found that 5 or 6 stars from a festival ball works great.

Step 5: Wadding is needed; toilet paper is cheap. I tear a piece in half and fold it until it forms a 1" square. I tamp this wadding down lightly onto the stars. When the casings are filled, I roll the string of casings into a bundle and wrap with twine. That finishes the job. JMcN



BUZZ BOMBS

While this approach to making the helicopter/buzz bomb type of device is really nothing new, I had a lot of fun with the ones I will describe here and thought that others might like to see the materials and composition I used. I had made up a small batch of Weingart's "Wheel Case Composition" drivers using his Formula 2, as follows:

Mealpowder	3
Saltpeter	2
Sulfur	1
Mixed Charcoal	1

I used Meal D, although I doubt this is critical, and 50/50 airfloat charcoal and 20-40 mesh charcoal for the one part of charcoal called for in the formula. After mixing this formula to be used in drivers, I had some left over and decided to try it in a buzz bomb, since I didn't want to make up another special composition for it at that time. It worked beautifully and consistently for the purpose! To make a buzz bomb, I proceeded as follows:

1) I cut a 4-ounce rocket case (1/2" i.d. x 5" long) in half at the center, making two 2 1/2" lengths, only one of which I used for each buzz bomb.

2) I ram in a clay plug with a conical (tapered) rammer, as shown in fig. 1.

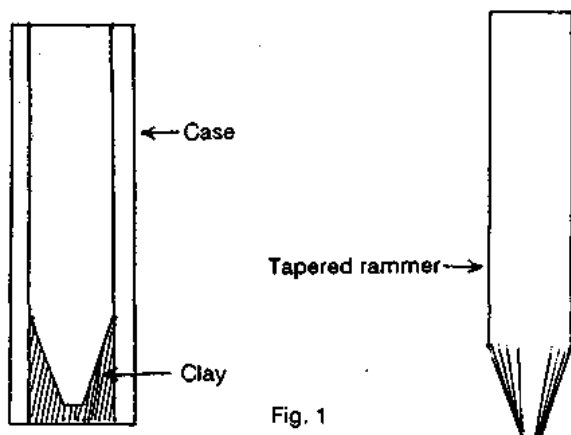


Fig. 1

The best rammers are made of metal; one can be easily made from a V2" wooden dowel. With the dowel in the chuck of a drill press and turning, I shave the end into the approximate shape shown, by means of a block-plane and sandpaper or other suitable tools. The exact angle of the taper

does not appear to be critical as long as it makes a clay plug that stays intact while the comp. is burning. I used a wooden rammer on my buzz bombs and had no problem.

3) I drill a 1/8" hole through the case wall and clay plug, about 1/4" to 3/8" from the end of the case and at a right angle to it, as shown in fig. 2. (I prefer to drill the hole before the comp. is rammed in, although this could be done afterward.)

4) I place a piece of visco fuse in the fuse hole.

5) I ram in the composition with a flat rammer to within approximately 1/4" of the top of the case. I add the powder in three increments and consolidate each with about ten blows.

6) I ram in a clay plug on top of the comp.

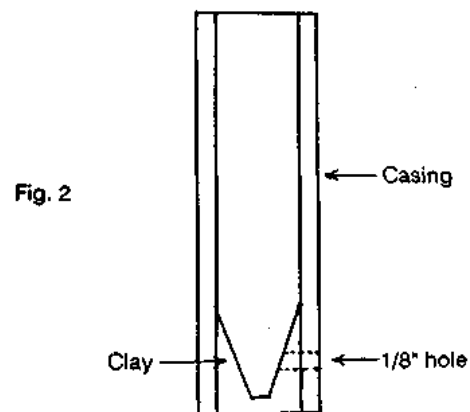


Fig. 2

I next make a wing. While the plastic wing from a "recycled" commercial buzz bomb can be used with success, I made my own in the following manner:

I obtained a 1/2" x 4 1/2" strip of thin wood or a 9" paint-stirring stick and cut it in half lengthwise,

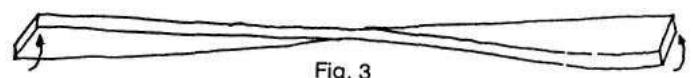


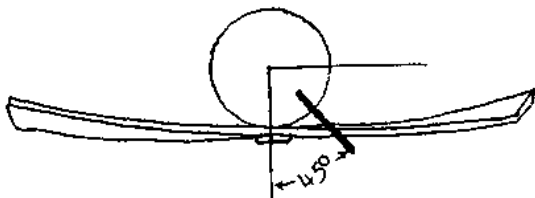
Fig. 3



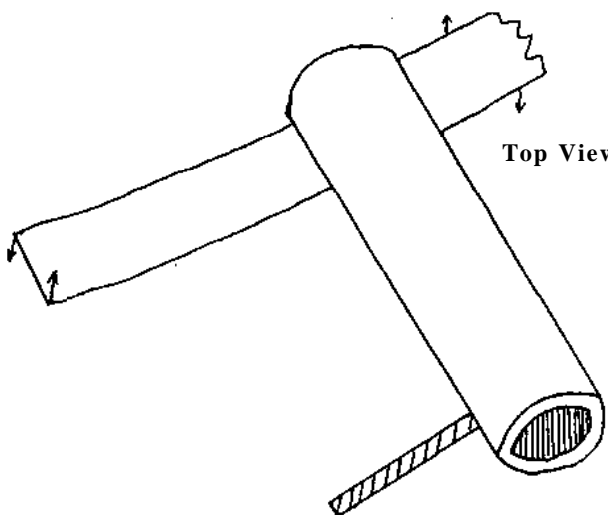
Fig. 4

then I cut the two lengths in half across the grain, which works nicely and gives me enough 1/2" x 4 1/2" strips to make four buzz bombs. Holding one of these over a candle flame, I give the ends a twist in opposite directions. It will then look something like fig. 3. Next, still holding the center of the strip over the candle flame, I bend the ends upward, as shown in fig. 4. I find that the wood bends quite easily over the flame and maintains its shape afterward. Aluminum and other materials could also be used for the wing.

End View



Top View



For the final step I attach the wing to the rammed casing. Using some glue and a thumb tack, I attach the wing flush with the end of the casing, with the fuse at approximately a 45° downward angle to the wing, as illustrated in fig. 5. After some experimentation I find that there is an optimum angle for attaching the wing to the casing, but this does not seem to be extremely critical, as I have had the devices function well with the fuse hole at all angles to the wing. It depends on the effect desired - that is, how fast or slow the buzz bomb will ascend.

Experiments with different types of compositions, such as slower-burning ones, or with glitter, titanium, etc., offer many possibilities. I use a slower composition and alternate it with increments of the regular comp given, so the device could be made to rise, then hover, and then rise again. Garnishments could also be added. To deploy at the top of the buzz bomb's ascent, I drill a hole through the top clay plug (or use a top-hole-making rammer) and add a few stars with blowing-charge or a salute. KO

Cross Section

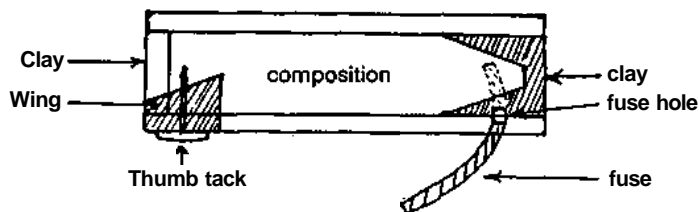
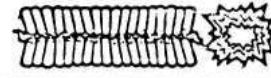
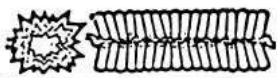


Fig. 5



FLATULENT FIREWORKS

(Sputtering Fireworks)

(A Novel Sputtering Effect)

In the course of experimentation I have discovered what is, at least for me, a new type of firework effect. If a sodium salicylate whistle composition is charged directly atop a nozzle rather than allowing an open unchoked length of tube as in a whistle, a curious "rat-a-tat" or sputtering sound occurs that sounds much like a machine gun or a rapid series of perfectly timed lady-fingers. After a moment, the rate of the sputtering falls and the sound becomes "whooshier", resembling a ruder sound with which we are all familiar, before degenerating altogether into a simple red spray. It is an unusual effect that could have many applications. Examples include use as a kick-off at the top of a fountain or glued to a shell to be heard during the ascent. A shell break full of these little sputters would surely be a crowd pleasing surprise.

The device is pictured in figure 1. The parameters shown are Nozzle Width (A), Nozzle Length (B), and Case ID (C). The first device I prepared had $A=1/8"$, $B = 1/4"$, and $C = 1/2"$. To explore the range of effects that this type of device might yield, I prepared a series of test devices in which each of these three parameters was varied in turn while keeping the others constant at some nominal value. The values that the experimental devices were given appear below.

(A) Nozzle Width: $1/8$, $3/16$, $7/32$, $1/4$, $1/2"$. With $B=1/4"$ and $C=1/2"$ kept constant.

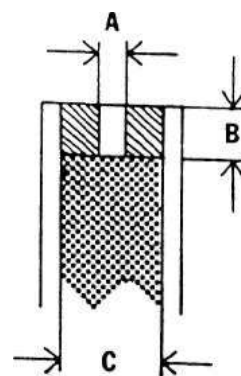
(B) Nozzle Length: $1/4$, $3/8$, $1/2$, $3/4"$. With $A=1/8"$ and $C=1/2"$ kept constant.

(C) Case ID: $1/2$, $3/4$, 1 , $1 1/2"$. With $A=3/16"$ and $B=1/2"$ kept constant.

For all the devices, Ventex was used for the nozzles, the composition was 1:2 sodium salicylate/potassium perchlorate and ignition was achieved by embedding safety fuse into the composition without priming.

Widening the nozzle (A) to $1/2"$ lowered the rate of the sputtering somewhat but the effect did not last as long. In general, variation of the parameters resulted in either no significant change, a spray without sputtering, or an explosion of the case. From these preliminary data, it seems that the basic effect produced by the initial device cannot be significantly modified, at least by these means. Perhaps a different whistle composition would yield variation.

Based on timing data, it appears that, with the initial device, only $1/2$ to $3/4$ of composition burns before the effect wears out. There doesn't seem to be any reason for charging more than this amount of whistle composition since the simple red spray that results is relatively uninteresting. The effect lasts for a total of about five seconds. This would appear to be a novel and interesting effect that could prove useful in many areas of the fireworker's art. I would be interested in hearing from anyone who already uses this effect, can expand upon it, or who can offer an explanation for why it works beyond simply that the nozzle lowers the oscillation frequency of the reaction. Write to me in care of AFN. JS





SAVE YOUR OLD CAKES

Here's a way to save a little money on the cost of paper tubes for your rocket motors, fountains, and wheels. What I did was to collect all the used multi-tube cakes I could find. This included a trip to the Indian reservation stands just after the 4th. Behind the stands I found enough fired cakes, Class C mortars, and rocket sticks to fill a truck. It's smart to also ask your friends and neighbors to save their items.

The trick is to find cakes suitable for the type of rocket motor as found in *The Best of AFN*. The key is simple: wall thickness.

Some of the cakes are thin walled and useless, while others have very thick walls which are suitable for many things. I simply cut off the end of a tube just above the old fuse holes, and then ram in some new clay. (Actually I use Durham's Rock Hard Water Putty).

Now the tube is ready to become a rocket motor, gerb, fountain or pinwheel. I found several size tubes and all worked well for my rocket motors, fountains, etc.

Here are a few of the names to watch for: Blossom after Thunder, 61 shot Reporting Green or Red, Dogfight, 61 shot Purple Ball, Lawman 25 Shots, Missile Base.

I won't be buying or rolling any tubes for a while, and it's a form of recycling that can't be beat. LK

GODZILLA POWDER

I've always enjoyed magic shows, fire eating acts and other fringe type entertainment feats. At the tender age of 18, with the help of a book on circus and carnival life by author Daniel Mannix, I learned to give a right reasonable fire swallowing demonstration. But it was only recently that I discovered how to do the old fire from the fingertips routine without singeing digits or having to bother the folks at the fire dept. Though I do not recommend that you try this, perhaps it is another small addition to pyro lore. The effect: at any point in time, by pointing the index finger at a candle or lighter flame, an 18 inch stream of fire will issue forth, with no fall out, very little residue, and only a small amount of risk.

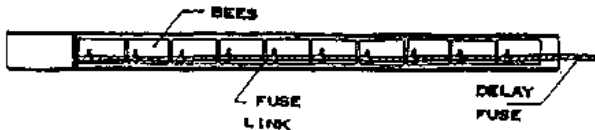
How I do this: The fuel is common tree rosin, available from the local music store in the form of violin rosin. One can attempt to light this stuff all day and it won't do much. I take a piece of #200 sandpaper and rub the rosin back and forth until I have a fine powder. I collect enough to fill a small plastic spray bottle, small enough to conceal in my hand. The orifice might have to be opened a bit to make sure than when the bottle is squeezed, a fine mist of rosin dust is emitted. When the bottle is squeezed over flame - Godzilla has landed!

Further experiments with this are in order, but I wonder if accroides resin (red gum), or fine shellac would give the same effect? Needless to say, I wouldn't try this where there is any danger of fire hazard, eeh



HAPPY BEES CANDLE

Every year we see some fireworks that we wish we had or had more of, after we saw their pyrotechnic splendor. This year after lighting a few different Roman candles, I saw some real winners and some that were not so hot; somehow everyone knew *Flashing Thunder* and *Thunderous Torch* were good but, one of the biggest disappointments and the hardest to find was *Bazooka Magnum*. At three feet long and 1 1/2" thick, it shot one of the smallest balls, and not at all that far or bright. In contrast, a candle that has been around for years, the 13 in. long 3/4" thick *Happy Bees* candle was one of my favorites. They look tiny and of innocent nature, but their performance is excellent - with sound effects. They come in 5 - 8 - 10 ball (*Bee*) and are from China "Flower Basket" brand. They are blue paper wrapped with red writing and are sold in 4 packs or individually at \$1.00 ea. retail, up to \$25.00 gross wholesale. Availability is very good and looks to be so in the near future.



The 10-bee candle I tested shot alternating red and green bees. Bees are small wingless tourbillions about 1" long and 3/8" wide with a highly compressed, fast burning powder. After being lit, you hear the conventional gurgle of a burning candle and then with a whoosh, out emerges a screaming red bee, spinning with tremendous speed. With a whistling buzzing sound, like something right out of "STAR WARS", they dart out as far as 200 feet. Next, the quiet gurgle and another whoosh, with a bright green bee darting off in a similar trajectory, each alternating at about three second intervals until finished.

This simple candle attracts a lot of attention for it's size, but don't be fooled by the small look of it. I have seen very few candles that could throw a ball this far or this bright and you get fantastic sound effects not heard in other candles.

Next time you get bored with the same old candles and you want something different, try a *Happy Bee* and "BEE" happy. KH

FIRE BALLOONS

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

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

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

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

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

Something's amiss if it takes more than a few minutes to construct a fire balloon. And when you watch it glide into the heavens, think of a 4th long ago when there were no fireworks to be had. eeh



DOUBLE VOICE CRACKERS

Just after World War II an independent film company made a film in China which was called "Chinese Firecrackers", but it would have been more appropriately named "Double Voice" crackers, because it showed the manufacture of a popular variety of Chinese firecracker sometimes known as a "Double Voice" or "Heaven & Earth" cracker. The 4th of July Americana Museum confirms this and says that the names "Earth & Sky", "Sky Bomb", and "Bing Bong" have also been used. These "Double Voice" crackers provide an effect similar to an old fashioned two-shot aerial bomb, but the design is different.

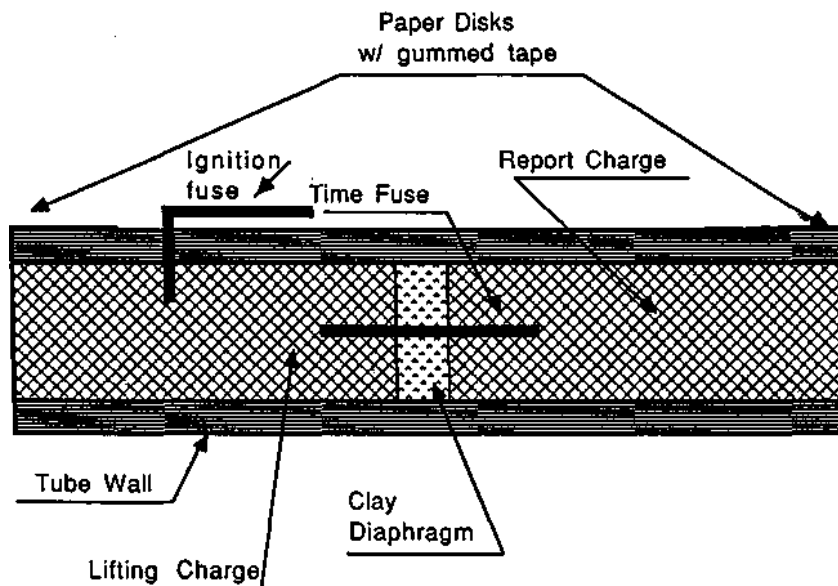
"Double Voice" crackers are designed to be placed upright on a solid surface to be discharged. When the fuse is ignited the bottom charge of the cracker explodes causing it to jump up into the air while igniting the time fuse leading to the second charge. The device then explodes a second time at the zenith of its flight.

I make a similar device by first rolling some 5/8" i.d. parallel wound tubes from heavy kraft paper.

A 5/8" wooden dowel with four or five layers of heavy duty plastic tape rolled around it makes a good case former and allows for the inevitable shrinkage of the drying tube. I try for a tube about 4 1/2" long with a 1/4" thick wall. When dry I trim both ends of the tube with a band saw, leaving a neatly finished casing 4" long.

The manufacture of "Double Voice" crackers requires a special set of tooling. I made a set from 5/8" doweling and a short length of ordinary 2x4" board. I made the ramming nipple by simply cutting a length of 5/8" dowel to 2-11/16" long, and drilling a 5/8" diameter hole 1" deep perpendicularly into the broad side of my 2x4" block. I put a dab of glue in the hole, and then tapped the dowel into it with a mallet until it touched bottom. Next, I used a drill press to drill a 1/8" dia. hole 3/4" deep into the center of the ramming nipple. The rammer can be made in similar fashion, drilling a 1/8" dia. hole 1 1/4" deep into one end of a 5" long, 5/8" dia. dowel. Since visco fuse usually curves a little, I slightly bevel the edge of the rammer hole with a counter-sink drill

Double Voice Cracker





THE BEST OF AFN II



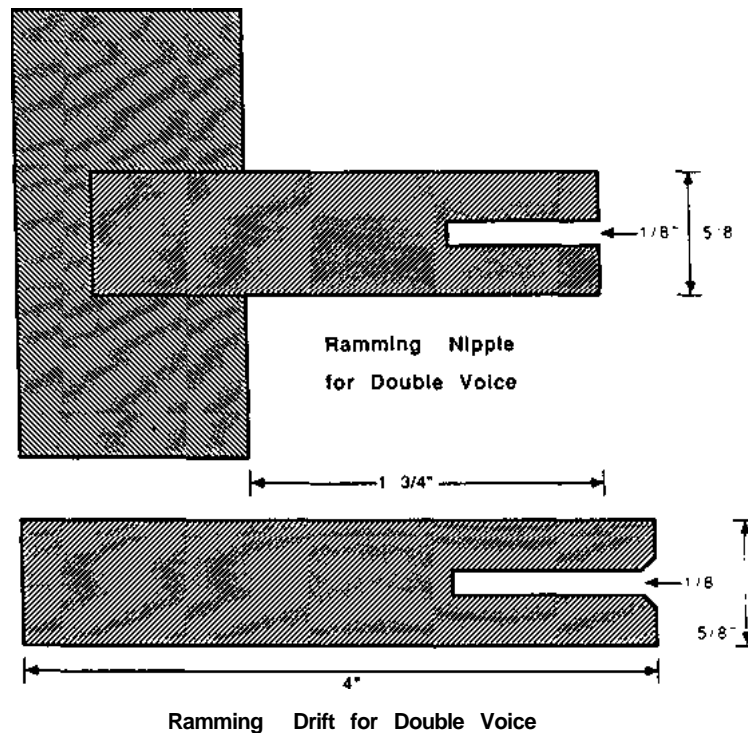
bit to decrease the likelihood of smashing the connecting fuse.

Next I place a 2 1/4" piece of green visco fuse firmly down into the hole in the ramming nipple. Now I take a piece of my hand-rolled casing 4" long and place it over the ramming nipple and snug against the base. Next I pour in 4 cc of Hawthorne Bond clay with a powder loading scoop, enough to make a 1/2" plug when rammed solid. Now I carefully place the rammer into the tube, trying to make certain that the visco fuse slides up into the cavity drilled in the rammer without being crushed. A few moderately hard blows with a rawhide mallet and the diaphragm of clay is set with its connecting time fuse.

In contrast with the Chinese procedure, I next drill a 1/8" hole into the bottom chamber with a drill press, and insert a 2 1/2" piece of visco. Then I completely fill that lower chamber with a homemade meal powder or 4Fg "lift charge", and then cover the powder with a 1" paper disc. I use a piece of 2" wide gummed paper tape about 7" long to seal the disc in place with pleated folds.

The finishing touch is the secondary report charge. In the film mentioned earlier, the Chinese used a nasty composition of chlorate/sulfur/charcoal for their report. As alternatives, I might use an ordinary 70/30 flash report, Dragon Eggs, or even stars and burst. I fill the upper chamber with the desired effect and then seal with another 1" chipboard disc and gummed paper tape over the end. I complete the project with colored paper. The old Chinese ones were sometimes quite elaborately decorated!

To fire, I merely place upright, bottom black powder end down, upon a hard, flat surface, light the fuse and get away. These devices cannot help but fly somewhat unpredictably. The late Orville Carlisle suggested to me that a special launcher made by welding a short iron pipe to a steel base plate would be a good safety precaution with these "Double Kicks" that he loved so well. It's hard to beat these for scaring away the demons at any wedding, baptism, or other occasion for ritual purification. AJS



WORKING WITH LAMPBLACK

Don't you just love a good burst of lampblack stars? In my mind there's not much that beats it. Don't you just hate the mess and clean-up that always goes with it? I sure do. Well, I've developed a neat, clean way to deal with lampblack, or any composition for that matter.

Here's a typical scenario. First off I'll lay a couple of paper towels on the work bench under the ol' 3-beam scale. Then I place an empty 1/2 gallon plastic container on the scale (the bottom half of a 1 gallon plastic milk jug works well). Next (and here's the key) I line the container with a 1/2 gallon size ZIPLOK PLEATED FREEZER BAG. These fit good, are heavy-duty, wide mouthed and sit up straight. You'll still need the container for side support though. I dump in and measure out the chemicals. When done, I simply zip the bag shut and mix the chemicals by slowly shaking and molding the bag in my hands. Normally here is where I'd pour the comp in a stainless steel bowl and wet it. With lampblack I open the bag, pour in the alcohol/water and zip it closed. I repeat the mixing to wet the comp. Then I squeeze it out on some waxed paper. I pat it down using a disposable glove to dry and cut. It's hard to get all the wet comp out of the bag but with lampblack I don't care to mess with it.

Clean-up is a snap. I toss the paper towels, gloves and bag in the trash. No mess or dirty utensils to scrub. This technique sure has helped me. I use it with all my comps now. NC

THE BURNING MUMMY

When it comes to fireworks, kids can be very inventive. When I was a kid, there were times when fireworks were impossible to get, and what kid wants to be without fireworks on the 4th? When the Big Day loomed, you can be sure that all the firecracker-less budding Tom Edisons were searching around for ersatz bangers. (Makes you wonder how many kids would be saved injury from homemade pipe bombs made of matchheads if they could get fireworks legally.)

I clearly recall two things we used to do when regular fireworks were hard to find. One I used to call "The Burning Mummy". It was easy to make and had a very good report, especially since we were close up when it went off. We would take a box of roll caps, the kind used in toy guns. Recently they have sold for 25 cents a box, but were a great deal cheaper years ago. We would not open the box but just simply wrap it in four or five tissues. Then we could lay it down on some concrete walk or other hard surface and throw a large rock or similar object on it. The entire lot of caps would detonate, producing a real nice report and setting the tissues on fire.

We could never walk away from a firecracker that did not work. Kids can do all kinds of things with faulty crackers. When we had a missing fuse or one too dangerously short to light, we would turn it into "The Genie". We would break the cracker in half, leaving the two halves still connected. Then we would simply hold a lighted match to the break. The result was a small shower of sparks, in effect, a miniature fountain. [We called 'em "Sizzlers" Ed.]. Also, if you let them burn for a very short time and then stamped down hard with the heel of your shoe, they would frequently go BANG! Nice effect so close up. TL



VISCO TIME FUSE EXPEDIENT FOR CLASS C

The examination of almost any domestic Class-C aerial shell tube item will show a piece of visco-type safety fuse used as the timing element in the shell. In some cases two pieces are used, no doubt for double dependability. Although visco fuse is adequate for most purposes in commercial fireworks it has two characteristics that make it difficult to use for precise timing. These characteristics are side-spit and side-ignition.

Side-spit is the spit of the flame through the side of the fuse. It is the burning through of the sidewall of the fuse by the flame front as it progresses down the length of the fuse. Side-spit is essential for lighting difficult-to-ignite compounds such as smoke mixtures.

Side-ignition is the sensitivity of the fuse to ignition through the sidewall rather than the end. It is considered a bad characteristic when fuse is too sensitive to side-ignition.

Although various makes of fuse burn at different rates, most burn about 4 seconds per inch (45 seconds per foot). This means that a portion of the fuse will be either inside or outside the casing of the shell, and only a small section will be covered where it passes through the shell wall. The flash of the lift charge is supposed to light the end of the fuse, but if side-ignition occurs close to the casing, the timing will be spoiled. Also, if side-spit occurs on the portion of the fuse inside the shell, premature ignition will result.

Time fuse, as used in display shells, is constructed in such a way that it produces absolutely no side-spit and is totally immune to side-ignition. Down the center of the fuse is a fairly small core of powder ~ small in relation to the diameter of the fuse. Around this core of powder are spun one or more layers of cotton or jute twine, then a thick layer of tar, another layer or two of twine and, in some cases, more tar, then a final wrap of gauze tape finished with a coating of sizing and white clay, or even an extruded plastic jacket.

The tar performs valuable functions, only the least of which is to waterproof the fuse. It completely covers the core so as to prevent side-spit and side-ignition. Just as important, however, is the fact that as the fuse burns, the tar softens, expands and melts, allowing the hot combustion gases to escape readily into the atmosphere. Without this venting quality, the gases would build up pressure, expand the core, shoot through, much as in quickmatch, and destroy the effectiveness of the timing. Another noteworthy feature of the tar is that it renders the fuse virtually unlightable with a match. Unauthorized (inexperienced) people find it very difficult to ignite time fuse that contains an asphalt or tar layer.

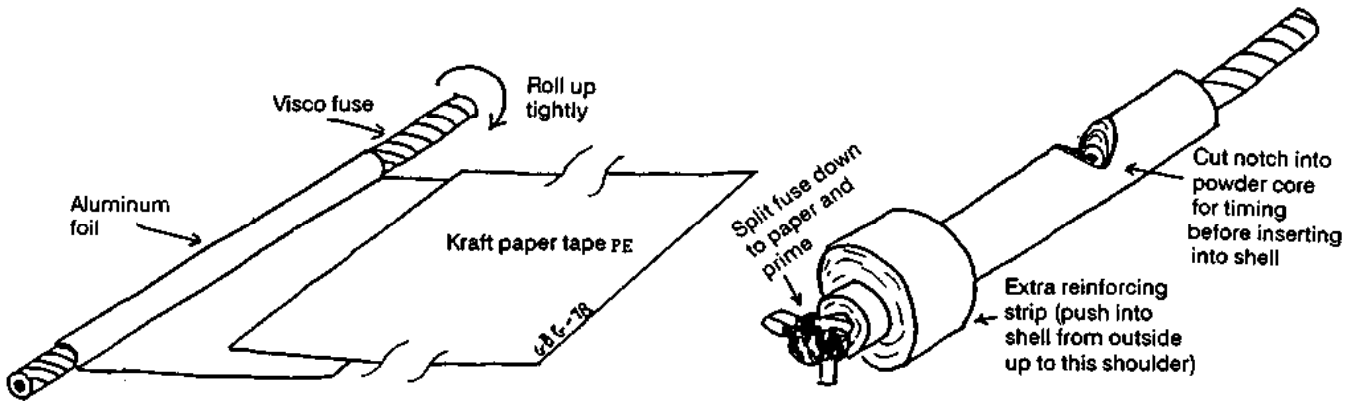
A slow-burning powder is also essential for consistent results in time fuse. A powder that burns too fast can also cause pressure build-up. Fuse powders are either special grained powders made with a high ratio of potassium nitrate or a reduced ratio of charcoal, or a mixture of fine-grain black powder and other mixed ingredients to slow the burning rate of the black powder. The homogeneous special fuse powders are preferred by blasting-fuse manufacturers, for there is no chance of erratic performance resulting from segregation (separating of the ingredients) or mixing errors. Although visco fuse is designed for a specific use, which is the primary ignition of commercial fireworks, it can be used for timing purposes if its characteristics are modified to eliminate side-spit and side-ignition. This is how I do it:

MATERIALS:

1. Visco fuse, (7/64"), burning time, 35-40 seconds per foot, cut into 2 1/2" lengths.
2. Lightweight aluminum foil cut into 1 1/2" x 3" strips.
3. Kraft paper strips of same dimensions as the aluminum strips.



THE BEST OF AFN II



I wind a strip of aluminum foil tightly around a length of pre-cut fuse. I spread adhesive on a kraft strip, then interleave the first 1/2" of it into the last wrap of the foil and wind the rest of the strip up tightly around it and allow it to dry.

The function of the aluminum foil is to conform to the irregular exterior of the fuse and so block the flow of gases. 3" gummed paper tape is excellent for the outer wrap and need only be moistened with water, eliminating the use of paste or glue, serving as a binder and providing a good gluing surface for attachment to the shell. Masking tape can also be used, but moistened paper tape shrinks as it dries, which further compresses the foil around the fuse.

After drying, I test a dozen or so of the wrapped fuses, which should burn evenly from end to end when lit, without popping or blowing through. If such malfunction occurs, it is because the fuse is too "hot" — that is, too fast-burning or having too large a powder core. Note again that fuse with a burning time of 35-45 seconds per foot is required; if a foot of it burns in only 25-35 seconds it will not be satisfactory.

I wrap a 3/8" x 3" strip around the end as a reinforcement and gluing-stop for attachment to the shell casing. I split the stub end of the fuse at this end down to the paper wrapping, dip in

priming-paste and then in grain powder for positive ignition by the lift charge. For timing, I cut a notch through the paper wrapping and into the powder core at a point experimentally determined to give the desired delay. This should be approximately:

Small shells	2 to 3 seconds
3" to 6" shells	4 to 5 seconds
Breaks	1 to 2 seconds

I punch a hole in the shell just large enough to accept the wrapped fuse but not the reinforced end, which I glue securely to the casing as I insert the fuse from the outside. On the inside, I slip a piece of piped match over the notched end and lead it to the center of the shell, securing it with glue.

Note: I do not cut off the stub end of the fuse extending beyond the notch, as this can provide a second-chance source of ignition if the match should fail to take fire from the side-spit at the notch.

I have used several dozen of these assemblies and have yet to have a misfire. I would, however, stick to regular time fuse or spoolettes for the main fuse in large shells and reserve the "Visco Expedient Time Fuse" for breaks and Class-C shells. GG



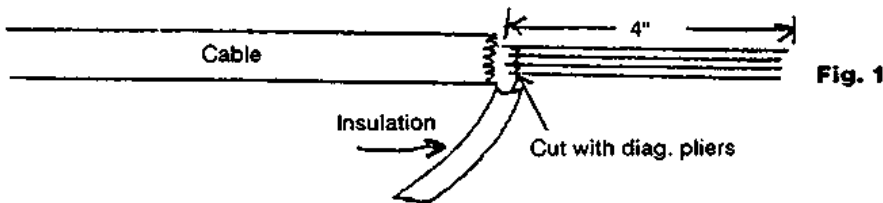
EASY SET PIECE BUILDING

The biggest problem most people have in building set pieces is attaching the quick match to the lance securely. Having built all the set pieces for a fireworks company a few years ago, I knew of an imported lance that had wires on it to hold the match. It is more expensive than regular lance.

I now alter my lance by adding my own wires. The way I do it is as follows:

Step #1 - Figure #1

I get four strand Bell wire and strip the outside insulation around the four colored wires, leaving the insulation on the four strands. I cut the four strands into 3" to 4" pieces and bend each piece like a horseshoe in the middle.



Step #2 - Figure #2

Using 1/2" or 1/4" masking tape, I attach the wire to the top of your lance with the horseshoe down and the ends of the wire up. Now I'm ready to attach the lance to the set piece.

Step #3 - Figure #3

I normally build my sets out of 1x1 or 3/4" particle board and attach the lance by drilling a 3/8" hole about 1/2" deep. Then I put the lance in and glue around it at the base. White glue works best. The wire must open the way the match is going.

Step #4 - Figure #4

After the glue has dried, the wires are spread and the quickmatch is laid on the lance. Then a simple twist of the wires and the lance and quickmatch are securely fastened. For sure ignition, a hole is then punched thru the match and into the lance.

Fig. 2

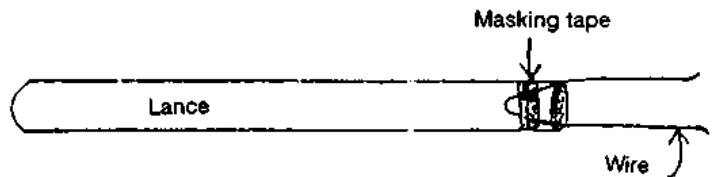


Fig. 3

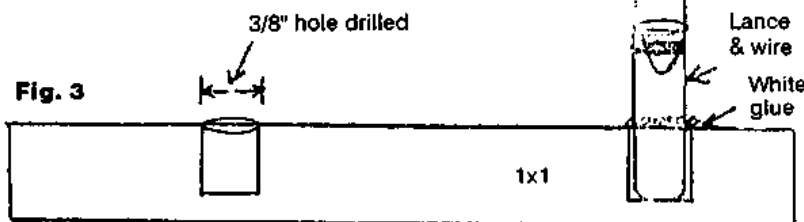
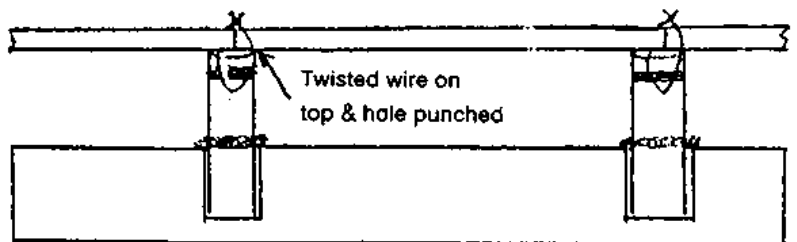


Fig. 4





TIPS ON SMALL SET PIECES

Ground displays and set pieces are the most neglected part of display pyrotechnics in this country. Most pyros are shell nuts and are incompetent at the rest of pyrotechnics.

Most of us live in the city and cannot fire shells in the back yard like the loving God intended we should. Even the meanest, nasty, most paranoid neighbors in the world can be slowly acclimated to occasional, quiet, reasonably sized ground displays. I have broken in quite a few sets of neighbors this way. Gradually they begin to trust your skills. Eventually they all enjoy watching and they make a nice evening's audience.

Nothing in pyrotechny could be as safe as the small set piece that is provided with a time delay that allows one to recover his chair and mug before the performance begins. Especially if you are training neighbors, a short, low power whistle can fire, a short lance provide a genteel saunter back to the lawn chair and then the goodies can begin.

The most important tool for making set pieces is a stop watch. I keep a note book that records the powder column length and burn time of everything I make. Unplanned timing looks sloppy and childish, while snappy, precision timing of effects that follow each other or burn together can make even a very simple set piece look professional. Naturally, this is an area where electric ignition can really improve the results.

In England, most wheel and rocket mixtures start with meal powder and are dressed up and slowed down with charcoal and other additives. Meal powder is very fast burning and very powerful for that purpose. It is also expensive and totally unnecessary. I made good fireworks for decades before someone gave me a jar of meal powder. In my life I have used about a pound or so. I don't have any idea how many fireworks I have made but my chemical consumption is best measured in tons, about a dozen or so I think. The only use that might justify the cost of meal powder would be quick match.

To make good set pieces the pyrotechnist first needs a stop watch, and next, incredibly good

quickmatch. Good quickmatch is noisy, so if there is a paranoid neighbor problem, quickmatch should be avoided - go all electric.

If he must avoid quickmatch, the pyrotechnist should consider using some of the techniques that were used prior to the invention of quickmatch. Most of these depend upon black match catching sparks from fountains or wheels. For instance a design in lances might be arranged outside the radius of a wheel. Strips of black match draped between the lances will catch the fire. In using this simple trick, which is a lot less work than quickmatching, it is advisable that each lance have two pieces of black match attached. Three or more provide additional assurance of rapid fire transfer.

Powder-pasted tissue paper can be used and might be helpful where the sparks to transfer the fire are few. In general, it is best to place such devices where the spark plume of the fountain or gerb is at its maximum width and spark count. For instance, a 1/2" wheel driver that sprays a plume of sparks five feet will light exposed match between one and three feet away. On a two-foot diameter wheel this driver could be used to light exposed match between a two foot radius and a four foot radius from the wheel axle. That area between the circles is about 37.7 square feet, so the shooter can light a lot of lances in that much area! If lances are about three inches apart each lance needs about 0.12 square feet so it is possible to use up to 302 lances. In practice, the effective ignition range of a wheel is not a rigid number, but it can be seen that this handy technique can be used on some very nice pieces.

Another old technique is simply loose powder sprinkled and brushed around so that sparks from the powder will light black match or powder pasted paper fuses on a group of rockets, crackers or what have you. Unless the shooter likes a surprise, the device should be well covered until firing time and it should be used early in the old show. The obvious reason is that it is very easy to set off. This technique can be surprisingly slow to fire the works. If hand mixed comp is used, the fire will spread slowly at first, so a flight of rockets starts off with one or two



and then goes wild. With sporting powder the flash is extremely fast, occasionally straight sports grain will fail to light fuses so a mix of handmade grain with a little sprinkle of sporting grain on top is usually much better.

This technique has a handy variation. I slop a little pattern of wheat paste on a piece of cardboard, sprinkle with home grain, gently press the grain into the paste, then sprinkle a bit of rifle powder over the surface, allow it to dry and store it carefully. Naturally, holes may be punched or cut into the cardboard to pass rocket sticks etc, and the technique works well on wood and many other surfaces. While the paste is wet, firecracker fuses or the fuses of "small bees", jumping jacks etc., may be pressed into the paste, being careful not to paste the devices to the board unless it is intended to do so. A card or board of two or three types of little fireworks placed to either side of a small wheel will be lit by the wheel and will add a little zest to a boring wheel. They can, of course, transmit the fire to the fuses of larger devices.

Now, if the neighbors permit, I can dress the wheel further, with, say, titanium salutes that are set off by the boards above. To do this safely and reliably, I use a polyvinyl acetate glue (Elmers, etc.) to glue the fuse of the salute to the board or cardboard. If the salute is a bit hefty, I suspend it at least an inch from the wood to avoid splitting the wood. A cardboard patch glued on the wood will help protect the wood. There is a little trick involved in assuring that the salute will light and stay put until it is to function. I make the salute with a very long fuse and glue most of the fuse to the board with white glue. When the glue is completely dry, I use a carpenter's chisel (sharp!) to cut away the top of the fuse to expose the powder grain. Then I smear the cut fuse thinly with a paste of powder and sprinkle with grain.

There are hundreds of variations and the pyrotechnist who uses his imagination can put it all together so that a silly little wheel becomes a nice display piece (if he gets the timing right).
LSO

MULTI-EFFECT FOUNTAINS

Multi-effect Class C fountains are a real thrill, like the "Happiness" and "Dancing Butterfly"?

My philosophy of fireworks manufacturing is summed up in three words - "Keep it simple". The Happiness Fountain is simplicity at its best. It has a small tube with some fountain comp rammed on top of whistle comp. This tube sits inside a much larger tube with stars, lady crackers, and a pinch of lift charge. The fountain showers some gold sparks, whistles, then a shower of multi-color micro stars and crackers.

My version of a Happiness Fountain starts with a 1/2" to 3/4" i.d. tube into which I lightly but firmly ram whistle comp for two-thirds of the tube height. I use 70/30 potassium perchlorate/sodium salicylate (or benzoate). For the rest of the tube, I ram a mixture of whistle comp with added 7%, 20-30 mesh, dried, glitter star comp. That's right! Granular glitter star comp mixed with whistle mix will give you a 4+ foot high shower of flashes! No choke is necessary - by the time the glitter goes out, the regular whistle kicks in with a screeching whistle. Filling the tube all the way to the top is important for creating this effect. If the whistling doesn't start right away, it means the need to ram less whistle comp in the tube before adding the glitter comp. A word of warning: Whistle mix is hazardous! Only wooden tooling should be used. I wear a face shield - burning comp can ruin eyes. I never hold the tube with my fingers while ramming. I never ram whistle mix indoors or near flammable objects.

The tube with whistle comp sits in a tube of the same height, but 1 1/2" to 2" i.d., and glued to a wooden base. I put a couple of teaspoons of lift charge in the bottom of the large tube, then place the whistle tube in the center of the larger tube and put stars, Jumping Jacks, crackers, etc. to the sides of the center tube. I cut a round disk of cardboard that slips over the center tube and fits in the larger tube just a bit. This way the whistle will not prematurely set off the last effects. Finally I add Ground Bloom Flowers for an interesting effect similar to the Dancing Butterfly Fountain. Then I attach a fuse to the whistle. The fountain is now ready to go! MB

SOME ADVICE ON SAFE RAMMING PROCEDURES

When ramming tube items, whether they are spoolettes, whistles, serpents, fountains, rockets or other similar items, there is always the possibility of accidental ignition of the composition. Most compositions commonly rammed are not so sensitive as to ignite simply from being compressed in a paper tube. Compositions containing barium nitrate and aluminum, and whistle compositions, especially those containing titanium, are the exceptions. While it is possible to safely ram some whistles without accident, one must be ever mindful of the danger and take precautions. Rockets, while generally containing "safe" compositions, have a different hazard in the presence of the steel spindle penetrating the length of the case. If the blind rammer should strike the tip of the spindle, ignition can occur.

In most cases, a debilitating explosion is not the result of an accidental ignition. A fire of greater or lesser ferocity, is of very immediate concern, however. Since few of us can manage the set up needed to press the more hazardous operations, one is led to consider the best way to manage the risks attendant to hand ramming of tube items.

In this case, like most other fireworks operations, isolation, awareness and preparedness are the most productive safeguards. Putting our attention on whistles and rockets as the most likely items to ignite during the ramming procedure, what can we expect to be the results of such an ignition? In the case of a whistle, the rammer would be forcibly ejected from the tube, with possible rupturing of the case with greater or lesser force, depending on the type of composition, and the whistle would function in a pretty much "normal" manner. Unless using gallic or picrate formulations, an explosion is unlikely. So you have a hot, large, directional flame, and evolution of copious amounts of grayish smoke. With titanium, the hazard is greatly increased as many very hot sparks are produced as well. In the case of a rocket, ignition will not produce the violent thrust of the finished article, since the spindle is still in place. Thus simple progressive burning will ensue. However, large quantities of charcoal sparks will be ejected to great distances, and they may be invisible under daylight conditions - you wouldn't see where they're going.

It should be clear at this point that in either case, no one has lost any limbs at this stage of the accident. Indeed, if face protection is in place, the most one has sustained is a relatively minor burn on the hand, and perhaps some singed hair. If one's clothing is appropriate (cotton), there should not be a great threat of immolation from that source. If one wishes to be able to return to one's work once the area has been made safe and cleaned up, the best first aid is cold water applied ASAP (seconds count!) to the burn. There is no better first aid for burns than immediate immersion in cool or cold water! Assuming these safeguards are available and used, where else may disaster lurk unexpected? The answer, of course, is storage!

NEVER STORE ANY MIXTURE OR INFLAMMABLE MATERIAL IN THE WORK AREA, other than that which is necessary to the work itself! This means all materials attendant to the pyrotechnic art such as containers of stars, priming powders, Meal D, lift powder, or flash compositions. They must be kept elsewhere, if only in a closet, or garbage can, if not in another building entirely, and they must be kept closed, and covered! This is how you live to collect your retirement in this business!

Finally, one must control all access of sources of ignition to your rocket or whistle composition. And your finished items must similarly be isolated. This can be very easily accomplished, and no excuse exists for the exclusion of these techniques, or something similar in purpose and function.

While covers of metal, such as sheet brass are preferable, here is a simple method which has worked perfectly for the author on three occasions of accidental ignition of four ounce rockets. On all three occasions, work was able to recommence as soon as the smoke had cleared, although needless to say, the experience was still upsetting! Whether ramming whistles or rockets, or anything else for that matter, the same technique applies. Simply obtain an ordinary cigar box, large or small depending upon one's needs, and store your working supply of composition in it. It is a simple and quick matter to flip up the



lid with the scoop hand, load your increment, and flip the lid back down, resting the scoop on top of the box. Then ram the increment with your mallet. (Non-sparking, of course). While a spark could penetrate the cigar box, it is much less likely that it will. If you are loading large items, and the box must be refilled frequently, keep your batch of comp. in a trash can nearby, with a close-fitting lid. It really takes very little time to refill that box! Finally, as each item is finished and removed from the spindle or ramming block, immediately place it in a suitable container. A swing top waste basket of the type used in kitchens will do if you must hurry, otherwise, a trash can with a close-fitting lid is much to be preferred.

The operating sequence I have used would go this way: The case is fitted on the spindle. Your clay, if used is rammed in. The box is flipped open, a scoop of comp. is introduced to the case, the box is flipped shut as the scoop is set down. The increment is rammed in. This is continued until the case is full, and the top clay, if used, is rammed down. If you drill at this time, the boxes, cans, remain closed. The finished item is deposited in the "safe". In my own experience, the four ounce rockets ignited from the blind rammer striking the spindle. A dimple was formed from a previous striking, and the tiny amount of powder retained in this dimple ignited from the pressure. I do not believe a spark from brass striking steel was responsible, hence this effect could likely be reproduced with aluminum tools as well. The ignition was each time characterized by a tiny explosion, like a paper cap, and a very noxious sulfur odor, almost like the phosphorous smell of paper caps. This was immediately followed by the progressive burning of the comp. in the tube. The shower of sparks produced in the work area was perceived as being much more voluminous than it appears when the same article is deliberately ignited under appropriate conditions. Any normal person's reflexes will quickly propel you out of harm's way, and in these instances I had only small, and "inconsequential" burns on one or two fingers holding the rammer. The cold water made it possible to minimize the effects of these to small, painless blisters, and work was resumed once the feeling of terror had subsided, and the smoke was cleared. One may also wish to be sure that no one has called the

fire department, or some other embarrassment!

Remember, safety results from planned innovation, and is best when self-imposed. Let your display be your advertising, not your work habit!

JHB

SAVE THOSE SHELLS

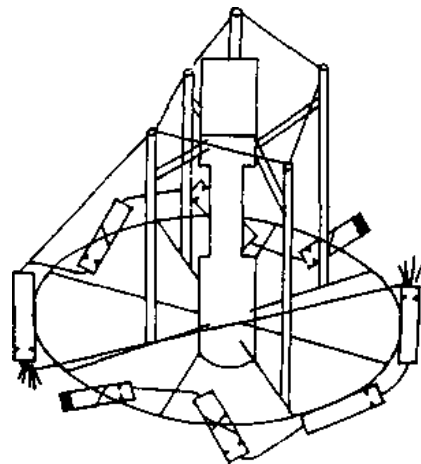
LANCEWORK IN A HURRY

Fellow lance workers, save those .38 and 9 mm shell cases because I've found a place to use them. If you have lancework art that you use year after year, try what I've done.

Do your picture in 3/8" copper tubing instead of rattan. When you have the desired pattern laid out, take a hammer and a block of wood and smash the copper tubing flat at every point where a lance should be fastened. Then solder one of the .38 or 9 mm empty cases to the tubing. Presto - it is ready to accept your lance tubes! You may wish to add a little rubber cement to the lance ends that go into the brass case.

Lance could be reloaded in the field and be ready for your next show. This setup will provide years of service for art that you use over and over again. It won't break like conventional rattan.

LY





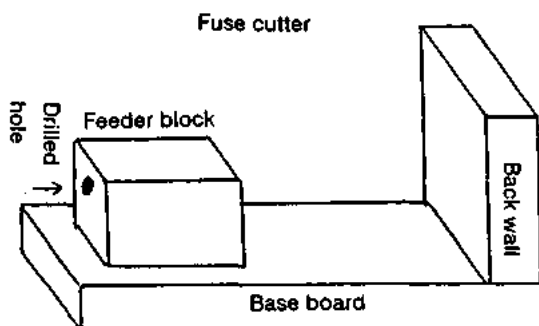
EL CHEAPO FUSE CUTTING DEVICE

The following ideas and tips may be practical for the hobbyist who may not have access to expensive tools, supplies, etc.

This device will be handy for cutting several hundred similar lengths of visco fuse.

Materials needed; approx two feet of 2x4" board, a few nails and some glue.

I cut the board into three pieces and assemble as shown in the diagram below. I drill a hole through the feeder block for feeding the fuse through, then mark off a line with a felt pen, on the base board, parallel to the back wall, between the feeder block and the back wall. For example, if I know I will need a hundred or so three inch pieces of fuse, I mark off a line on the base board three inches from the back board (I use other colors to mark off other lengths of fuse I may need).



To use, I simply feed the fuse from the roll through the hole in the feeder block until it reaches the back board. Leaving the scissors right on the marked line, I can feed fuse and cut continuously many hundreds of pieces of fuse all the same length. For safety's sake I am always cautious that using a scissors to cut visco fuse may result in an unexpected ignition. Therefore, a sharp knife or razor blade may be substituted.

SC

CHOKED GERB-MAKING TECHNIQUE

I start by drilling a hole 1" deep into a small block of wood. I then insert and glue a 1 1/2" long piece of wood dowel into the drilled hole so it protrudes 1/2". The dowel will be the same diameter size as the inside diameter of the gerb cases I wish to fill. I hand sand the dowel so it is smooth and has a very slight taper around its top edge. The board and protruding dowel are now the "base" and "spindle". From the same diameter dowel, I cut a section that is approximately 4-inches longer than the gerb casing. This will become the rammer. I hand sand the rammer with extra fine sandpaper until it is extremely smooth, then let it soak in a bath of hot melted paraffin wax for a few minutes. I sand again, this time using extra fine steel wool. This step will seal the pores of the rammer and make removal of the rammer from the case much easier. I cut a 2" length of gerb tube and affix it to one end of the rammer, using epoxy cement and nailing into place. This will serve as a handle/puller and help prevent the top of the rammer from splitting when repeatedly struck with a mallet.

I make my choked gerbs by placing a parallel wound gerb tube onto the spindle and ramming the composition in increments as usual, stopping one inch before the end. I make several in this fashion and set them aside. I now have gerbs packed tightly with composition which is recessed 1/2" deep on one end and 1" on the other. Next I mix up a small batch of plaster of Paris and water. I bundle a dozen or so gerbs together, then spoon in some of the wet plaster to fill the top of each tube. Before the plaster sets, I take the bundle of gerbs in hand and gently but repeatedly tap the tubes so that all the air bubbles that may have been present in the plaster are released and floated to the top. When the plaster has set on one end (usually within ten minutes), I turn the bundle over and fill the other ends in the same manner. The nozzle ports can be drilled in about an hour, if the drill bit is dipped into ice water prior to drilling out each nozzle. This method may also be applied to some fountains, wheel drivers and small rockets. [Drilling is forbidden with cases of titanium-containing compositions. Also, see J.B.'s "Some Advice on Safe Ramming Procedures"]. SC



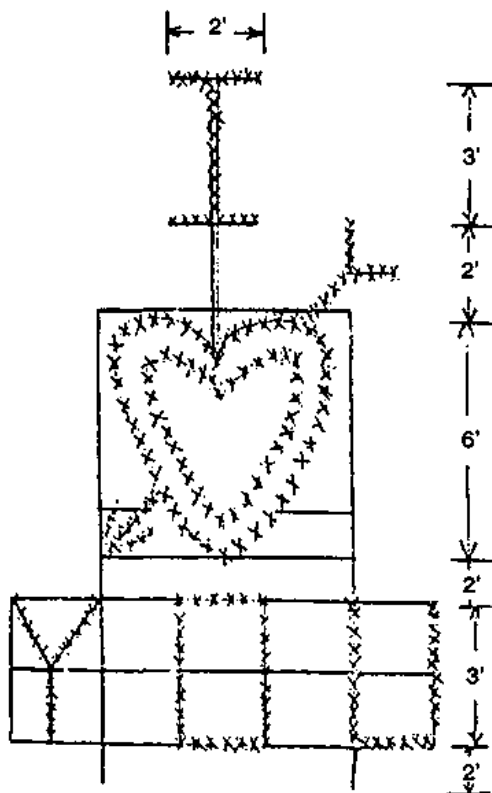
A PYRO WEDDING

My bride and I were married in September last year. About three weeks before the wedding I began a secret present for her.

The present I built was a huge set piece that said vertically I LOVE YOU and matched in were two 3" finale boxes, six 4" shells and three 6" Chinese color silk shells from Temple of Heaven. The shells were all timed out at 15 second intervals except for the finale boxes. They were to go one at the start and one at the end with one each 4" and 6" simultaneously.

After the ceremony the ushers got everyone outside for the fireworks. I took my bride up to the set piece and had her light a six-inch piece of safety fuse. Thirty seconds later we started our new life with a bang and a kiss filled with rockets and bombshells.

Here is a diagram of the set piece. The "I" was yellow. The arrow was color changing - yellow to white. The double heart was color changing - red to blue. The "YOU" was blue. All lettering was 2x3 feet. JMcN *ir*



GERBTIP

Gerbs made with glitter mixes are top notch items with plenty of crowd appeal. While Dr. Winokur suggests that they are best made in unchoked cases, some of our readers have reported having great success with choked cases. Unfortunately, the choke has a tendency to become clogged with dross. Here's how one pyro solved that problem:

All my glitter gerbs use a standard choke and work just fine. To inhibit dross formation, I ram a hot mix at periodic intervals. I ram 3 tspn. of glitter, one at a time, and the 4th tspn. is a mix of either Meal D/charcoal with gold glitter or Meal D/Ti with white glitter. I believe it would work with a 4:1 ratio too. Of course, this idea is not unique to me. However, this is how I get choked glitter gerbs to work. JCB

HELPFUL HINT #3

When the need arises to crush chemicals, the job can be speeded up by placing the chemicals on a board and covering it with a small piece of window screening. A bottle is then rolled back and forth over the screen, which helps crush the chemicals and also prevents the crushed bits from being scattered.



BASIC SKYROCKET CONSTRUCTION

Rockets are among the oldest pyrotechnic devices known, probably antedating even the rudimentary firecracker. There is little doubt that the first rockets resulted from four successive discoveries:

1) that a mixture of potassium nitrate and charcoal when ignited would burn without access to atmospheric oxygen;

2) that this mixture would burn more fiercely when confined in a bamboo stalk or other container than in the open;

3) that the jet of flame and gases issuing from the container would be longer and more forceful if the opening were "choked" or restricted in size; and finally

4) that by ramming the mixture solidly in a tube, with the addition of a little sulfur, and forming a hollow central cavity through most of the charge, the impulse of the exhaust gases could be made to propel the case for some distance.

Of these discoveries, the first three might well have been stumbled upon accidentally, but the last must have required a definite effort of some early pyrotechnist's imagination. The principle involved is, that the more surface area of powder exposed to the first flame, the greater will be the initial thrust. A little calculation will show that a cavity about 1/3 the diameter of the charge and extending about 7 times its diameter into the powder (a typical figure) will increase this surface area by at least 7 times over that of an "end-burning" solid charge. This principle was described in John Bates' "The Mysteries of Nature and Art", second book, written in 1634 but was certainly discovered long before.

The applications which have been made of the rocket principle for missile propulsion, signaling and illuminating devices, jet-assisted-take-off for aircraft, life-saving line carriers for ship-to-shore and ship-to-ship use, high-altitude telemetry and sounding, weather modification (as in cloud-seeding to combat hailstorms) and even as boosters in connection with today's huge liquid-propellant space vehicles, are too well known to

require elaboration. We are concerned in this article only with solid-propellant rockets and specifically with those used for pyrotechnic display, generally called skyrockets.

(It should be noted that this category does not include so-called amateur or model rocketry, from which it differs in several important respects. Amateur rocketry generally makes use of solid end-burning charges of comparatively slow-burning propellants such as a sulfur and zinc dust mixture, either poured into the casing in a molten state and allowed to solidify or molded or machined to fit. The case itself may be of metal (never used in skyrockets) and reusable after recovery, and the exhaust nozzle must be carefully formed to take maximum advantage of the available thrust, which does not reach a peak until the rocket is well on its way. This nozzle is closed by a brittle plastic or metal disc incorporating an electrical igniter, which ruptures when enough heat and pressure have built up to sustain burning. A skyrocket, on the other hand, develops maximum thrust within about the first second after ignition and thereafter travels mostly on momentum, with the remaining powder contributing mainly to the brilliant "tail", which is noticeably lacking in amateur rockets.)

Solid-propellant rockets of all types have the disadvantage that they are "one-shot" devices and cannot be turned on and off at will like those with liquid propellants, but this lack is compensated for by the fact that they can be stored indefinitely, ready for instant use. Moreover, they bypass the failure-prone valves and other sophisticated mechanics that have plagued space technicians in the building of missiles and space vehicles. (In the unlikely event that the reader does not know it, rockets are even more efficient in the vacuum of outer space than at sea level, since they do not depend on the pressure exerted by the exhaust gases on the atmosphere nor on atmospheric oxygen for combustion.)

For the pyrotechnist, two big advantages of the rocket over the aerial shell are that it does not require a mortar for firing, only a suitable above-ground launcher, and that there is not the abrupt set-back or shock like that delivered by



THE BEST OF AFN II



the lift charge below a shell. Again, there is a disadvantage, that of the falling case and stick which today precludes the firing of rockets in public exhibitions except over large clear areas or bodies of water. Where the latter conditions prevail, however, it should be remembered that the comparatively mild acceleration of a rocket permits the use of chlorate stars which would be too sensitive for the conventional aerial shell. (Note that the name "stickless rocket" is sometimes applied to comet shells which leave a brilliant trail as they ascend, but these require a mortar and lift-charge for firing.)

Skyrockets today come in many sizes. While Brock, in his "History of Fireworks", has mentioned eight-foot-long monsters with sticks of 20-foot length or so, the largest that are likely to be encountered, even in exhibition work, would not exceed about two feet in length or three inches in diameter. The great majority are under the "one-pound" maximum (8" long) and range from the very small "bottle rockets", so called because they are essentially nothing but open-ended IV² black powder firecrackers and can be launched from the neck of a pop-bottle, to those about six inches long, complete with a nose-cone filled with stars which bursts at the top of its trajectory. Some of the smaller rockets have no such "garniture" and are called "honorary" rockets, deriving their whole effect from the glowing tail and the "whoosh" as they go up. The propellant is always a mixture of potassium nitrate, charcoal and sulfur in varying proportions, with more charcoal used in the larger sizes as noted below. Usually, bigger grains of charcoal are included than actually necessary for combustion, to enhance the effect of the glowing tail. Metallic inclusions like steel or iron filings, titanium, etc., can also be used to increase brilliance but should be kept to a minimum since they add to the weight of the rocket without contributing to thrust. (Iron or steel particles should be treated to prevent rusting by the potassium nitrate.)

For dimensional and construction details in this article, I have chosen a typical "one-pound" rocket, but note that the proportions given for length, diameter, etc. can be equally well applied to larger or smaller rockets. For example, the 1/4" nozzle for a 3/4" bore can be reduced to 1/8" for a 3/8" bore, with other measurements reduced ac-

ordingly, as noted in the instructions for a "sub-ouncer" rocket described at the end of the article. The only proportion which varies from small to large rockets is that of the charcoal to the other ingredients.

TOOLS: Fig. 1 is a cutaway view of a typical "one-pound" skyrocket, with the hollow core left unshaded for clarity.

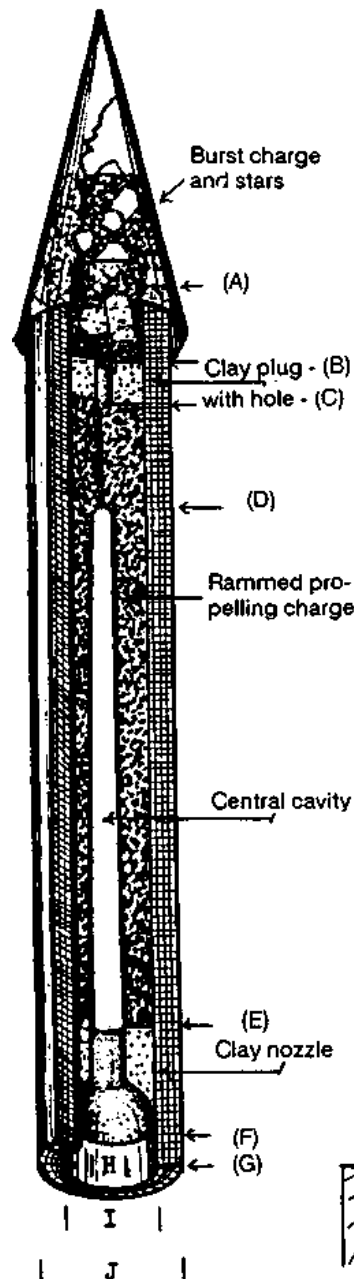


Fig. 1

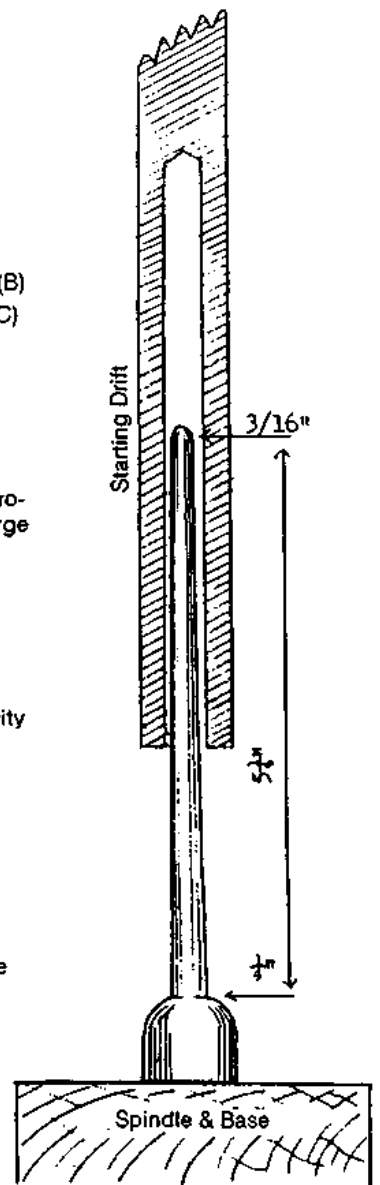
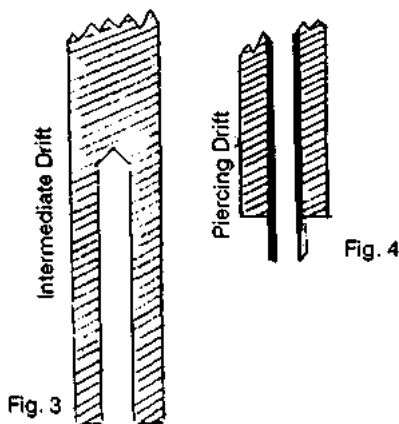


Fig. 2



As with certain other fireworks nomenclature, the term "one-pound" is deceptive, since it is derived from the weight of a lead ball of the same diameter as the outside of the casing; the rocket actually weighs less than a half-pound when completed. The casing is rolled around a 3/4" metal or wooden former, beginning with an 8" by 17" strip of hardware paper and finishing with an 8" by 20" piece of 120# chipboard inserted into the last turn of hardware paper, both pieces well pasted. When dried, this results in a very sturdy tube with a smooth bore. But case rolling is an art in itself, too elaborate to cover here; modern mass-production has made it almost unnecessary for the pyrotechnist to "roll his own" except as a pastime on rainy days!

The same does not apply to rocket loading tools, however, and the pyrotechnist with some machining ability and access to a lathe can profit by making his own tools. These are illustrated in figures 2 through 5. It is essential that the spindle and drifts be made from non-sparking materials such as brass or aluminum, since the greatest danger in ramming black powder is from accidentally striking a spark. In factory work, the spindle itself is often of steel or gunmetal for durability and long wear, but this demands that the drifts be made of non-ferrous materials. I prefer brass for both spindle and drifts, although aluminum is cheaper, easier to machine and quite satisfactory unless large-scale manufacture is planned. The spindle in particular should be highly polished to facilitate ease of removal after the charge is rammed.



The starting drift is the most difficult to make (fig. 2) because the central hole which fits over the spindle is comparatively long and must be bored exactly parallel to the outside for its entire length. This fact almost demands the use of a lathe, or at the least a drillpress. The hole must be just large enough to fit over the spindle at the base (in the example, 1/4"). I have shown only one intermediate drift, but two or more are generally used, with progressively shorter holes to match the rising charge of composition and fractionally smaller diameters to correspond with the taper of the spindle. These drifts can be made of hardwood dowel material if desired, of the same diameter as the former on which the case is rolled, but I wind the top with wire or have a tight-fitting metal sleeve to prevent spreading and cracking from repeated mallet blows. If of larger diameter than the drift itself, such a sleeve will present a better surface for the mallet to strike and facilitate removal from the case. I use a finishing drift (not illustrated) with no central hole to ram the "heading" above the top of the spindle and the top clay plug, if the latter is to be solid. I prefer to do this and afterward drill a small hole to communicate fire to the "pot" to ignite the burst charge. A quicker method is to use a "piercing drift" to ram the clay and form the hole in the same operation (fig. 4). This can either have a projecting pin about 3/16" in diameter or a tube of thin brass or aluminum ramming through the drift as shown. I prefer the latter because it actually removes the clay and does not press it down into the powder, and it is easy to clean out if it becomes plugged. Moreover, I examine the removed clay to see whether the hole extends just through the plug and into the composition (as it should) or is too short or long and adjust the length of the little tube according. I start with a tube pressfit into the drift and flush with the top, extend it about 5/8" out the bottom, so I can cut or file it to the correct length. Just a little black powder showing in the end of the tube after ramming the clay indicates that a hole of the right length has been made.

Fig. 5 shows a simple powder scoop that I have found very convenient to introduce the composition into the casing with minimum spillage. I make a length of dowel about the same diameter as the bore or slightly smaller, with a piece of tubing fitting tightly on the end and shaped



THE BEST OF AFN II



about as shown. When I insert it into the case and tap it lightly, all the powder will fall into the tube.

I use a fairly heavy rawhide mallet to ram the composition, mainly because a solid metal hammer would soon deform the top of the drifts. (Note: a rubber mallet is completely unsatisfactory; it does not deliver enough impact to consolidate the clay or powder properly.) I install the spindle itself on a substantial base, such as a block of hardwood; by drilling and tapping the underside of the metal shoulder and running a 5/16" or 3/8" bolt up through the wooden base, after recessing the bottom to accept the head of the bolt.

The only other tool I use (optional) is a conical form around which to shape the paper nose. I taper it about as shown in fig. 1. I slit a disc of about 6" diameter radially out from the center, wrap it around the former with the bottom edges even, and past it where it overlaps.

CLAY: I use either fireclay or what is known in the ceramic industry as "grog" or "grout" (the former obtainable at brickyards and the latter at ceramic shops). I use its powdered form, which usually has enough residual moisture to compact firmly when rammed, though it feels dry to the touch. I test its suitability by removing the case from the spindle after forming the choke and examining it. The rammed clay should be smooth and hard to the touch, though grooves can be scratched in the surface by a sharp instrument. If it has a tendency to crumble, I dampen it slightly, preferably with oil. Water, especially in excess, may cause shrinkage as it evaporates.

PROPELLANT: For a one-pound rocket, Weingart has recommended a mixture of 16 parts potassium nitrate, 12 charcoal, and 3 sulfur (by weight), while Brock has specified 13, 7 1/4" and 2 respectively. It can be seen that the two writers differ mainly in the proportion of charcoal to be used, but that in both cases this is much larger than that of strong black powder (15, 3, 2). Lancaster, in the formula he has supplied for Ellern's *Military and Civilian Pyrotechnics*, recommends proportions that work out to 15 1/2", 8, 1 1/2", which is pretty close to Brock's, no doubt indicating British preference, but he does not specify which

caliber rocket this applies to.

Since every pyrotechnist seems to have his own pet formula, I might as well recommend mine too, which is 14 potassium nitrate, 8 charcoal and 2 sulfur, and refer the reader to Weingart's sage if simplistic advice: "If rockets burst before ascending add more coal [sic]; if they ascend too slowly add more saltpeter". In general, however, the larger the rocket, the more charcoal should be used, and for a spectacular tail, it should be about a half-and-half mixture of fine and coarse. For smaller than one-pound rockets, the potassium nitrate should be powdered; for larger ones, the granulated grade may be used.

RAMMING: I slip the case over the shoulder of the spindle, where it should fit snugly, and I dump a scoop of clay in and push the starting drift down over it and give eight to ten hard blows with the mallet to form the choke. I then remove the drift and add a scoop of powder, which I consolidate by replacing the drift and giving it about half-a-dozen somewhat lighter blows. However, I am not too gentle, as the proper performance of the rocket will depend on firm packing of the composition. I repeat this process until the case is full to about an inch from the top, changing to the shorter intermediate drift(s) at the proper time, and using the solid finishing drift for all powder above the spindle top. (Two marks on each drift to show its lower and upper limit are helpful; if I use the second drift too early, it may scratch or deform the spindle.)

Finally, I put in another scoop of clay and consolidate it with either the finishing or piercing drift. As an added touch, I put a daub of priming-paste on the fire-hole to insure ignition of the burst-charge (black powder with 2% dextrin or starch and moistened with water).

FINISHING: I invert the nose-cone and about half-fill with stars and a burst-charge of about 3Fg or 4Fg grain or strong meal powder; apply adhesive around the rim of the rocket, which I press down into the cone and again turn it right-side-up to dry. I make sure the cone is properly aligned. (If fancy paper is to be wrapped around the case, it should be pasted on before attaching the cone, with about two inches extending



beyond the choke end.) I insert about six inches of black match or (preferably) 1/8" safety fuse into the nozzle, with a good four inches extending, and attach it with another daub of priming paste, which should completely fill the hole in the choke. When this sets, I twist the extending paper around the fuse and tuck it in. I then smear the stick with glue on one side for about six inches and securely bind it to the case with twisted wire about an inch-and-a-half from each end. A stick for this size rocket should be roughly 1/4" thick and three feet long. I make sure it is parallel with the case before the glue dries.

COMMENTS: As stated, the foregoing description applies to a basic "one-pound" commercial skyrocket, made by hand. In practice, they are often, if not usually, made by the use of hydraulic gang-rammers, on the same machines used for Roman candles. I have seen such a machine capable of ramming 144 cases at the same time, but the same steps described are followed for each operation, only with more than one casing. "Shifting boards" are used in place of powder scoops to dump exactly equal amounts of clay and composition into all tubes at once, and all rammers (drifts) go down to the same depth and at the same pressure, achieving great uniformity of compaction, which says something for mechanization in fireworks manufacture!

I have been asked why, if rocket casings are loaded with black powder, they don't explode like a firecracker. The answer is, that by virtue of being tightly packed, the powder burns only on its surface. To "explode", black powder must have a little "breathing space"; if about half the powder in a rocket were placed loosely in the casing, it would undoubtedly blow up, if the quality of the powder were good. When this happens, it is a sure sign that the ramming has not been done correctly, leaving air pockets within the charge or around it, or that the powder is too strong.

Another question asked is, why doesn't the powder crumble and fall away from the sides of the case after it is removed from the spindle, if no binder is used? The simple fact is that it doesn't if firmly compacted. There is enough adhesion between the particles so that the rammed charge remains solid, even under comparatively rough handling, as experience will demonstrate.

"SUB-OUNCER" ROCKETS: Newcomers to the pyrotechnic field may wish to learn first-hand the principles of rocket construction without investing in tools for the one-pound size or mixing large batches of powder.

The materials I use are only a couple of feet of 3/8" dowel, a roll of 3" gummed paper tape, a nail about 1/8" in diameter and 2 1/2" long, a piece of board for the base of the spindle and a suitable stick such as 1/8" dowel about two feet long. Construction of the spindle and drifts will be obvious from fig. 6.

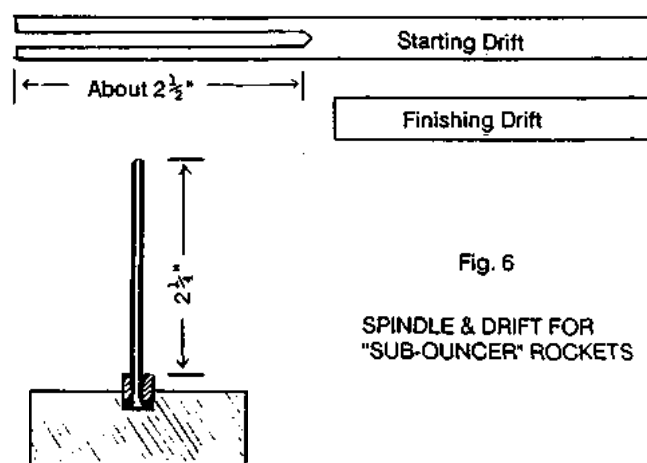


Fig. 6
SPINDLE & DRIFT FOR
"SUB-OUNCER" ROCKETS

I cut off a 1/2" length of dowel and drill a hole lengthwise for a press-fit over the nail; then I bore a 3/8" hole 1/4" into the board to be used as a base, and, pushing the nail into the piece of dowel up to the head, I glue the piece into the base as shown. I file off the point of the nail into a rounded end and I make sure the length of it is perfectly smooth. I cut the two drifts from the dowel to any convenient length that will extend above the 3" case when inserted, and a 1/8" hole bored in one of them as shown. This illustrates the fact that a rocket spindle need not necessarily be tapered, and, if it is perfectly cylindrical, only one drift is needed until the charge reaches above the top of it. The main reason for the taper in larger spindles is to facilitate removal of the charged case after ramming.

I make the case from a 10" length of the 3" gummed tape rolled around another length of dowel. This is best done by first rolling up the entire length, keeping the ends even, then unroll-



THE BEST OF AFN II



ing all but about the last turn-and-a-half, I wet the remaining length with a wet sponge or cloth, and re-roll it tightly, again keeping the ends even. Making up a number of such cases is good practice, and when they are dry, they are ready for loading. I rub the former with paraffin occasionally to prevent sticking, and sometimes a slight backward twist given it to remove it from the rolled casing.

I load and ram exactly as previously described for one-pound rockets, except that only the starting and finishing drifts are used. If I want to add a garniture of stars, I use a piercing drift when ramming the top clay plug, with a sharpened length of 1/8" nail in the bottom, or I drill the hole afterward. In either case, I make sure the hole extends just into the powder, or it may come too close to the central cavity and blow through prematurely. In place of a nose-cone, which is impractical in this small a rocket, I glue another short length of gummed tape around the case with about half its width extending beyond the case. After I place the "pot" in the tube thus formed, I glue or tape the upper end shut.

Small experimental rockets like the "sub-ouncer" are excellent for learning the rocket principle and are adaptable to other uses such as making "line rockets", which run along a stretched wire, or for attaching to revolving wheels as turning cases, or even as small fountains or "gerbes". In the latter two instances, however, it may be well to sacrifice some of the thrust produced by the hollow core in favor of longer burning-time. This is done when I shorten the spindle to half its length, or even less and ramming the space above it solid. Once the technique of making these small rockets is mastered, all sorts of modifications will suggest themselves.

In conclusion, and to forestall possible questions, there are two techniques in rocket construction which have not been mentioned here. One is that of ramming the case solid, afterward boring out the central core, and the other is formation of the choke by twisting a cord around the case to make a restriction or "waist" while it is still damp (a clay choke may also be formed inside in larger rockets). Neither technique is used much in this country any longer. MPVH

DIMENSIONS:

A-G (case length)	8"
J (case o.d.)	1 1/4"
I (case i.d., bore)	3/4"
A-B 3/4"; B-C 5/16"	
C-D (heading)	1"
D-E (core length)	5"
E-F (choke length)	1/2"
F-G	5/8"
C-E (total charge length)	5-3/4"

PROPORTIONS (approx.)

Bore	1
Choke opening	1/3
Case length	11
Charge length	8
Cavity length	7
Heading length	1

Note that all proportions are in comparison with diameter of bore.



Fig. 5



TOURBILLION STICKS

I have noticed that there is some confusion about the nomenclature and construction of tourbillions in regard to the part called the "stick". The name of the part, as well as the information, is much too general to be used in the description of a piece requiring so much precision.

Recently, I built a few 1/2" i.d. tourbillions according to the instructions given in *The Pyrotechnist's Treasury* by Thomas Kentish [available from AFN]. Kentish, Weingart and Lancaster all write about using a curved stick for balance. My immediate impression, from all of them, was of a wooden stick bent into a simple arc. At one point in his writing, Kentish seems to forego even the curved stick and simply says to taper it toward the ends. Perhaps that is why his basic design calls for four lifting jets on the underside.

Having had experience with model aircraft and having learned efficiency of construction, my first thought was to use the rotational energy rather than waste it, so I pitched the stick - - not into the trash, but into the shape of a fan! From this point on I would like to call the stick a rotor, as in helicopter, because now that is what its function is.

Kentish says to use a piece of deal (pine) 1/8" thick. Now, that is a little bulky for a 1/2" i.d. tourbillion, don't you think? But a standard tongue depressor is made of maple and is 1/16" thick and is of exactly the dimensions needed: 3/4" wide x 5 3/4" long. It is even rounded on the ends, made to order!

First, I soak the tongue depressor in warm water for just a short time because the water penetrates it easily. Five minutes will do. Then, I wrap it around a 1" diameter dowel in a spiral fashion (fig. 1). I wrap it halfway around only and do not use a smaller dowel, or there will be too much drag during rotation. I fix the ends with rubber bands and let it dry. I have done two layers, four at a time, with no problems.

Caution! I set the pitch of the rotor compatible with the rotating jets (side jets), or the tourbillion will try to auger itself into the ground.

After the rotors are epoxied to the cases, I rub the tops of the rotors with linseed oil to keep moisture from straightening them out again.

If I wish to increase the efficiency of the rotor, the ends may now be tapered, as Kentish suggests.

Feathering or rounding the upper part of the leading and trailing edges further reduces drag and increases lift.

I note and mark the convex side of the tongue depressors before they are soaked (fig. 3). The curvature is slight; but close inspection, narrow edge on, will reveal it in almost all of them. I wrap them with the marked side out (fig.1).

On one of the tourbillions I made, I did not incorporate these final points. Nonetheless, it spun without traveling and rose vertically as if on a wire. PP

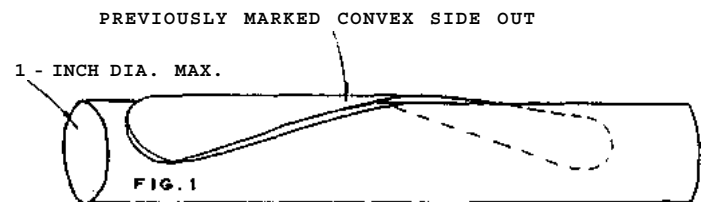
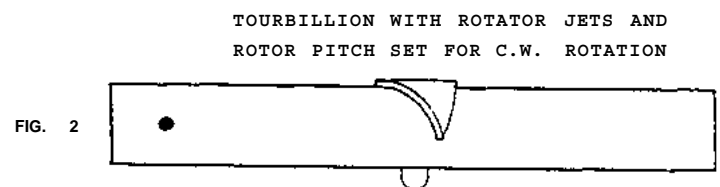
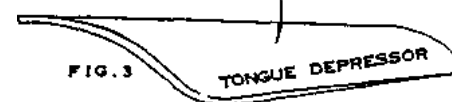


FIG. 1
TONGUE DEPRESSOR BEING WARPED FOR CLOCKWISE ROTATION.



TOURBILLION WITH ROTATOR JETS AND ROTOR PITCH SET FOR C.W. ROTATION



MARK THIS CONVEX SIDE BEFORE SOAKING

FIG. 3
TONGUE DEPRESSOR



FAST ROCKETS IN A HURRY

Here is a quick way we have found to make small rockets for our festivities.

First we take some 1/8" wooden dowel about 18" long and sharpen one end in a pencil sharpener. Then we obtain from our local hobby store a quantity of model rocket engines. We usually use A8-3 engines as a compromise, as the larger the engine, the less room for additions.

We insert a V2' drill bit into the top of the rocket casing and turn it by hand until we can begin to see grains of black powder in the clay/delay comp. in the tube.

Next we drop into this cavity our favorite flash comp., (we like to use 70% potassium chlorate/-30% aluminum powder) about two-thirds from the top. Now using a 1/2 x 3/8" dowel, we plug the front of the tube and seal with glue.

After the plug has dried, we spread on a line of white glue and fasten the engine to the 1/8 x 18" dowel. The top of the engine is flush with the blunt end of the dowel. Then it is dried.

All that is left is to insert a piece of visco fuse into the nozzle of the engine, tape it to the stick and the rocket is ready to rip.

We enjoy these just for the sake of something that is quick and easy to make, with superior results. However, there are pitfalls. For instance, we must make sure to select an engine with a delay rating that will insure detonation of the report charge while still at a goodly altitude, or the crowd will forsake applause and chase you after running from the descending rocket - take my word for that! J&W

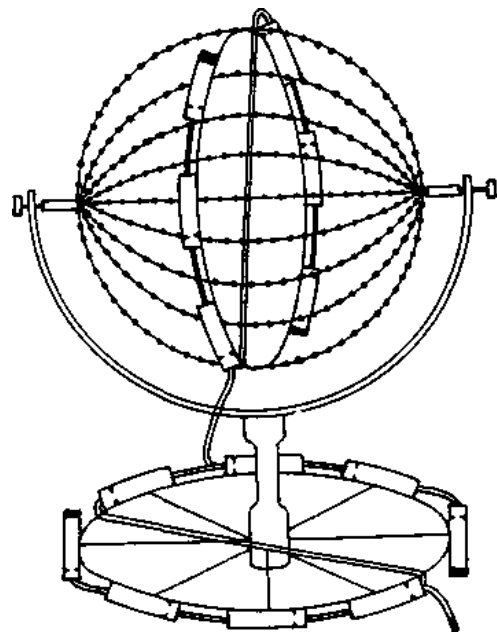
MORE ON "FAST ROCKETS"

Some time ago AFN carried an article by J&W Industries Ltd. titled "Fast Rockets in a Hurry". I enjoyed it very much and would like to add a few comments.

I would hope that anyone making skyrockets from model rocket engines will use only the lower powered kind, 1/2A, or A only. B through F (especially D, E and F engines) are very powerful, and to the careless, it could be a disaster. An F engine, for instance, puts out 35 pounds of thrust, and if attached to a stick and put in a bottle ... well, I'd rather not think about what might happen should it tip over, or something else.

I don't know what it's like in the rest of the world, but in the state I live in, the people in charge seem to get a thrill out of banning things. I hope model rocket engines will never have to one of them. Be careful!

Perhaps it might be wise on those model rocket engine skyrockets to remove the manufacturer's name, so that no one can blame the wrong person for these homemade devices. CS





A STROBING ROCKET

I have discovered an exciting variety of the 1 lb. black powder rocket. The rocket takes off with intensely bright flashes and a very loud banging. When it reaches its zenith, it floats around until it runs out of fuel.

Using a regular 1 lb. spindle and casing, I ram 1 increment of clay for the nozzle. Then I ram 4 increments of 1 lb. rocket fuel. This is followed by 3 or 4 increments of white strobe mix, which is slightly dampened with nitrocellulose lacquer. The strobe mix is pressed to 1/2" above the spindle. This is topped off with 1 increment of clay. 1 increment = 1 1/2 tsp.

A very important note: Strobe mixes are quite sensitive to shock. I learned this about 2 years ago and feel fortunate to still be in one piece. **DO NOT POUND STROBE MIX!** There are no assurances that ramming them with a press is any safer, although I have had no bad experiences in over 100 rockets.

I use a homemade arbor press to ram the strobe and clay plug. Prior to obtaining the press, I used an old-fashioned bottle capper.

The strobe mix I use is:

Ammonium perchlorate	60%
Magnalium 200 mesh (gran.)	25%
Barium sulfate	15%
Potassium dichromate	(added)5%

These rockets can carry a small garnishment, but they do not have as much thrust as a black powder rocket.

All rockets have the potential of exploding on takeoff, but these do it with an annoyingly frequency. About 1 out of 10 act more like an open-ended salute than a rocket. So "light fuse and retire quickly" is my Eleventh Commandment.

My purpose in writing this article is to share my experiences with others. I will assume no responsibility for any use of the foregoing descriptions.

WCB

ROCKET TIPS

I found C.S.'s article on constructing rockets using commercial engines very interesting [*More on Fast Rockets*].

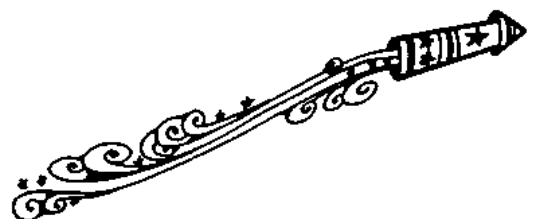
I have made rocket engines from scratch for years, but have just recently discovered that the time savings, reliability, and better performance of commercial engines make them a viable alternative. The time saved in constructing motors can be spent developing new pyrotechnic payloads!

I also wholeheartedly agree with C.'s warning pertaining to attaching sticks to high thrust commercial motors and turning them into skyrockets.

I construct finned rockets and for guidance use a straw glued to the body of the rocket. The straw (with rocket attached) is slipped down over a stiff, three-foot long wire (a straightened coat hanger will do). This arrangement is similar to the way model rocketeers launch their rockets. It greatly reduces the chance of mishap. I have recently seen commercial Class C rockets use this type of system.

I construct the fins for my rockets using pressed styrofoam, like the type used in meat packing. The material is lightweight, can be cut to any shape, and the price is right.

I have launched many rockets using the above techniques, all with excellent results. SWH





ROCKET FLIGHT BOX

Searching for a spectacular effect for a minimum of expense? A rocket flight box may be the answer. I mainly use them for 4 oz. whistling rockets. I prefer at least one of the flight boxes at shoots to be quickmatched together for an instantaneous effect! Here's how I make mine.

First I cut three pieces of 1/2" plywood 12"x18". On one of the 12"x18" pieces I make lines with a pencil and T-square every two inches both ways so that there are 54 2" square boxes drawn. I tack the penciled-lined board onto the top of one of the other 12"x18" plywood pieces so that they align with each other. Now, with a 1" wood drill bit, I drill holes on all of the points where the lines intersect. The holes must be clear through both pieces.

There should be 35 1" holes in each board. Now one of the drilled boards is glued to the remaining 12"x18" board. Two 8"x18" pieces of plywood need to be cut for the sides of the box. For the ends, two 8"x11" pieces. With the glued boards as the bottom of the box (hole-drilled board up) I nail the box together. The box should have five solid sides and only the top and bottom inside of the box will have holes. The next thing I do is to cut 35 - 10" long pieces of 3/4" thinwall EMT electrical conduit and place them in each hole of the box. Now I am ready to put the 4 oz. rocket sticks into the tubes, which will ensure a safe, steady take off.

I fuse the rockets on the ground while they are laying on their sides in rows. This way they are easier to fuse and the rockets can be loaded into the tubes one row at a time. I always allow enough space between each rocket. My favorite way to fuse the rockets is to take a little commercial black powder and sprinkle a few grains up into the venturi of the rocket motors and lay a strip of bare quick match underneath each motor, holding the match on and blackpowder in with a couple strips of masking tape. In this way a couple of rockets will take off first and set the entire box of rockets off and save hours of tedious fuse splicing that is otherwise necessary. This box does not work well as a timed rocket battery unless the shooter is careful that rockets taking off don't set each other off. MB

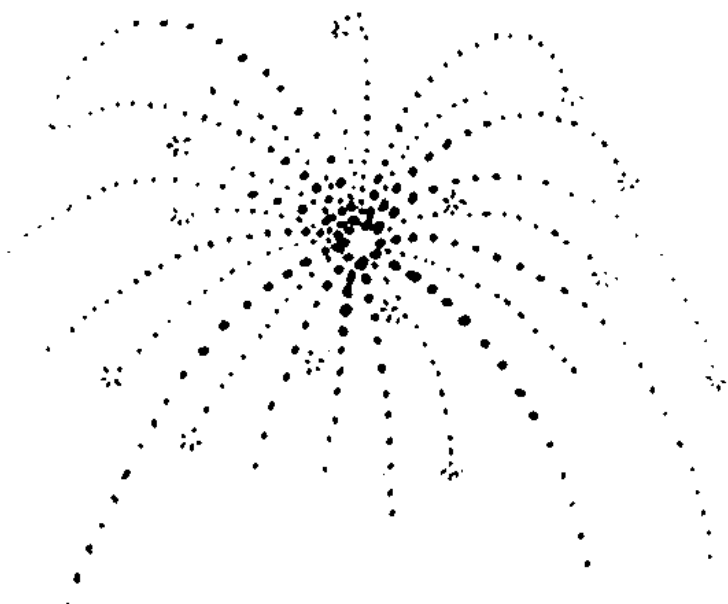
ROCKET PELLETS

I am not sure what S.M. refers to by composite rocket motors [Flash, AFN, April, '87] but I have been experimenting with rocket fuel pellets cored through the center and stacked in a 3/4" i.d. tube just like the shuttle booster. I plug one end with Ventex and when dry drill an orifice through it before the fuel pellets are in. The orifice end may also be made with rammed ordinary clay. After the fuel is loaded I glue a ventex plug in that has previously been formed in a mold and dried.

Unexpectedly, there is some indication that a common 75-15-10% composition that makes an excellent motor, when rammed dry, burns faster when mixed with 3% dextrin and compressed into a hard pellet.

Unfortunately, when working with this mix I had reduced the orifice slightly. That may have been the cause of the dilemma. I have been experimenting with various size orifices and have had several blow up.

I intend to continue experimenting with other composition ratios and orifice sizes until I have a powerful, reliable reaction motor that can be assembled with a selection of pellets for special effects, such as whistles, meteor tails, deploying parachutes, salutes, etc. ALS



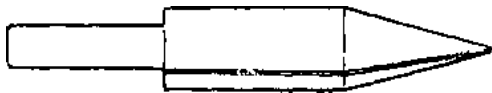


ROCKET NOSE CONSTRUCTION

I've noticed that no pyro supply or paper products company makes rocket nose cones, whereas, the shell builder is offered a variety of plastic shells, cardboard hemispheres, etc., to ease his task. So for rocket builders, here is a method I use to quickly roll high quality nose cones.

Most rocket literature shows a sky rocket's heading rarely larger than the motor diameter. Some show a cone starting immediately at the end of the motor. This would do if I wanted all tail and a minuscule star display, but a rocket can carry much more than that. The rocket builder must therefore decide the optimum payload for himself.

I use a hardwood mandrel to form my cones. The lathe turned part has a $\frac{1}{2}$ " deep slot running down the straight section and continuing up to the top, as shown in illustration #1.



I prefer a head diameter about twice the rocket's bore and about $\frac{3}{4}$ the motor length. I also prefer a cone angle of about 30° for streamlined long flights.

CONSTRUCTION MATERIALS

I've found a pliable, cheap cardboard used for drain fields called leach cloth that's sold in some plumbing and P.V.C. pipe stores. The cardboard is a pinkish tan and is 15 thousands thick and comes in a 3'x8" roll for about \$15.00. A lifetime supply. Manila file folders also make fine cones.

FIRST STEP

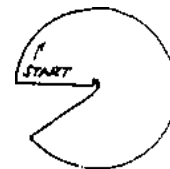
I cut strips for the rocket cylinder section, remembering to leave an extra $\frac{3}{4}$ " length to slip over an adapter ring glued to the motor. I use about 5 turns on the mandrel. The paper end is inserted in the groove and twisted one turn till overlapping. Then I squeeze white glue in a zig-zag pattern and smooth it out in a thin even layer on the rest of the strip. Now I wind it tight and apply masking tape to the edge. If making

large cylinders, I can greatly increase the uniformity by rolling the former between two smooth plywood boards, with a lot of hand pressure. This further compresses the glued cardboard from both sides, making it easier to slip off the former.

A manila paper cylinder only 50 thousands thick, 2 $\frac{1}{2}$ " i.d. x 4 $\frac{3}{4}$ " is so firm from this method that it will support my 180 lbs. standing on end.

CONE CONSTRUCTION

I cut an approximate circle twice the cone length, and cut a 60° V, cut to the center and punch a hole at the tip with a paper punch. Now I insert one edge of the V in the former and twist until the entire circle is rolled into a cone. I tape the edge and trim it until I get a good fit with about $\frac{1}{8}$ -inch overlap on the cylinder. I unwind the cone now and transfer the flattened out "Packman" to stiffer material for the template. I cut a new piece from the template and wind on the cone, until an overlap starts. Then I glue the remainder of the circle and twist the former with firm palm pressure. I seat the glue and finish off with a strip of masking tape on the seam. Note: template shape on #2 drawing.



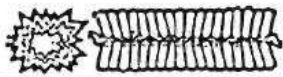
HEAD COMPLETION

I install the cylinder on the mandrel, apply glue on the leading edge, being sure to keep glue off the mandrel. I push the overlapping cone over the cylinder and twist together and tape.

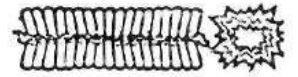
I roll the edge against a flat hard surface to blend the glue joint. Now I twist off the mandrel and the first nose cone is rolled.

ADAPTER

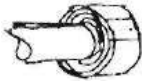
I wind a $\frac{3}{4}$ " strip of cardboard around the rocket motor until the i.d. of the cone is reached. Then I unwind it and use it as a template for the other



THE BEST OF AFN II



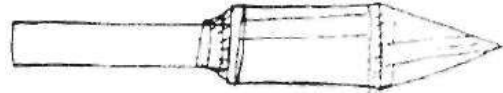
strips. Note fig. #3.



FILLING

I fill the inverted cone with stars, leaving 3/4" to be filled by the adapter. Then I finish off with masking tape, blending head to motor as in fig. #4.

By using this system I can produce cones in quantity in front of the old TV.



Note: For a stronger burst I use 1/2" wide fiberglass packing tape lengthwise over the tip and down the other side 4 or 6 times, and wind three or four bands around the cylinder. I now have a nose cone that won't just pop the tip off.

BS





STINGER MISSILES

Two years ago the Chinese fireworks industry introduced an unusual, spin stabilized skyrocket into the U.S. fireworks market. The Black Panther brand *Warhead Launcher* was initially approved as Class C merchandise but was later withdrawn from the market because of its high content of titanium flash powder. Federal regulations specify that no Class C aerial item may contain over 130mg of flash, but this item supposedly contained between 4 and 6 grams of solid, pressed flash per unit! Of course, the *WHL* was an immediate hit in the marketplace. It was imported in its original form for only one season and then it was replaced with another version containing black powder and stars in place of the flash.

WHL fans need not lose hope. This *Stinger Missile* is simple to make, and actually out performs the Chinese *WHL*. But a set of tooling is needed. Fig. 1 shows tools designed to use cut sections of standard 1 lb. rocket tubing. A machinist can turn the spindle on a lathe from brass or other non-sparking stock. The drifts are made on a drill press from hard aluminum alloy rod.

To make these *Stingers*, I cut the rocket tubing on a bandsaw into sections 2 1/2" to 2 3/4" long. Naturally, I take care to cut the tubes at a true 90° angle. Then, depending on what is free at the time, I use either an arbor press or a hydraulic press to load the tube. First comes the nozzle. A good nozzle is made of 4.3cc of powdered Hawthorne Bond clay. It's available from ceramic suppliers.

A great propellant is straight, homemade meal powder: 75/15/10 potassium nitrate/sulfur/charcoal, blended with hot water and precipitated with alcohol. (See *T7, Preparation of Black Powder*, or *CIA Black Powder Revisited* by Don Haarmann, AFN #35, Aug. 1984). My standard loading scoop is a 4cc cartridge reloading scoop; each motor should take about 6 scoops of meal powder.

After the propellant has been charged, the colored comet charge goes next. I dampen the mix slightly with the appropriate solvent (I like

to use 99+% isopropanol) and then measure the comp into the tube. I press it firmly in place by using moderate pressure on the press. Many different comps could be used, but I must be careful to select a comet comp that is reasonably safe to press at high pressure. I have used a green formula from Shimizu. It requires between 6 and 9cc of unpressed powder to provide an adequate time delay.

The following comes from *Fireworks: The Art, Science & Technique* by T. Shimizu, available from Pyrotechnica Publications.

Green Star

Barium nitrate	28.3%
Potassium perchlorate	47.2
Parlon	4.7
Red gum	14.2
Soluble glutinous rice starch	5.6

Now the side vent is drilled. First I must determine where the propellant grain begins, just above the nozzle (probably about 1.3cm above the bottom of the tube, depending upon how the tooling was mounted). I'm ready to drill, so I use my drill press (it's even possible to use a hand drill after a guide hole is first made with a scratch awl). I use a twist drill slightly less than 3/32" dia. and penetrate just into the propellant grain at an angle tangential to the inside wall of the tube.

When I wish to add a report, now is when I do it. 3cc of 70/30 (potassium perchlorate/dark aluminum), with a dash of Cabosil works for me. Then I place a 3/4" paper end plug over the flash charge, just touching the powder enough to keep its mass from shifting when the device spins on takeoff.

To finish the device, I lightly glue a paper disc 1 1/4" dia. over the top end of the tube and seal it with 1 1/2" wide gummed paper tape. I lightly paste some decorative paper wrap and lay that on. All that's left is the fusing and I like to use a 3" piece of slow Thermolite igniter cord, and tape it to the side of the device with a small piece of



THE BEST OF AFN II

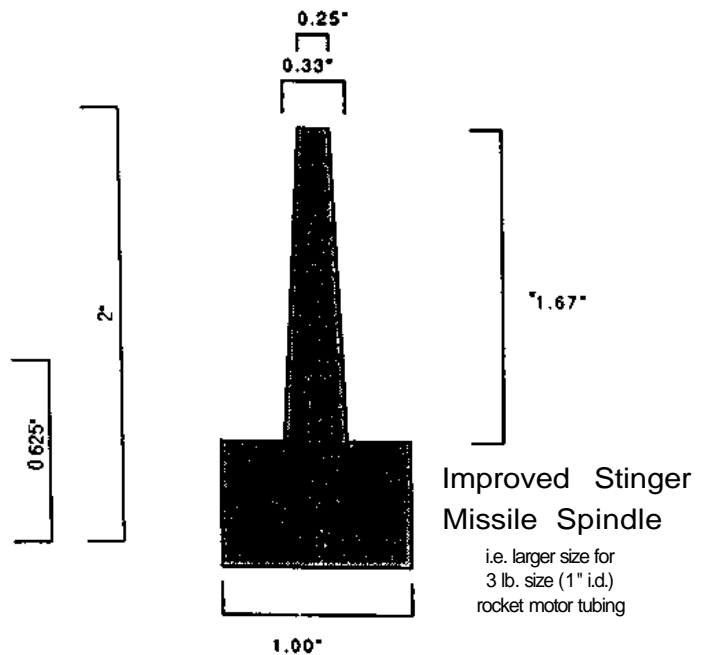
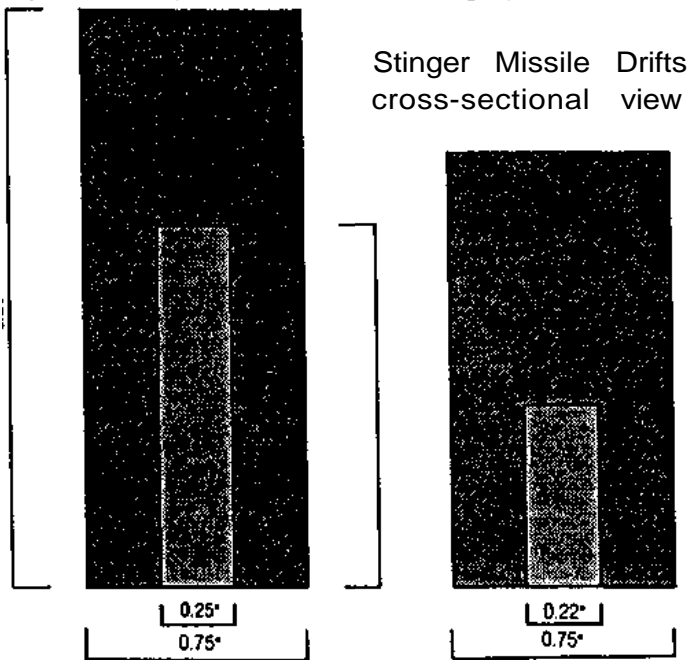
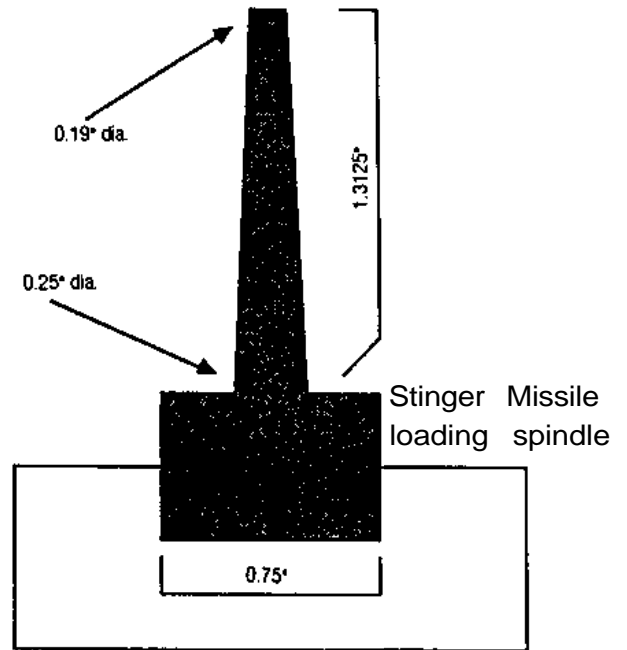


tape. (I have experimented with a 1/8" side vent hole with good results, in which case regular visco fuse may be used). It is now ready to be fired from a *Warhead Launcher* spindle.

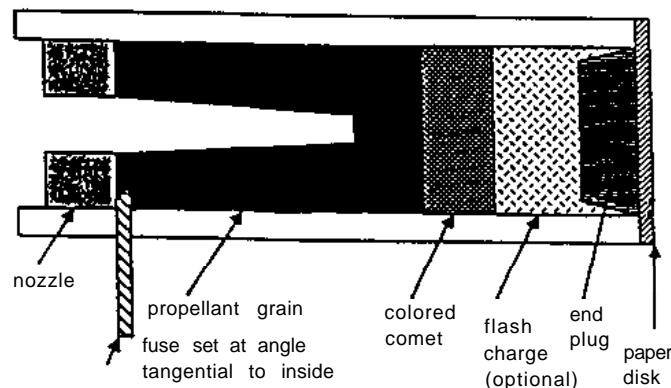
My feeling is that the standard issue *WHL* launching spindles are too small in the base so when I use them I am sure to firmly secure them before firing. If I don't, I feel that the torque from the *Stinger* can tip the launcher over, with potentially disastrous results.

I have made my own pin-type launcher. It was made from a nail pounded through a large board and then filed round at the point.

These missiles can easily fly 1000 feet high! Imagine a volley of them fired in a display! WK



Stinger Missile





SIMPLE CONSTRUCTION OF A MULTIPLE-FIRING ROCKET RACK

One of the most beautiful pyrotechnic sights is a rocket barrage. Many dozens of rockets streaking skyward producing a virtual curtain of golden sparks. Exploding at their apogee, they fill the heavens with whatever garnishments they carry as their payload. A flight of several dozen class C rockets launched in rapid succession makes for a wonderful part of an amateur display. I prefer to make a rack that is lightweight, transported easily in a small car, set up in a few minutes and costs very little (saving expenses for the purchase of the rockets themselves). Here's how I do it.

For each rack, I obtain ten four foot 1" x 1" grape stakes. Grape stakes are the wood stakes usually sold in small bundles by the garden nursery stores. They are used to support tomato plants and such. You can find prettier boards at the lumber yard, but you'll end up paying double. Four of the boards will be used to support and help guide the racks; the other six will be used for the frame itself, first, I take one of the boards, laying it on a solid surface then hammer in thin 3" common nails almost (but not quite) through the board, one at every inch along its length. See figure #1 below.

Next, I lay another board directly under the board with the nails so they are parallel. I place a few of the other boards perpendicular between the first two, and space them out as shown in figure #2. Now I can hammer the nails through the top and bottom boards, leaving a 1" gap in between. I remove the middle boards that were used as spacers. What I have left is something that resembles a miniature ladder with the nails as "rungs". See figure #3. I make two of these "ladders".

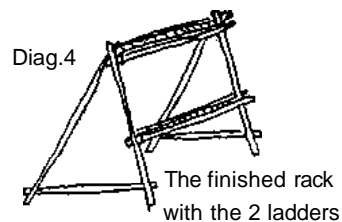
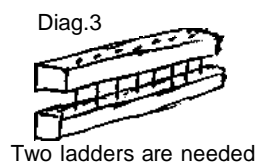
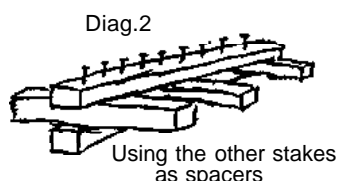
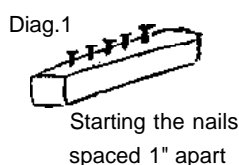
I assemble the rocket frame as shown in figure #4. The two ladders are wedged into the legs of the simple double "A" frame rack and nailed into

place. I finish off the frame by wrapping the various intersections with a bit of strong twine. The sky rocket sticks are dropped into the spaces created by the nails of the two ladders. The engines all rest on the top ladder.

Now I fuse the rockets so they fire in rapid succession. I use a five-foot length of igniter cord ("ignitacord" or "thermalite") or else I use raw black match. When using the igniter cord, I loop the cord around the middle of each rocket fuse and proceed to the next one. The cord stays in place because it is composed of small strands of wire. I then mix up a small batch of black powder and nitrocellulose lacquer to a consistency similar to molasses. I liberally paint all the rocket fuses at each intersection where igniter cord and rocket fuse meet with this solution. The rocket rack is ready to fire in about an hour. This method works particularly well for "side ignition" of visco fuse. In other words, visco fuse is typically difficult to ignite except at the ends where the powder core is exposed. Using this method, that problem may be overcome. I used to add a bit of FeTi powder to the primer mix to make it burn hotter, but I have had equally good results when I have omitted it. Since igniter cord comes in three different rates of burning times, one is able to vary the timing of the barrage. If the rocket fuse is of the paper firecracker type, naturally the primer is not needed.

When using raw match, the same principles apply, except I smear the rocket fuses first with the primer, then lay the match across it, tying into place with a few winds of kite string or even masking tape.

As a side note, 1/4" Japanese time fuse can be primed using the above solution then dipping into meal powder. Drying time for time fuse is at least 24 hours. SC





STAR FORMULAS

PURPLE STARS

	<u>No.1</u>	<u>No.2</u>
Potassium chlorate	60	56
Strontium carbonate	6	6
Copper oxide	5	5
Lactose	20	24
Dextrin	4	4
Hexachlorobenzene	5	5

RED COMET

Potassium chlorate	62
Strontium carbonate	18
Aluminum fines (#810)	1
Red gum	13
Dextrin	6

Note: Black powder prime should be OK as carbonate in the $SrCO_3$ is a neutralizer.

BRIGHT GOLD COMET

Potassium nitrate	16
Sulfur	3
Charcoal, fine	2
Cryolite	4
Aluminum #808	11
Aluminum #810	4
Aluminum #813	1
Dextrin	4

TITANIUM/CHARCOAL COMET

Potassium nitrate	15
Sulfur	3
Charcoal, fine	8
Antimony sulfide	2
Titanium fines	2
Dextrin	3

WHITE ELECTRIC STAR

Potassium perchlorate	30
Barium nitrate	5
Aluminum #808	10
Red gum	4
Dextrin	3

For 1/2" cut or pumped stars. Needs heavy prime.

RED ILLUMINATING STAR

	<u>No.1</u>	<u>No.2</u>
Strontium nitrate	55	60
Aluminum #809	-	15
Aluminum, Ger.blk	15	-
Sulfur	15	15
HCB or PVC	10	6
Red gum or shellac	5	4

Note: for 1/2" cut or pumped stars. Very intense light but slow. Needs hot prime like meal/silicon or red lead/perc. type. Dampen with alcohol.

AQUA MAGNESIUM STAR

Barium nitrate	45
Potassium perchlorate	8
Copper carbonate	4
Parlon*	20
Charcoal	4
Sulfur	8
Mg/Al 50/50	7
Dextrin	4

*See footnote below.

PURPLE MAGNESIUM STAR

Strontium nitrate	38
Potassium perchlorate	8
Charcoal	5
Sulfur	5
Mg/Al 50/50	12
Copper carbonate	10
Parlon	18
Dextrin	4

Note: if stars are hard to cut or shatter on cutting, substitute PVC for half the Parlon.

BARIUM SULFATE GREEN STARS

	<u>No.1</u>	<u>No.2</u>
Barium sulfate	33	35
Potassium perchlorate	35	30
Magnesium, 100 mesh	3	-
Magnesium, 325 mesh	-	10
Aluminum #809	6	-
Parlon	15	20
Red gum	6	5

Note: use alcohol



MAKING STARS

There are those that can and those that can't. In the beginning you may feel somewhat discouraged and think you belong in the latter group of fireworks enthusiasts, but don't be. It takes a while to get off the ground. As with anything else, your knowledge and abilities will increase on a direct ratio with your interest and dedication.

One of my first projects was to make red, blue & green stars of the deepest colors I could. Later I found that there are other shades that are needed to complement the deeper hues.

The basic chemicals for colors are STRONTIUM for red, BARIUM for green and COPPER for blue. Now here are five formulas that work and will give a very deep shade of colors which are as good or better than your commercial stars. My technique is to keep quantities small in the beginning and mix the fuels together thoroughly before adding the chlorates. I keep in the forefront of my mind the fact that chlorates, especially barium chlorate, are friction sensitive in the extreme and that no rubbing of these mixtures is ever permitted. Also, I watch for static electric generation as they are very spark-sensitive too. Finally, some of the dusts are toxic so I wear the protective clothing. One of the reasons I subscribe to AFN is that it is a constant reminder not to get careless. Even small burns hurt.

All weights are given in grams.

DEEP GREEN

Barium chlorate	24
Red gum	6
Barium nitrate	8
Dextrin	2

WHITE

Potassium nitrate	28
Antimony sulfide	6
Sulfur	8
Dextrin	1.5

DEEP BLUE

Potassium chlorate	65
Copper oxychloride	12.5
Lactose	12.5
Dextrin	5
Hexachlorobenzene	5

PURPLE

Potassium chlorate	24
Strontium carbonate	3.75
Copper oxychloride	2.5
Shellac	4
Hexachlorobenzene	2
Dextrin	1.5

DEEP RED

Potassium chlorate	6
Strontium nitrate	6
Red gum	1
Stearic acid	.25
Dextrin	.5
Charcoal (air float)	2
Hexachlorobenzene or Polyvinyl chloride	.25

When mixing these, I add about 10% water to the mix to begin with, then add more as needed. I usually retain a small quantity of mix, in case I have over-watered. Anon Pyro

THE "How the heck did he do THAT?" SPECIAL EFFECT STAR

I have a few boxes of wire coated sparklers. By bending the wires around a pencil, small, irregular pieces of the sparkler composition will fall off. I combine these rock-hard sparkler chips with my favorite pumped star formula for a truly amazing aerial effect. The chips also work well when used in gerbs and fountains to produce an interesting pseudo micro-star fountain effect.

SC

MAKING CUT STARS

When I attended my first CMPA meeting, I overheard a couple of greenmen discussing the problems of cutting stars. It seemed they had both had trouble getting them to come out right and preferred making them on a plate. This struck a familiar chord with me, because in spite of numerous descriptions I had read, my first batches of cut stars were nothing to brag about. My earliest attempts consisted of pouring shellac from a can into a mixture of sodium oxalate and potassium perchlorate.

Somewhere in Weingart's book there is a reference to cutting stars on a sheet of paper and just leaving them there until they are hard, then breaking them apart. This is where I started and while the stars are not too good, it did introduce me to the principle of "Falling Leaves" (although I didn't hear about them 'til years later!). At any rate, one learns early that SOUP does not make good stars.

In *Pyrotechnica #1*, J.S. outlined the star-cutting procedure, using a box of damp composition, which is used to form a cake or loaf of composition. This is then cut into manageable cubes. Slices are cut from these smaller portions, which are then diced to form the stars. This process is an excellent one for turning out quantities of stars, as anyone can tell you who has pumped more than a pound or two of small (1/4" - 1/2") stars. But it does necessitate a lot of cleanup, with dusty priming flying around. Besides, you need a batch of adequate size to make the extra work worthwhile. While one solution would be to have a few different sizes of star boxes, another solution would be to cut the stars on a flat board, as Weingart, Shimizu and Lancaster have recommended.

Cutting stars on a board, in my opinion, is definitely more time-consuming than the box method, but it has a few advantages for the small batch or for special stars, or for new mixings where the correct amount of dampening is undetermined. With the star BOX, it is essential that as much pressure be used as is practical to bond the comp. together. With a star BOARD,

the mix can be considerably overdampened without being ruined. This gives me a chance to correct the remaining portion of the mix before cutting. If the mix is too crumbly as it is being beaten down, it is a simple matter to dump the comp. back into the mixing bowl and further dampen the entire batch. The star board can also be used successfully with some stars that don't usually cut too well, such as those made with alcohol & rosin or shellac as a binder, and those made with flake aluminum.

A star board can be made simply by getting a smooth board, preferably hardwood, and varnishing it enough to waterproof it and protect against scratches. I made mine with a piece of 12x18x1" maple, with seven coats of polyurethane varnish, sanded between every other coat. An old Standard-rocket stick furnished the edges to hold the comp. in place. Brass screws or copper nails are best to lightly tack the edge strips down. Varnish helps here too.

While Shimizu recommends using a small mallet to tamp down the star comp., it is faster to make it a little on the wet side and pat it down with your hands. A light rubber glove will help keep the dirtier mixes like lampblack stars, from seeping indelibly into the fingerprints for the next few weeks! It's also best when starting out to use a mix that won't suffer from too much water. A simple charcoal or aluminum streamer is more forgiving than a glitter mix. Colored stars, especially those containing chlorate, are best left until one has enough skill to prime the star lightly, but enough to avoid sticking and avoid producing too many "crumbs". Some of the mixes containing metal and a resin binder are sticky enough, but just don't hold together very well when pressed into a loaf - they're too light and fluffy. These can still be cut with patience if pressed out in one flat sheet. It is also possible in some cases to slide the entire sheet right off the board and onto a drying screen lined with paper, to be cut or broken up after it has hardened somewhat. Weingart recommended this for a few of his cheaper willow-type stars. Also, a sheet of paper can be used to cover the board before the side strips are



tacked down. Then, if the stars are not so wet that they ooze back together, they can be cut and left on the sheet of paper to be dried elsewhere. The star board is sometimes more convenient for cutting very tiny stars, to be used as cores for round, color-changing stars, or for stars which must be small, such as the strobe type. Where uniformity is important, the star board can be superior to the box for keeping the thickness equal on all the "sheets" of composition. Cutting them square is possible - it takes patience!

To use the star board to cut a batch of stars, begin by tacking the strips down around the edge. For 3/8" stars, the strips should be about 3/8" high, but the width is not important. The star mix should not be so damp that it can be poured into the frames, but it must have enough moisture to flow when pressure is applied. 8% moisture, by weight, is a good place to start, but it's a good idea to keep some dry comp. available in case it's overdone. Fill the frame as full as possible with the damp comp. and beat it down, particularly at the corners and along the edge. The middle is easy to smooth out. When there is a solid mass, use a knife to scrape off the high spots if desired. Then take off the strips carefully, as the comp. may stick and cause cracks. If the mix is stiff enough, it can be cut up right on the board and primed. Usually it's a little too sticky for this and a layer of prime should be dusted over the surface. Then a cut is made across to form a long strip of comp. This is rolled off onto another work surface where it can be cut into individual cubes. These then can be additionally primed if needed for hard-to-light stars or to keep them from sticking. Once a few strips of comp. have been sliced from the sheet, there is enough room on the board to do all the cutting there. Another way is to cut a lot of strips first and prime the edges, then cut these across, forming several stars with each cut. Remember to clean up before it dries! Don't be discouraged! There's bound to be a mess and some trouble the first few times but once accomplished often enough, no one would want to pump stars again unless there's a darn good reason! JB

1/8" CUT STARS

When I first heard of 1/8" stars, I thought it had to be another bother like trying to make Chinese fuse. That idea turned out to be very wrong. In fact, it is almost as easy as making 1/2" or larger cut stars.

These small 1/8" stars are used primarily as cores for the starting of round stars and for strobes. They can be used a lot of other ways, but using this size for strobes will be the main idea of this article. Strobes made larger than 1/8" will fall to the ground still burning so this size is a must.

The two most important considerations are what the stars are cut with and the dampness of the composition. Aside from these, the technique is about the same as cutting regular stars.

I use a frame, 12x12" by 1/8" thick, along with a knife 16" long which is 3/32" at the thickest point. The composition is dampened first. From the variations I have seen in the last year, there is no way to tell how much to dampen it. (For this demonstration, I am speaking of strobe stars.) All I can say is that the operator must gain this from experience but I CAN say that it must be somewhat wetter than normal stars. After I pack the composition into the frame, there is a light sheen of moisture that can be seen in the light when viewing the top. This "excess" moisture helps hold the star together and provides extra adhesiveness for the prime coat.

The frame is then removed and the long, thin knife is used to cut the stars to size. After cutting the stars, I prime mine with 4Fg black rifle powder. I believe the coarseness of this prime coat helps a great deal in the stars taking fire, soaking up some of that excess moisture in the priming process.

Once tried, I think many are going to be amazed at how simple it really is. MG



STACKED STARS

Any amateur reading Dr. Takeo Shimizu's five pages on color-changing stars in Lancaster's *FIREWORKS PRINCIPLES AND PRACTICE* is most likely at first amazed by the degree of skill required to produce the stars, and then discouraged from ever trying it himself. The beauty of Japanese shells is NOT easy to achieve, but stars with several successive changes in color or other effects which are satisfactory for many applications CAN be easily made.

All that is necessary is the joining end to end (with a suitable priming paste) of different pumped stars of the same diameter. To hold them in alignment while the paste dries, they can be inserted in a plastic or metal tube that the paste will not stick to. One must also be sure not to use too much paste or paste that is too thin.

Since the stars are individually made and dried before being "stacked" together, many problems inherent of the Japanese layering method are avoided. For instance, Dr. Shimizu mentions "driven in" moisture and its subsequent drying thru the layers of composition. A possible problem he does not mention is the carrying between layers of oxidizers or other soluble ingredients by the moisture and the possibility of impaired performance or increased sensitivity as a result. Starting with dry pumped stars gets around this and the paste can be made for the specific application, that is, sulfur-less for use with chlorate stars or a hot burning primer for use with hard to ignite compositions, etc. Unless the paste is too wet at the start, transfer of soluble ingredients between adjoining stars will not occur. Because they are separated by the mutually compatible paste, the danger of direct contact of incompatible compositions is avoided. For example, an ammonium perchlorate star could be joined by means of sulfur-less priming paste to a chlorate star with less danger of ammonium chlorate formation than if they were adjacent layers on a spherical star. While this combination is not recommended, the stacked stars are the safe way to do it, should it be done.

The one drawback of stacked pumped stars is that to function properly they must be ignited at the end only and burn progressively from one star to the next. Comets, wherein the star fits the tube snugly and the fuse enters below the star are a good application and they can also be made to fit the i.d. of a rocket case to be blown out and fall with several changes and a long burning time. To avoid side ignition and breaking apart in shells or mines, they can be rolled in a few turns of thin paper and closed on one end, making them, in effect, pill box stars with layered compositions.

One thing I know, some of the most beautiful stars I've ever seen were STACKED. HD

COMETS AS RISING TAILS

Comets attached to the outside of round shells make an attractive ascent effect. The best compositions to use are long tailed glitter, charcoal streamer, or flitter, made from a potassium nitrate based, easily ignitable composition.

It is somewhat difficult to attach a flat based pumped star to a round sphere so I have modified the pumping technique somewhat. I use a 1 1/4" diameter pumped star about 1 1/2" long attached next to the lift ring on a plastic 4" round shell. Instead of pumping the star on a flat surface, I pump it directly on the surface of a finished shell. I set the shell on a base of a short piece of 3" PVC pipe and fill the star pump and apply pressure to the damp composition while the pump is resting on the top of the shell. Now when the star is pushed out it will have a concave surface exactly matching the shell. With a plastic shell I use a Q-tip soaked in solvent to smear a round area thoroughly a few times near the top loop. The star is pressed on and securely attached. More than one star can be attached, if desired. DB



BLENDER COMETS

In our never-ending quest for a better way, many a household appliance has been violated by us pyros. We mill our powder on record players, we mix star comp in washing machines, we evacuate our vacuum ovens with refrigerator compressors. Inevitably the blender would also aspire to pyrotechnic greatness. I've made some pretty nifty comets on this device. Here's how I do it:

Cases first. These light paper cases are not really necessary to the comet's function, only to its manufacturing process. I cut some 8 1/2x11" sheets of scrap paper in half lengthwise and roll each around a 1 1/2" mandrel to form a tube 4 1/4" long. I glue it and then fold the bottom inch over to close that end. It is now a flimsy little cup which will not hold water. I make about fifteen at a time.

Also needed in the manufacturing process is the same number of small rods, 4" or so in length. Old pencils work nicely, so do 16p nails.

My comet formula is as simple as can be:

Potassium nitrate	800 grams
Water	300 grams
Charcoal briquettes	500 grams
Sulfur	100 grams

I weigh the charcoal briquettes into a can and then bludgeon them with a blunt instrument until I am satisfied that the pieces will not stall the blender.

Now for the good part. I sneak into the kitchen and heat the potassium nitrate and water on the stove until the nitrate dissolves (about boiling). One convenient property of potassium nitrate is its tremendous solubility in hot water. At room temperature it will precipitate, forming a rock. Now I pour the steaming hot solution into the blender. With the blender whirring merrily, I add the charcoal and sulfur. Ahh ... savor the succulent vapors of hot saltpeter and brimstone! When was the last time such a tantalizing aroma emanated from your kitchen?

The mixture is now marginally ignitable. To remind myself of what I am doing, I sometimes

take a sample outside and light it, then ponder whether I really want to be whipping the stuff up in an electric appliance. Sure, I keep a bucket of water handy.

After blending full blast (whoops) for about five minutes, meanwhile persuading the charcoal chunkies to enter the vortex with a spatula, I'm pleased to see a smooth gunpowder-type puree. At this point I work quickly, lest it form a rock in the blender; after it cools it will be a solid as the potassium nitrate precipitates.

I pour about 100 grams of the hot slurry into each of the comet cases. At this point an interesting phenomenon occurs. The slurry becomes stiff and unpourable after sitting for a minute. Agitation such as whipping it with a spatula or rapping the hot comet on the table causes it to re-liquify. My chemical engineer friends call this a *thixotropic* or shear thinning fluid, but none of them have offered an explanation as to what magical intermolecular forces are the cause.

While the comet is still hot and gushy, and reminding myself not to get carried away by the Freudian implications, I make a center hole by pushing one of the rods, nails or pencils into it. I pick up the case and rap each thixotropic comet on the table several times to summon the magical intermolecular forces and settle the composition. When the comets cool, the rods are withdrawn. The resultant center hole makes for fiercer, more reliable burning.

I launch my blender comets from a 1 1/2 tube with 10 grams of black powder. The effect is a pleasant lingering tail of soft orange sparks.

For a yet more pleasing effect I can add some garnishment. I take a string of 16 firecrackers and bend it into a semicircle. I stick a pack into the paper case before pouring the comet puree. Thus, the comet will crackle loudly as it ascends.

The only remaining problem is to clean the charcoal out of the blender and off the kitchen table before the Mrs. returns. Be prepared to answer embarrassing questions like "Darling, why did you put pepper in the daiquiris?" PM



COMET PROBLEMS

KC. has brought up some interesting points regarding the attachment of rising comets to round shells. I wrote an article about forming a pumped star directly on the outside surface of a finished round paper or plastic shell. Normally pumped stars have a flat bottom and top. Since it is difficult to join a flat surface to a spherical surface, I recommended placing the pump, filled with damp composition, on the shell's surface. That way a comet star can be formed with a concave surface matching the convex surface of the shell. After drying, the star can be hot glued to the shell.

K. was concerned that the use of hot burning compositions in the comet mix could spell trouble. He envisions the rising comet softening the plastic shell wall, and perhaps burning right through. He states: "This could possibly cause a premature break or low break from a burning comet igniting the stars instead of the burst charge. And my second point is that even if this does not happen, you still have that hot tail softening the plastic hemi, and you now have a weak point on your shell which could cause an irregular burst." He suggests placing a small chip-board disc on the bottom of the tail before attaching it to the shell.

I have shot quite a few shells with attached comets and I can assure K. that this scenario does not happen. I have never witnessed any premature breaks or any effect of the comet on the break. What usually happens is that the heat produced by the burning comet softens the glue and the comet is dislodged from the shell by the powerful air stream it encounters on the way up. The comet then falls behind the shell in its upward trajectory. An observer on the ground will see the ascending comet burn out and the shell break open above the top of the comet trail.

Keeping the comet attached and still burning when the shell breaks requires careful design. First, the composition chosen must be ignited by the mortar fire only at the top surface. The sides

must be protected from burning by wrapping with several layers of masking tape (which is dangerous in itself, for it can come down as burning embers) or a few layers of 60 lb. kraft paper pasted around the cylindrical surface of the comet. To assure that the comet will take fire, I will place a piece of thermolite or black match on the top surface and paste or tape down. This technique covers the entire surface of the external comet, with only the comet fuse exposed. The comet should have a total burn time of between 4 and 5 seconds. When ejected from the mortar, the rapidly spinning and rising shell will still dislodge its attached comet as soon as the glue softens near the end of the comet's burn time. Yet the observer on the ground, 300 to 1000 feet away won't notice the subtle separation. There is no compelling reason, in my view, of trying to guarantee that the comet stays with the shell until the exact moment of the break, for even after separation occurs near the zenith, both shell and comet will be tracking each other closely in the sky. DB

COMET COMPOSITION

Careful readers of Tenny Davis will have noticed the tip that his Snowball Sparkler composition makes excellent comet stars. Folks who have tried their hands at comet stars will know that a hard star is necessary, yet one that is easy to light. This composition fills the bill.

Potassium nitrate	64
Barium nitrate	30
Sulfur	16
Charcoal dust	16
Antimony sulfide	16
Aluminum fine powder	9
Dextrin	16

THE KAMURO STAR

Many of us have seen the beautiful Japanese Kamuro shell at displays perhaps not knowing the name of the shell seen. The stars of a Kamuro shell burn for a long time, giving the shell a willow tree appearance in the sky. Just as the stars finish their outward trajectory and start heading straight down to the ground, the silver/aluminum streamer core ignites. This produces a dramatic finish of widely separated, short bright silver flitter "ropes". There are many variations of this basic theme. Some Kamuro stars end in a short burst of color, usually red. The appearance of the willow tail varies from ordinary charcoal streamer to a more commonly used extremely long tailed glitter-type effect. Sometimes the tail starts off as a dull red charcoal streamer and then brightens to a long tailed glitter/flitter effect before igniting the silver core.

In the Bensen & Hedges International fireworks Competition in Montreal last June, the Ogatsu people absolutely packed the sky with a dense volley of 15 - 20 large Kamuro shells. That extremely impressive climactic effect stimulated my interest in designing my own version of the Kamuro star. A good Kamuro star was deemed to possess certain essential properties: 1. A burning time of 4 - 6 seconds (for shells up to 5" diameter); 2. A tail which lingers in the air for nearly the entire burning time of the star; 3. A tail brighter than charcoal with at least some hint of a glittering or mottled effect; 4. A small aluminum flitter core.

I usually don't make new formulas from scratch but prepare them by mixing together various proportions of two existing formulas. The idea is not to try to arrive at the exact composition used in a Kamuro shell for there is not one specific formula in use anyway. It is easier to try to arrive at one that simply meets the specifications above.

I have used three compositions to make a Kamuro star. The flitter core uses a bright flitter mix with a relatively long burn time because of

the high percentage of aluminum. The boric acid is added to buffer the pH of the star composition, which helps slow down any decomposition of the aluminum in the wet state.

Using a solvent spray of 50/50 alcohol/water I roll the flitter cores in a pan to a finished size of 5mm diameter. Then they are dried in the shade.

The streamer composition is made from a slow burning willow mix. The mix is ball milled for 24 hours, dampened with 20% water and passed through a 10 mesh screen and allowed to dry. Then the dried grains are put back in the tumbler for 2 - 4 hours. The resulting product should pass completely through a 50 mesh screen but should not be fine as flour. The wet granulation step greatly aids the spark density.

Any simple glitter mix can be used for the willow component provided it contains at least 8% aluminum. I used a slight modification of one of R.W.'s compositions as given below. I do not ball mill the glitter mix.

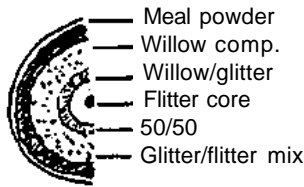
If the glitter mix is applied directly over the flitter core, the core may not ignite as the temperature produced by the burning glitter layer may not be hot enough to ignite the core moving through the air. To assure ignition, a 1mm layer of a mixture of 1 part glitter and 1 part flitter is applied. Then the main streamer composition is prepared from 1 part glitter mixed with 3 parts willow. I apply the glitter/willow mix to the cores until the star size reaches 11 - 12mm diameter.

After these cores have dried in the shade for a few days I put them back in the rolling pan and bring the size up to 14mm with just the willow mix. Another finishing layer of meal powder, .5mm thick, is added to give a final size of 15mm. The illustration below shows the various layers in the cut-away view.

The star should be tested by firing it out of a 3/4" mortar tube to be sure the star goes through all



of its transitions and achieves ignition of the flitter core. It is not unusual for the flitter core to ignite when the star is tested on the ground but not in the air.



This star produces a striking imitation of the commercial Kamuro stars with its pleasing transitions. They can be used in shells of 4" or larger.

1. Flitter Core

Potassium Perchlorate	40%
Aluminum dark (not German)	64
Dextrin	5
Boric Acid	1

2. Willow Comp

Potassium Nitrate	37
Sulfur	12
Charcoal	45
Dextrin	6

3. Glitter Comp

Potassium nitrate	50
Charcoal	20
Aluminum 12/x (spheroidal)	9
Antimony sulfide	12
Barium carbonate	5
Dextrin	4

DB

A FIERCE YELLOW STREAMER STAR

While we're on the subject of star compositions I will pass along this formula for a bright yellow star with a nice streamer tail. Whistle comp, made from sodium benzoate and potassium perchlorate is used to produce the yellow flame and the ferrotitanium supplies the streamer tail. I have found it necessary to add 5% charcoal to keep the star burning as stars made with whistle comp alone burn fast but tend to blow themselves out because of the vibrational burning characteristic of whistle comp. The formula is given below:

Yellow Streamer

Potassium perchlorate	70 parts
Sodium benzoate	30 parts
Charcoal	5 parts
Ferrotitanium 100 mesh	40 parts
Dextrin	4 parts

Readers familiar with whistle comp will understand that the perchlorate and benzoate must be well mixed to burn properly. The ferrotitanium is added last and I find I need only shake it with the color comp to assure reasonable mixing. If this mixture is made into pumped stars I add only about 5% water as the main ingredients are very soluble in water. I use a spray of 70% alcohol in water to form round stars with this mix and they come out very hard. The stars can be primed with black powder, slower burning Chrysanthemum 6, or glitter composition. DB

TWO JAPANESE METHODS OF MAKING ROUND STARS

1. This method produces fairly round, primed stars very quickly. The stars may be used for rockets, for Japanese poka shells, or if carefully made, may be used as cores for round stars. The method relies on the composition picking up water easily, thus mixtures containing more than, say, 20% bright aluminium are difficult to use.

They sprinkle a 1mm layer of star composition evenly on the bottom of a 1 liter glass laboratory beaker (straight walls, flat bottom but rounded at the join).

They gently dampen the surface of the layer by spraying with water, but they try to keep the walls of the vessel dry. They hold the beaker at the spout with the thumb inside and the fingers outside, and rotate it for about half a minute; at this early stage they rotate the wrist only - no big arm movements. They scrape the walls clean of adhering material, and rotate again to let that pick up more powder, and to round it up a bit. If there is still dry powder in the container, they sprinkle on some more water; this amount of water should be judged carefully as too much would result in the small, light lumps sticking together.

Now the stars are grown as usual: they dampen the grains very lightly and rotate the beaker for a full minute. They sprinkle on a very small quantity of powder and rotate a few times. They inspect the grains and break up any clumps that have formed. They rotate again, add an amount of powder, then rotate for a minute or two. It is very important to rotate the stars after the addition of water so as to spread the solvent as evenly as possible. After this addition, the stars are most easily influenced as to shape, but are not individual entities, therefore the smallest amount of powder possible is added to separate the grains, followed by the very important rotation. Long rolling at these additions also ensures dense stars.

I consider it most useful to carry on by the "toro" method (described next) once the stars have grown to 3mm or so.

When using willow mixes, or those of high aluminum percentage, dust tends to fly around; this becomes more worrying than troublesome, of course, when using Paris green or realgar. You can get round this by wrapping a cloth over and around the beaker's mouth before rotating.

2. The toro technique.

The Japanese always use this technique (as far as I have seen). It has two main advantages: it allows the stars to grow more uniformly, as the paste may be spread more evenly than water on account of its viscosity; it presents an obvious and methodical method for priming the stars.

For cores, I advise the use of 3mm cut stars; although these are troublesome to make, they will probably be the easiest cores for beginners to use. The Japanese use rounded sand grains, but the worker must be very skilled to be able to manipulate such fine grains. I have found tapioca to be very useful.

Experience will tell you how "strong" to make the toro; clearly at the start, when the cores are likely to stick together, then a thinnish toro should be used.

They start with 50-100g of dry cut stars in the 1 litre glass beaker, and add a spatula-full of toro, and mix it in with the spatula. They swirl the beaker. If the stars are not evenly coated (you can tell this from their glossiness) and/or, if there are many groups of stars stuck together, then they will put their right hand into the beaker, open-palmed, and wipe the stars between their hands and the glass against the vessel wall and drop them; they repeat this until the paste is evenly distributed. They rotate the beaker for a short while, inspect the stars, break up any clumps, and rotate again. They sprinkle in a little powder, and swirl for a minute or so. They hold the beaker between their two hands around the circumference of the beaker (about half-way up) and, starting with its bottom in a raised position away from them, flick it with their wrists to a position with its bottom in a raised position towards them. This important technique brings



stars up from the bottom to the top, thereby allowing uniform growth. They swirl and flick until they believe that the stars have an homogeneous coating. They sprinkle in some more powder as needed, swirl and flick. It is important that clusters of stars are broken up as soon as possible. If after drying two stars are found stuck together, they are left as a pair. The coating process is carried out three or four times before drying.

Stars are sorted (by sieves) once or twice only, and near the beginning of the procedure. I have seen no evidence of stars being selected for important shells in Japan.

A shallow tray is used to measure the star diameter. Some stars are poured in, formed into an ordered line on one of the sides of this square-tray and are counted. (Evidently, doing this a few times is a test for the uniformity of the stars.) Therefore they must work out a program of numbers corresponding to the stages at which compositions must be changed. For example, (using an 11.7cm edge):

3" red-purple peony:
purple(21) red(14) hiki(13) hayaku(12.4)

4" amber-flash peony:
koro(21) ginlan(20) green(19) amber(13)
hiki(12)hayaku(11)

Hiki: this is the composition that Dr. Shimizu calls "Chrysanthemum"; it uses only pine charcoal. It is used just before hayaku in every star except willow (brocade or ordinary).

Hayaku: this is essentially just unmilled gunpowder with 5% starch. It is used as the final coating on all stars.

Koro: this is Dr. Shimizu's "flash". The one I encountered (and had to put through a sieve a few times) in Japan was a mix of: barium nitrate, P1000 aluminium, antimony sulfide, sulfur and potassium chlorate! It was always used at the core of willow stars; it is interesting, therefore, to note that the real meaning of its Japanese

symbol is "dew", which is indeed what it looks like in this case.

Ginlan: this is pretty hard to translate. It is an aluminium/chlorate mix (and yes, the other ingredients in the one I was using were starch and antimony sulfide). It is used because it is very easy to light, and is very hot burning.

I imagine that I am pretty much the only person who was stupid enough not to understand what Dr. Shimizu is saying in the section on priming in his last book. Nobody sits around mixing small quantities of two different compositions so as to achieve a graduated priming system at a changeover. There is no need for this. Except for the case of colour changes in peonies, all composition changeovers are accomplished by using the old toro for the first couple of additions of new powder. Together with the next technique, this ensures ignition of any mix.

High aluminium mixes (such as Shimizu's "golden wave" with its 40% aluminium) are not going to be ignited by cooler mixes (such as willow). There are the general rules, therefore, that koro is always ignited by ginlan, and ginlan is always ignited by green. (Green is used because it is cheap.) The white star - a perchlorate/aluminium star - is also ignited by ginlan. There is little need for worry that the willow mix (as in the above example) will not ignite the green. In using the above golden wave star with realgar, obviously a chlorate colour mix is an unacceptable prime; therefore I would suggest the use of an intermediate layer of an ordinary nitrate/aluminium brocade mix which will be easily ignited by hiki.

I hope that this essay contained some information new to you, and that it was of interest. I would, of course, be interested in any improvements on what I have said, or in other questions related to this topic. JBC

[We are very pleased to be able to publish the article above. The author spent a year working in a Japanese fireworks factory. We hope the article will be the first of many that will detail his experience.]

SIZZLING COLORED COMETS

The sizzling colored comets described in this article have brilliantly colored heads, have short white tails and produce a sound much like frying bacon. They are very simple modifications of standard potassium perchlorate color compositions, are inexpensive and are relatively easy to make. These sizzling colored comets are suitable for use as comet stars in shells or for use as single large comets.

Below are standard formulations for blue, purple and red stars. The blue and purple formulations are taken from T. Shimizu's article in *Pyrotechnica VI*. The red formulation is analogous to those presented by Shimizu. They all use potassium perchlorate as oxidizer, red gum as the primary fuel, and dextrin as the water soluble binder. The only modification of these formulations, to turn them into sizzling color comets, is the addition of 10 to 20% of 20-50 mesh atomized magnesium. Varying the percentage of coarse magnesium has the effect of increasing the density of the tail and the sound level produced. The addition of unprotected magnesium makes it inappropriate to use water to activate dextrin as the binder. Instead, alcohol, denatured ethanol or methanol (with proper ventilation), should be used to activate red gum as the binder.

The dampened composition is fairly sticky, and while cutting stars is possible it is not easy; making pumped stars is preferred by the author. On drying, the stars/comets are quite water resistant and priming can be easily accomplished by dipping them into a water slurry of home-made meal powder containing 5% dextrin. To make the stars/comets easy to handle while the wet prime is drying, they can be sprinkled with dry meal powder or rolled in a bowl that is partially filled with dry meal powder.

It is somewhat difficult to judge the color of these comets when burned on the ground. In part this is because they will be surrounded by a number of bright white sparks which are not propelled very far from the star. However, the main reason is that one's eyes do not perceive color well when over-powered by the high light intensity produced by these stars. Tests should be made

with the stars/comets in motion and at a distance of at least a few hundred feet.

The comet stars function very much as one would expect. When the star burns, the large particles of magnesium are partially consumed within the flame envelope. This has the effect of raising the flame temperature which in turn results in increased light output. Because the composition is fuel rich from the addition of magnesium the size of the flame envelope is greater making the star appear slightly larger. Because the magnesium particles are large and rounded, only their outer surface is consumed inside the flame envelope. Thus burning particles appear white, in the absence of a color agent and chlorine donor, and form the tail of the comet. (Readers wishing additional information on the subjects of chemical color production in stars, flame temperature, etc. are referred to a paper on those subjects that appeared in *Pyrotechnica DC*). The mechanism of generation for the sizzling sound produced by these comet stars is not fully understood. KLK

STANDARD COLOR FORMULATIONS: (parts by weight)			
Chemical	Blue	Purple	Red
Potassium perchlorate	64	64	64
Parlon	14	13	10
Red gum	9½	9½	10
Copper carbonate	13	5	--
Strontium carbonate	--	8	13
Dextrin	5	5	5
ADDITIONS TO MAKE SIZZLING COLOR COMETS:			
Magnesium 20-50 mesh, atomized (use alcohol)	15	15	15

[Note: It should be emphasized that the author devised these beautiful comet stars by taking a standard parlon star, substituting red gum for the dextrin, using alcohol instead of water and then adding a unique atomized coarse magnesium. Water is never used in magnesium formulations. To our knowledge, the magnesium described here is available only from KSI, Inc., 1471 Blair Rd., Whitewater, CO 81527.]



COMMENTS ON SIZZLING COLORED COMETS

I was very interested in the article about sizzling colored comets. I have made similar items in the past, although using entirely different methods. Also, while impressive, they are not so modern as they might seem. The 1903 Scientific American Cyclopaedia, cribbed from Kentish I believe, lists a series of formulas for "asteroids", which utilize chlorate and sulfur, along with magnesium filings. Depending on the coarseness of the filings, an illuminating or trailing effect could be obtained. These formulas, while inherently dangerous and ill-conceived in their original form, can be easily updated by substituting potassium perchlorate and rosin (or Vinsol or red gum).

It is interesting to note that the sizzling colored comets formula modifications require a star mix that will burn on its own, unlike illuminating mag mixes which rely on the fine magnesium as a fuel. I have found that the hotter burning illuminating mixes, when containing RSI's coarse magnesium particles (about 10%) do tend to consume the particles at once, which illustrates that 1) the magnesium can be used for a trailing effect, with additional candlepower as a bonus; 2) illuminating mixes, whether they contain magnesium or aluminum, are fundamentally different from trailer mixes, despite the similarity of materials.

Since my formulas utilize fine magnesium, nitrates, and/or ammonium perchlorate, they are less stable and more esoteric, and I believe that no purpose would be served in publishing them now. However, some worthwhile academic comparison can be made.

The article gave no information on yellow, green or white. It is well known that the barium nitrate greens are weak in color, but the addition of coarse magnesium would undoubtedly improve the color, and since little, if any water would be present (see LSO on moisture in non-aqueous systems), there would be little danger of a barium nitrate "deathmix" being formed.

In a non-aqueous system, one could probably use even an antimony sulfide white mix, and still gain brilliance as well as the glamorous tail.

For amber, one could easily form a cryolite analog to the red mix, and the parlon would likely help "blend" the usually annoying "gap" between the violet and yellow spectra found in such stars. For a better yellow, I would delete some parlon from the green and substitute cryolite, remembering that a yellow must still be fairly strong to contrast with a white tail.

As far as cutting stars of this type goes, not only is red gum and alcohol star mix sticky, it also tends to become fluid, thus sticking back together after being cut. Red gum is also soluble in acetone and lacquer thinner, which sometimes obviates some of the difficulties, although at the expense of even worse fumes. Also, I have found a 10% solution of rosin in alcohol makes red gum/magnesium mixes cohere with much less overall dampening, and in many cases, they become much easier to cut, and quicker to dry. The BIOS formulas in Lancaster that had been made this way have kept for seven years.

Despite these small improvements, it would probably be best from a production viewpoint to substitute coarse maghalium, probably 67/33% mag/al, if it would work, because then stars of this type could be cut with water, thus eliminating the fumes and speeding thing up considerably. Also, water is cheap while other solvents are not. And conventional prime could be used.

After experimenting extensively with metal-containing mixes in non-aqueous systems, I have come to the conclusion, though not a hard and fast rule, that it is best to restrict non-aqueous binders to those mixes which require them, and no others. In the narrowest definition, this would mean strontium nitrate/red magnesium only, and use water, aluminum, carbonates, and chlorine donors with everything else. Also, from a production viewpoint, straight alcohol mixes are less of a nuisance when being pumped or made as box stars, (using smaller quantities in a covered container) while a 35% alcohol/water solution, where applicable, is much more user-friendly when it comes to cut stars. JB

ROUND FLITTER STARS

Achieving an easily ignitable aluminum flitter star seems to be a problem, so I will review here some of the relevant considerations for the preparation of this attractive effect. Aluminum flitter stars can be made from any of the three basic oxidizers: potassium nitrate, potassium chlorate and potassium perchlorate.

Comp. #1

Potassium nitrate	40
Sulfur	10
Boric acid	1
Aluminum	50
Dextrin	6

Comp. #2

Potassium perchlorate	40
Aluminum	60
Dextrin	6

Comp. #3

Potassium chlorate	60
Aluminum	40
Dextrin	6

Nitrate flitter, or golden wave (Shimizu), is one of the cheapest and easiest to ignite of the flitter compositions and is given above in Comp #1. The ease of ignition of this formula is dependent on the type of aluminum used. If 325 mesh bright flake aluminum is used, the star will be difficult to ignite and will almost certainly not ignite if a simple meal powder prime is used. If aluminum dark (about 450 mesh flake) is used, the star becomes much easier to ignite, but the burning rate will become very fast with only a short burst of dense sparks produced. The solution to this is to use a mixture of bright and dark flake or to roll a core of bright aluminum flitter mix and roll over it a layer of dark aluminum flitter. Boric acid is important as a pH buffer to reduce the extent of decomposition in the wet stars.

Drying the stars in the shade, preferably with a fan blowing on them, is highly recommended as wet nitrate-aluminum stars are prone to heat up, crack and even ignite in the hot sun.

Problems in making large stars can be avoided by stopping the star rolling when the cores have grown to 12mm diameter. They should be allowed to dry for a couple of days in the shade before enlarging. After the cores are completely dry, an igniter layer or prime can be applied, which is made from a 50/50 mix of composition #1 and meal powder. It should be applied with at least a 1mm thick coating of this prime mix. A final 1/2 mm thick coating of meal powder can be applied for simple flitter stars. For a transition from a chlorate color to flitter, it is best to apply the color mix on top of the dried, primed cores. Glitter to flitter is very attractive and in this case, glitter is hot enough burning to ignite the flitter core without the intermediate prime layer.

Composition #2, a perchlorate flitter burning with a silver rather than golden silver sparks, is very attractive, but is more difficult to ignite than the nitrate flitter. For a transition from an ammonium perchlorate color to flitter, the perchlorate flitter mix is the only sensible choice because of the incompatibility problem of ammonium perchlorate with potassium nitrate or chlorate. As with nitrate flitter, it is best to use a core of slower burning flitter. I usually roll a core with a composition of 65% aluminum bright and 35% potassium perchlorate (plus dextrin) to a size of about 8mm diameter. Over this I roll a 2mm thick layer of composition #2 using all aluminum dark. After drying these 12mm cores, I roll on a 1mm thick igniter layer made from 50% composition #2 and 50% meal. When a transition from color to flitter is required, the color composition is substituted for the 50% meal. The absence of sulfur in the flitter comp allows compatibility with the sulfur-sensitive chlorate color comps. Glitter mixes may not be hot enough burning to layer directly over the cores made from composition #2, so I use 50% flitter/50% glitter as an igniter layer to assure ignition. Meal is used as a final priming layer on the surface.

Composition #3 is a chlorate flitter which is quite easy to ignite, especially if a mix of aluminum bright and dark is used. The lower percentage of oxygen in chlorate vs. perchlorate prohibits the use of large percentages of aluminum. Chlorate flitter stars are sometimes



called sinter stars as they don't spray the sparks out as vigorously as perchlorate but tend to smolder with sparks breaking off by rapid motion of the star through the air. The chlorate flitter stars can be ignited usually by a meal powder prime without any special igniter layer.

Aluminum round flitter stars are easy to make and the absence of sticky red gum results in less composition adhering to the bottom of the pan during the rolling process. The stars tend to be quite round and uniform in size.

Crossetting flitter stars are easy to make using pistol primers as cores. It is first necessary to waterproof the pistol primers by spraying with a can of flat aluminum spray paint. After drying, several hundred primers are rolled in a pan, alternately misted with a 50/50 alcohol/water solvent and dusted with increments of composition #2 until the desired size is reached. These stars will break with a crack into several fragments, producing an attractive crossette-like effect. DB

THE LOWDOWN ON GOLD FLITTER

The formula for the "Golden Flitter Star" which caused the "surprise" featured in another article in this book is one typically taken from Weingart and left uncredited. It appears on page 142, after F.E. Peters' wonderful Sinter Star, and is followed by three more mixes for White Flitter. Technically, they are all "sinter" stars, as they are designed to burn hot, keep the fire to themselves, and throw out molten aluminum droplets, or a complex slag, from a very hot reaction. Mixes of this type are not intended to be glitter mixes, and their burning activity resembles that of charcoal stars, where aluminum has been substituted for the charcoal. They are not as bright as electric or illuminating stars, although they produce substantial illumination. Shimizu's Silver and Golden Waves, on pages 224-5 of Lancaster are similar in effect. "Electric" stars, as a general term, tend to contain less metal, of coarser particle size, where the particle or flake is ignited in the star's surface and immediately flies off as the first generation spark effect.

Depending on the type of aluminum used, flitter stars can appear in the air as a bright, brief tadpole; a long, brilliant ray; or a thick, spreading cloud of aluminum scoria. They are not intended to produce a colored star with a silver tail, but a rather uniform, spreading mass of incandescent particles, which hang in the air. While brighter than charcoal stars, the effect can be mistaken for a charcoal or titanium effect, depending on the color of the sparks. The Brazilian shell called "Metallic Gold Flitter" contains a star of this type, as does the Brock shell, "White Trailer

Comets", which are actually 1/2" box stars. They are a problem to make, and don't keep well. But to some manufacturers, they seem a safer alternative for gold and silver than the chlorate counterparts.

The reason that many of Weingart's flitter mixes don't perform well, and this applies to the Faber mixes for electric stars in Davis as well, has to do with the type of aluminum available. They are all designed to use the "denser, stamped powders favored by the Europeans", as Lancaster says in his book. The aluminum which works best is the nearly impossible-to-obtain German "Blue Head", which is a light pyro, but very dense, like the more familiar black pyro grade. This material, unlike the fluffier American milled powders, resists the heat of the fuel rich compositions, and does not really get going until after it is ejected from the star as molten droplets of aluminum "slag". It is for this reason that many older aluminum mixes are pale and bright, with too little tail effect, since they tend to consume the "bright" aluminum right in the star itself, leaving no residue to "sinter" out and react later with the atmosphere. In the case of the Faber stars, when made with "Blue Head", and a little chlorowax, they actually split into fragments, like a palm tree, before going out. Sometimes a combination of German black pyro and atomized aluminums will produce a similar effect, but it is not identical to the delicate gold palm spray.

In order for the older flitter formulations to work, they have to burn through very quickly,



and throw that scoria, like the oiled lampblack stars of older times. In this case, the Blue Head should be the "fine" aluminum, preferably with the equally impossible-to-obtain "Yellow Head" bright polished for the "medium", and B12 coarse flake for the "flake". It is possible to adjust with 809 American dark atomized, and larger percentages of the coarse flake, and get some very attractive effects - a sort of "chandelier" trailing sparks, but they become very hard to work and cut.

One traditional method used to consolidate "flaky" star mixes is to dampen them, not with water, but thin paste, and then add some alcohol to speed penetration and drying. It is easy to see what a stinking mess this could become if an oxalate/aluminum reaction got going, along with fermentation of the paste, although a high enough alcohol content should prevent fermentation. It is a method best left to those who are familiar with it, but it does make the bulky stars more manageable.

The golden shade is difficult to produce because potassium nitrate is the oxidizer, and with aluminum, it produces a brilliant lilac color. The addition of lilac to strong yellow produces what is referred to in theatrical lighting as "Straw" - canary, rather than lemon yellow. When the aluminum burns up in the star, a pale yellow, or "No Color Straw" shade is produced, similar to that produced at much higher candlepower in the yellow illuminating star in Lancaster, which contains cryolite. This color is really little more than full-spectrum white light, with the deep blue frequency "notched out", and a reduced level of violet. The broader and deeper the "blue notch", and the less violet, the closer the color approaches amber. Amber differs from orange in that it contains some red and blue, and orange does not.

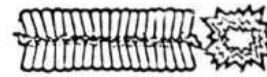
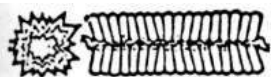
A better effect is obtained when the luminous light output matches the incandescent light output from the aluminum, glowing at the proper temperature. Sometimes a little extra charcoal can make up for deficiencies in the aluminum, if the mix is a little too bright and fast, and not throwing off much slag. In this case, the color is "Amber Gold", and contains no blue, just a little violet; green and red are limited.

I had to make this mix many times to get it to be anything but an embarrassment, but I have kept several pounds of it in a plastic bread bag in an unheated building, ranging in temperature extremes from -30 to +100° for two years, with no signs of deterioration. I have seen better formulations for this effect than Weingart's, being better adapted to modern varieties of aluminum, but even in this case, when rammed as large comets, very dry, the shelf life was only about two years before discoloration and the evolution of hydrogen sulfide set in.

There are two ways to proceed in order to make this a successful project. The first and simplest is to substitute cryolite for the oxalate, and use fine, atomized aluminum powder for the "fine" aluminum, then use four parts of 810 "bright" aluminum, and one part of 812 or 813 "flake" aluminum. This makes a dense, fast-burning star that is easy to cut or pump, with a brief, brilliant ray-like effect. It appears very bright up close, but high in the air it is not much brighter than an aluminum glitter. It looks best with deep green or red stars, as it tends to overpower deep blues.

I have not found the use of cryolite to significantly alter the color or characteristics of the star - that is to say, the oxalate is no "magic ingredient" that causes it to break up or twinkle any differently, although the color is a little better. The mix I have used which has kept so well uses cryolite, along with 808 "light pyro" for the principle aluminum, and the aluminums mentioned above. The stars are not very dense, but still cut well. The large percentage of all that greasy flake aluminum causes a "shingling" effect, keeping water out, and later holding it in. As difficult as it is to tell when it is damp enough, it can hold a tremendous amount of water, and dampening must be kept to a minimum. I used about 25% water. The sintering effect produces a long, tadpole-like tail, with a "liquid" appearance, but there is no granular, or spreading effect, and little duration.

One observation about colors in the yellow family: yellows, whether produced by low-temperature glitter reactions, or high-temperature barium nitrate/aluminum reactions, are affected by atmospheric conditions more than



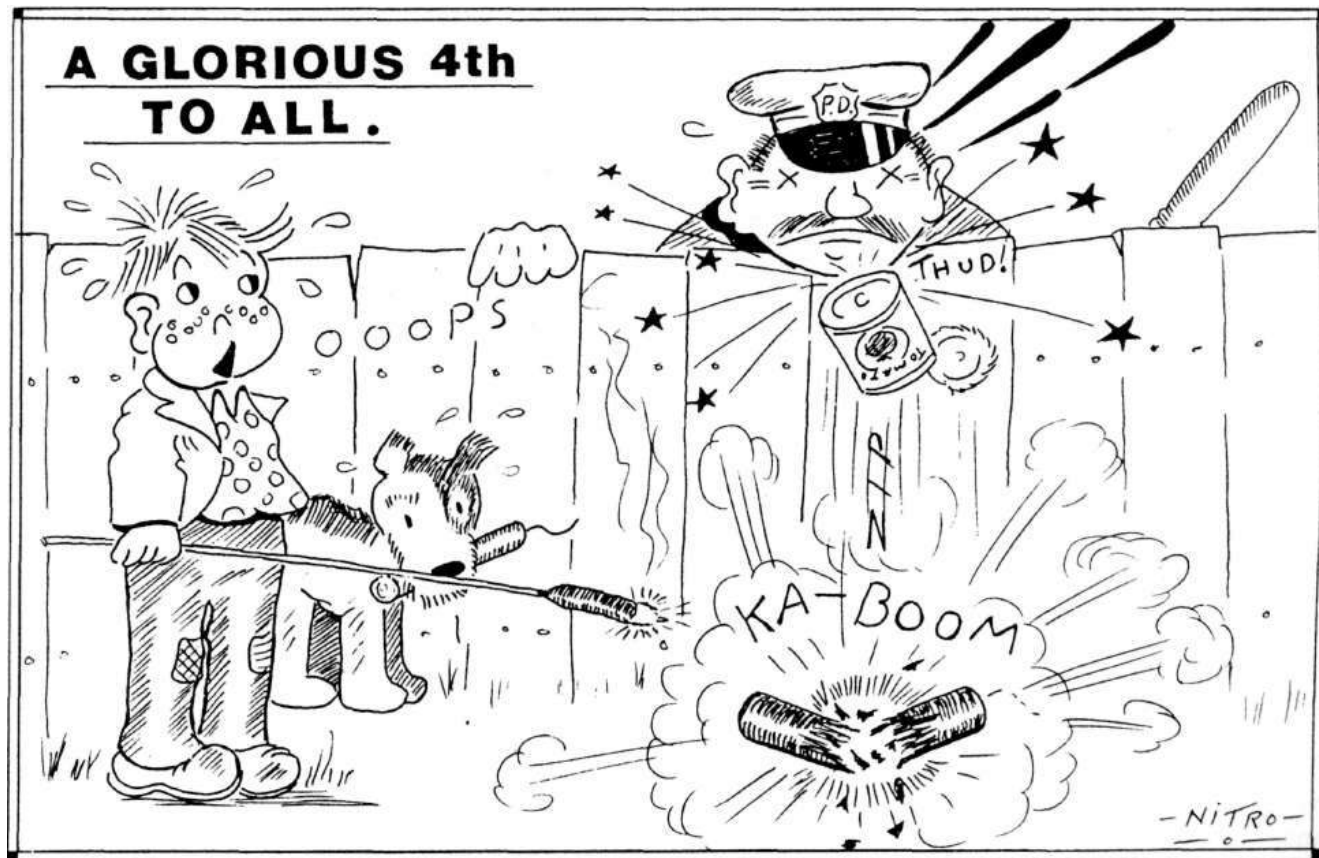
other colors. A pale yellow star observed in warm air at sea level is a very attractive pastel shade, while 1000 feet higher at 15° below zero it appears to be a nondescript ivory tint.

As has been illustrated, flitter stars in general were a product of a specific period of pyrotechnic evolution, and require many experimental adjustments to function properly. While quaintly attractive, even a well-made gold flitter star is not likely to turn many heads at a PGI convention, because it may be overlooked as a "glitter star that didn't work". The new sodium nitrate/aluminum/parlon yellows are much brighter and deeper in color, but the dimmer flitter stars do look good when used with deep color stars, in place of charcoal stars as the filler.

When I operated Green Dragon Fireworks, I routinely used gold flitter with ammonium perchlorate red stars, and it was very attractive. I also made 1" cavity stars from it, using a potassium perchlorate/ strontium nitrate red in the

cavity, because a little more brilliance was needed. It is a question of matching appropriate contrasts, and balancing the luminous intensities of the components to each other. A two-break, 5" shell of red, gold flitter and deep blue, with about 50% of the stars being blue to make up for their dimness, as the first break, and a spiderweb as the second break, creates the old "fife and drum" sort of patriotic effect, creating deep emotional tones as it fades slowly from view. The more frequently seen red, silver and blue, followed by a heavy flash report, gives the more modern impression of the Air Force coming to the rescue.

While it takes experimentation and patience to produce a good flitter star in the current pyrotechnic environment, one must not allow convention to block research into worthwhile phenomena. This is what separates an actual pyrotechnist from the rest of the crowd who just go "ooh & ah!". There is no substitute for the satisfaction of personal discovery, for in this way the student makes the material his own. JHB





ROUND LAMPBLACK STARS

Lampblack is a substance that currently has a limited popularity among star makers. It is one of the filthiest of the pyro chemicals to work with and has a much higher cost than charcoal, its primary substitute. Yet stars made with lampblack have an astonishing density of sparks in the tail which produces a very attractive effect. Weingart lists several formulas for cut and pumped stars using lampblack with potassium chlorate as the oxidizer.

Compositions with high lampblack percentages are difficult to dampen and usually require dampening with an alcohol-water mixture to lower the surface tension. The dampened comp has to be thoroughly mixed to incorporate the oxidizer uniformly into the lampblack. This involves a lot of vigorous beating and just plain hard work. The stars take 3 to 5 times as long to dry than most other stars. If too much binder or water is used they will sometimes not dry out at all. Making round stars avoids much of these difficulties.

Round stars with a charcoal effect that usually ends with ignition of a color core are seen in virtually all firework shows. The easiest compositions to make simply consist of mixtures of charcoal dust and expensive meal powder. The charcoal percentage is varied to control the burning time and tail length. It is possible to avoid the use of meal by employing simple mixtures of potassium nitrate, sulfur and an excess of charcoal. However the spark density produced from simple mixtures is poor and the spark tails are usually quite thin. If the mix is dampened and mixed thoroughly, some improvement results as the potassium nitrate leaches into the porous charcoal particles allowing them to take fire more easily. After dampening, the mix must be dried out and screened to at least 80 mesh for use in making round stars. The simple mix could be ball-milled but this is impractical and dangerous for many in the field.

The high cost of meal combined with the superior effect of lampblack led me to investigate methods of using potassium chlorate-based lampblack mixes for use in round stars. I discovered that compositions containing high per-

centages of lampblack with no charcoal were useless for producing round stars. The stars came out with grotesque spikes of composition on their surfaces. This problem is caused by the high degree of cohesiveness of very fine lampblack particles and the intense shrinkage occurring when the low density composition is dampened. Figure 1 shows a cross section of a damp round core that has been sprinkled uniformly with a dry high-lampblack percentage comp. Dampening the star with an alcohol/water mixture results in a star looking like figure 2. The composition has "shrunk" around the sphere to form little bumps which get worse as more composition and solvent are added to enlarge them.

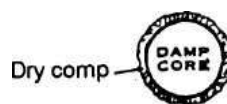


Fig. 1

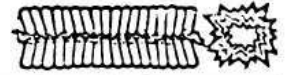
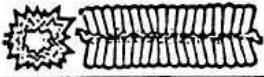


Fig. 2

The simple solution to the problem is to cut down on the lampblack percentage by substituting air float charcoal. This lowers the cost, makes the mix less messy to work with, and makes it easy to roll stars that are truly round. The higher combustion temperature of chlorate vs nitrate-based charcoal compositions also makes the ignition of cores less problematic. One of the formulas I use is shown below. It is a medium fast burning composition of high ignitability and excellent spark effect. Adjusting the percentage of air float charcoal will control the burning speed and tail length. The use of potassium nitrate insures easy ignitability and will permeate the pores of the charcoal better than the less water-soluble chlorate. A much large ratio of carbon/oxidizer is possible with chlorate-based compositions than nitrate. This is due to the greater oxygen availability of chlorates.

LAMPBLACK STAR COMPOSITION

Potassium chlorate	33
Potassium nitrate	8
Charcoal dust	32
Lampblack	22
Dextrin	5



To make attractive round stars with this composition it is advisable to start with dry, round, colored cores about 5mm to 9mm in diameter. I place the cores in a large round bowl, then dampen the cores by misting with a 50% water/alcohol mixture from a pump sprayer. I keep the stars rolling around while adding increments of dry composition until the stars cannot pick up any more. Now I respray the cores while rolling them around the bowl until they just begin to stick together. I try not to stop rolling for more than a second or so while I add increments of dry comp again. If composition starts to build up on the bottom of the bowl, I move the stars out of the way and spray the composition directly to soften it so the stars can pick it up. As always, practice makes perfect.

It is advisable not to try to apply more than a 4 mm thick layer at one time to prevent any drying problems. I let the stars dry for a few days between coatings, if I want to add a very thick layer.

The composition is so ignitable I use it instead of meal to prime round stars with compositions that are compatible with chlorates. The high percentage of potassium nitrate in meal prime can leach into the outer layers of a colored star composition if too much is used. The color purity will then suffer. A chlorate-based prime such as a faster modification of the above formula will not alter the color purity of cores even if a thick coat is applied. DB



ANOTHER APPROACH TO FALLING LEAF STARS

This project is for those of us who also fly balsa wood R/C planes. If you are like me, you probably have piles of scrap ultra light-weight balsa wood lying around your workbench. I use the thin planks (1/32" or thinner) to make a type of falling leaf star shell. Falling leaf stars, as their name implies, look something like hundreds of twinkling leaves gently floating down from the sky. Here's how I do it.

First, I cut the balsa wood into several dozen 1/2 x 3/4" pieces. Then I coat one side of each piece with one of my favorite star formulas that has been wetted a bit more than usual (so that the composition may be spread on the wood with a butter knife). Next, I prime only one half the the "leaf star (while it is still damp) by dipping its long side into a small bowl of meal powder. I prime only half of the star since the composition is spread thin and I don't want it to burn too rapidly as it slowly descends. In this case, the appearance of the twinkling effect is attributed to the star appearing to burn on and off continuously. As it floats down, it rapidly spins along its axis, thus giving its extraordinary illusion.

By the way, thin sheets of balsa wood may be obtained in any hobby or craft store. Yes, balsa wood is somewhat expensive and the process is a bit labor intensive. However, when used in only a few shells, the effect is worth the bother. In production, of course, the star composition is spread out on whole sheets of a suitable type of paper, stacked sheet on top of sheet, then cut into small leaves. SC



CRACKLE STARS

Pyros who are skilled at making round stars in a pan might like to try their hand at making crackle stars. Crackle stars are similar to other round stars except they have an exploding core.

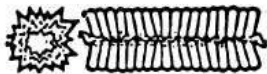
The stars in use in commercial shells are made exclusively in the Orient. The exploding cores are made from a mixture of potassium chlorate and realgar (As_2S_2). The manufacturing process is described in *Fireworks, the Art, Science and Technique* by Takeo Shimizu. Experienced pyros realize that realgar is not only poisonous and difficult to obtain, but the realgar-chlorate mixture is extremely sensitive and dangerous to work with. In fact, I was told that crackle stars are no longer made in Japan for that reason. A safer and simpler procedure for making these stars was described in PGI Bulletin #15 (Japanese Crackle Shell). The author suggested the use of percussion caps available at gun shops for star cores. I have found percussion caps to be expensive and difficult to roll composition on. In their place I have been using pistol primers which are cheaper and have a more rounded shape, and are easier to roll in the pan.

Primers contain a small amount of a heat and shock sensitive composition (probably lead styphnate) and a flame producing composition which ignites the smokeless propellant. Tests were conducted with various sizes of primers (rifle, pistol, magnum primers, etc.) to determine which were the loudest. It turned out that the intensity of the sound produced by all of them is essentially the same with the possible exception of small pistol primers which had a somewhat diminished crack. It was found out that the difference between the various primers was in the amount of flame producing composition applied and not the detonating composition, which was varied.

It has been recommended to apply a coat of spray paint over the entire surface of the primers before using them. The paint covers the polished steel outer primer surface which makes it much easier for the star composition to adhere. The paint also waterproofs the primer which is very important when applying water bound compositions. A damp primer cap cannot dry out if it is inside a star.

Primers perform best when coated with a hot burning composition such as an aluminum flitter mix. Tests have shown that the hotter and faster burning the star composition is, the louder the crack will be. To make a load of crackle stars I simply dump about 200-500 primers (painted) in a large bowl and mist once or twice with a mixture of 50% alcohol/water and then sprinkle a small amount of flitter composition on while the stars are kept moving in a circular motion. After many repetitions of misting and sprinkling the primers will grow into perfect spheres of any desirable size.

As is usual with round star manufacture, it is important to prevent or remove any build-up of star composition on the surface of the pan. Occasionally the few coated primers will stick together in the early stages of manufacture which will require separating them with a knife or similar tool. I have found that crackle stars are as easy to manufacture as ordinary round stars. Their only drawback is their cost (a little over one cent each) which makes them unacceptable for commercial use. They seem quite safe and should not explode from the gentle process of rolling them in a pan. Primer cracker stars are every bit as loud and impressive as the commercial versions. DB



RED STROBE STARS

Those attending a recent PGI convention could not help enjoying the sight of L.S.'s red strobe stars. Some of my round shells fired in the competition also used a similar red strobe composition. Strobe stars with a good red color are nearly impossible to make using magnalium or nitrate based strobe mixtures. Shimizu found the optimal formulas in the article he published in *Pyrotechnica VIII*. The formula I use is a slight modification of Shimizu's selected formulas.

RED STROBE STARS

Ammonium perchlorate	50
Magnesium 100-200 mesh	25
Strontium sulfate	25
Potassium dichromate	5
Nitrocellulose lacquer 10%	25*
*for cut stars	

STROBE IGNITER COMP.

Potassium perchlorate	74
Red gum	12
Charcoal, air float	6
Aluminum, dark	3
Potassium dichromate	5

Top Coat Igniter

Meal powder	7
Charcoal	3

[The combination in a formulation of ammonium perchlorate and magnesium presents a vexing problem. As John Conkling points out in his *CHEMISTRY OF PYROTECHNICS*, no moisture may be allowed to contact the mix and it should be watched for self heating and formation of ammonia gas. It is important that only NC lacquer be used as the binder. Additionally, potassium dichromate in this formulation requires protection of the worker against inhalation.]

The binding agent is nitrocellulose lacquer (available from KSI). Other binders cannot be used because they act as fuels which promote continuous burning. The potassium dichromate acts as a catalyst in the decomposition of the ammonium perchlorate and also protects the magnesium from corrosion. Strontium sulfate

may be difficult to find but it can be easily made by mixing solutions of epsom salt and strontium nitrate. I filter the white precipitate that forms through a coffee filter and let dry.

The usual procedure is to make cut stars and after they have dried, coat them in a pan with the strobe igniter formula, which can be applied using alcohol as the solvent. I make sure the igniter layer is at least 1/2 mm to 3/4mm thick. When that layer is dry, a final igniter layer, the top coat igniter, is applied with nitrocellulose lacquer. The use of water or alcohol is not recommended as potassium nitrate may leach through the strobe igniter layer, ruining the color or worse, making the star unignitable. Nitrocellulose lacquer may be diluted with acetone to a concentration of 1 - 2% which can be used in a spray bottle to mist the stars with solvent and binder. Round star makers will notice that the stars wet with acetone/NC lacquer will pick up much less composition than a water or alcohol wetted star.

It is possible to make round strobe cores by using the NC lacquer spray. I always work outdoors for health and safety reasons. I coat the strobe mix directly on lead shot which has been previously coated with a thin layer of clay. After many applications of spray and powder, the star will reach the desired size of 9mm. It is necessary to apply spray while the stars are moving in a bowl, until they just start to clump together and then I hit them with a few shakes of composition from a shaker can applicator. Then after drying, I apply the strobe igniter and top coat igniter using the same NC spray bottle. I try to make each igniter layer have a thickness of 0.75mm so the final size of the star is 12mm. The round stars strobe faster than the cut stars because ignition occurs simultaneously over the entire surface of the star rather than at one end of a cut star.

A spark strobe star can be made by simply adding about 10% 40 mesh titanium to the red strobe formula, then cut or pump stars about 1/2" and apply the igniter layers. The titanium sparks are violently blown off the star in bursts of sparks. The red color will suffer a bit, but the addition of the titanium seems to have very little effect on the strobe frequency. DB



MICRO STARS & LINSEED OIL

One of the ten thousand pending projects I never did complete was the analysis of a fascinating little "bottle rocket" sized toy rockets from China. Most of the Chinese bottle rockets are boring - zip - fop affairs, no full tailed effects like the good ones we first got from Japan after the war. Of course, the present report is so weak only the CPSC could like the new ones. The report is now so weak that it does not always blow out all the sparks and the fire hazard is therefore higher. Silly safety?

The new little rockets were wonderful! They had a fancy fuel motor and micro star heading that really worked beautifully. Of the 30 - 40 stars in a package, the size of an ordinary pencil eraser and brass holder, more than half usually got lit and made a fine display with about an eight-foot radius.

One of the things that flipped me out about them was the use of an oil along with parlon and an acid amide resin with magnalium and barium nitrate for the fuel. Great green flames in the sky! Oil! For a burn rate moderator. Most beginners have never tried the effect of oils on powder. Well, if it burns at all, rest easy, it will burn darn slow. Not much use of that effect is made in fireworks.

But here was a cute little motor that would have been a good firecracker, if you left out the oil. (Rocket motor oil?) The oil of course, helped the tooling and other things, but mainly it changed the burn time for the motor by one or two orders of magnitude. This allowed a really high energy fuel mix to be used.

Railroad flares often used the old oil trick, back in the real days of yore.

Now the oil trick brought back some memories of an embarrassing situation that arose when I first tried "oil tailed stars" in a rocket heading. I grew up on the northern outskirts of San Antonio, barely had a good place to go fishing, or shoot birds with a pellet gun. I had to carry my .22 almost a mile, by bicycle, to shoot the gun, so life was cramped with city government ruining my childhood whenever it could.

I made rockets, Sputnik was up, the race was on, we all made rockets. Most of the kids were testing the splatter pattern of returning high speed mice, but I was into bigger flashes, louder booms and nicer stars.

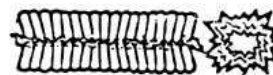
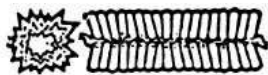
I tried "oil tailed stars". The recipe said to cut them 1/4" on a side. I had gone a few drops heavy on the linseed oil, and the recipe did not say how long they burned. I tried several on the ground. They were hard to light and not impressive, and left a mess on the sidewalk.

The neighbors down the block were outside, but I decided it was all right. (Those neighbors only occasionally called the police.)

Perfect launch, hot rocket, delay, *flop*, and out came about thirty little bitty white flames with a few sparks. About halfway down to the neighbor's patio, the white flame went out and the "senko hanabi" effect started. The blobs were still trailing smaller sparks behind them. Pretty soon the neighbors were running and yelling as the blobs hit the trees and kept right on coming down as much smaller blobs. Well, that was all for the night.

But what I wanted to tell you is that boiled oil with drier added should be used. I apply it as a solution in petroleum-naphtha and NOT turpentine. First I wet down the comp and granulate it while wet, allow it to dry and then oil treat it. The oil can cause spontaneous ignition if the material is not spread out in a very thin layer, no more than $1/A^n$ thick. Now I allow a week for the comp and oil to dry, then I grind the comp, spread it out again for a few days and mix it with more of the same recipe. The second half of the mix, which does not have oil in it, I make as fast burning as possible. Now instead of coming down like buck shot from Hades, the stars will be really beautiful. The formula is not critical. One can be found in Kentish. [Available from AFN].

The senko hanabi mixtures treated with one or two percent addition of linseed oil make some rather surprising micro star effects. I form the comp into micro stars with window screen mesh, by the usual wet process. I dry well and treat



with the linseed as above. If I kept track of the amount of water used to form the micro stars, I add about half that volume of petroleum paint thinner to the linseed before applying, as an aid to uniform distribution of the oil. When they have dried for two weeks, I coat them with an equal mass of meal powder or very fast 5-1-1 for priming. It should end up with free flowing grains that burn like rifle powder and leave an

ash that falls fifty to one hundred feet or more, as tiny stars throwing a fuzz of small sparks as they fall. They are so tiny, they make a nice heading for small rockets.

I have also tried grinding them to about 40 mesh, mixing with twice their weight of 5-1-1 of meal and granulating as micro stars. LSO

MORE ON MICRO STARS

I was particularly interested in the article by LSO on Micro Stars & Linseed Oil. There have been very serious repercussions in the United Kingdom over these new Chinese rockets. I think that it is worth making the point to your readers that provided that these rockets are well made, they are extremely novel as he suggests. There is, however, a serious technical problem which may interest your readers.

If you consider that the rocket has been made by charging a composition containing metal powders into a small tube and then making a hole up the centre of it in order to make it into a rocket, then you have also all the characteristics that are necessary for an explosion as well.

One of our dealers in this country [England] has, in fact, been selling this rocket and by the time they were on sale to the general public for November the 5th, they all had to be recalled because they were exploding in the bottles with the intensity of a metal-based thunderflash.

The presence of linseed oil certainly does have this phlegmatising effect and provided that the rocket is well made, then, of course, all is well. The fact is, however, that it is a very narrow bore tube; the making of the hole up the centre probably takes place after the composition has been loaded and one only has to knock the device around to start to break down the centre cavity; then you have got an explosive charge all nicely made for you with loose composition.

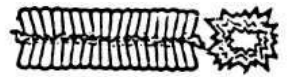
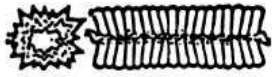
Whilst we suspected that this was a problem, we did not really think that it was going to happen commercially with the unfortunate political con-

sequences that it had in this country of selling them in the shops, so beware.

During the time that I was involved in the commercial manufacture of fireworks at the old Pains, and subsequently the Pains Wessex factories, we frequently had problems of exploding rockets and exploding gerbs, simply because of this problem of loose powder getting into the choke hole of fireworks which were made in this way. The worst ones were rockets which were charged solidly and then pierced afterwards because they were very prone to subsequently breaking down. You only had to pick up a rocket and tap it gently against a hard object and you would have a good chance that it would blow up and that was that.

We even had the problem with gerbs that had been made in tubes that had been choked down with the choking machine after rolling. The reason for this again is that you get a loose lap inside the tube. This comes away inside the choked area and loose powder collects there, again with a consequent explosion. You can normally avoid this, of course, by using clay chokes but there are advantages of using tubes that have been pulled in with a choking machine.

Having read LSO's article and experienced the unfortunate consequences of fireworks being sold by people who really do not understand them, I immediately wanted to make this point because it is quite a serious one. I think people should think very carefully before they start making rockets which contain metal powders in the rocket motor. RL



ROUND STARS - SIZING UP YOUR STARS

One of the advantages of round stars over pumped stars is that they can be rolled to any size desired. Beginners can get plenty frustrated when they discover that their stars formed in the pan are a collection of EVERY size! Lack of size uniformity of stars ranks second to bumpy syndrome (see *Those Ugly Bumps*) in causing defeatism of round star makers.

Batches of commercial round stars made in rolling machines that I have seen, often have poor size uniformity. These stars are used in non-critical commercial applications such as in small canister shells which employ non-color changing stars. The stars in a round shell burst should change color at nearly the same moment and burn out simultaneously for the most elegant effect. The highest quality Japanese shells have stars which are selected for size uniformity to produce this effect.

The causes of this vexing problem are complex and rarely discussed in the pyro literature. With the generous technical assistance from round star maker J.W. and my own observations over the years, we will present our theory and solutions, first lets look at the rolling conditions which greatly encourage the process of formation of stars with poor size uniformity.

I. Use of cores with poor size uniformity.

It is important to use cores of good size uniformity as it is quite impossible to improve on the initial star size uniformity. If cores differ in size by as much as 2:1, then under the best rolling conditions, the finished stars will maintain the same ratio of largest to smallest.

II. Use of large batches of stars in pan.

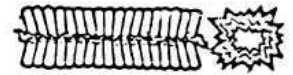
When large batches of stars are rolled by hand or by machine, in which there are many stacked layers of stars moving around in the pan, the size uniformity will suffer. The cause of the problem

in this case is usually insufficient mixing during the dusting/ dampening cycles. A powerful force mitigating against uniform mixing is size stratification.

When a can of mixed nuts is shaken the larger nuts tend to work their way to the top. In the case of stars in a pan the top is the area that receives the majority of the solvent and composition, especially in large star tumblers with tens of pounds or more of stars in them. In the March 9 edition of Physical Review Letters, as reported by Science News, Anthony Rosato and coworkers investigated the properties of size stratification with computerized Monte Carlo simulations of a shaken can containing large and small balls. Rosato concludes that the size difference among balls makes it more likely that a small, rather than a large, ball will fill a void that may open during the shaking process; for a large ball to move down in the pan, several small balls must simultaneously move out of the way, whereas it only takes the movement of one large ball to create a void that several small balls can fall into. The researchers write that the extent of size segregation depends on the relative sizes of the balls and the distance the balls are lifted during shaking. With the large stars working their way to the top to receive preferentially the increments of composition and solvent, it is easy to see how the size uniformity worsens with increasing rolling time.

III. Use of improper solvent/ binder.

It is very important that the solvent system used be capable of wetting the cores. For example, spraying alcohol/water directly on lead shot and dusting comp over them will often result in a condition of poor uniformity starting up almost immediately. Some cores will have grown to double or triple the size of the shot while others will still have only a few patches of composition on the surface. Grease and a polished surface make it difficult for the solvent to wet the surface



uniformly. When using lead shot one should spray paint on the cores to improve the grip of the surface. Or you can wipe the cores with an acetone soaked rag and roll a thin layer of clay on the surface first. Extremely fine bentonite clay is easy to pick up with alcohol/water solvent on cleaned lead cores.

One must pay close attention to this effect in color changing stars. I had a problem rolling a metal fuel green mix over a dried, water-bound, lactose based blue stars. I sprayed the dried blue cores with 95% alcohol and sprinkled on the green mix containing, among other ingredients, 12% red gum and 12% 100 mesh magnalium. The red gum was to serve as the alcohol soluble binder in lieu of dextrin. The stars developed a patchiness indicating that the green comp was not adhering well. A small number of stars that had coated completely were stealing composition from the stars with an incomplete coating. The problem was overcome before size uniformity degraded seriously by spraying with water/alcohol instead of alcohol, which softened the blue cores' surface to make it tacky enough to grab onto the green comp. The idea is to pay close attention when applying comp over previously dried cores in color changing stars to assure that the first layers of comp are applied uniformly. I try to use the same solvent system in each layer if I encounter difficulties. Remember when making color changing stars to let each layer dry before applying the next color.

IV. Rapid star growth.

Stars grow rapidly because the tackiness of the binder in conjunction with its solvent system is high. Stars with a high percentage of red gum sprayed with alcohol can be very tacky, and will grow rapidly while also laying scum on the bottom of the pan if the increment size of the composition is too large. Spraying alcohol directly on the scum will allow the stars to rapidly clean the bottom of the pan but be aware that overdampened stars can also pick up composition right off the surface of underdampened stars resulting in poor size uniformity. Avoid the scum and the sizing problem by switching to a mixture

of alcohol/water that barely dissolves the red gum and use dextrin as a binder. The stars will grow more slowly but will be much more uniform in size. One has to strike a compromise between speed of growth and size uniformity. If the stars cannot pick up the dampened scum from the pan, it is essential that it be removed with a rag. Scum left in the pan will waste composition and steal it from the surface of dampened stars.

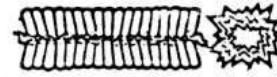
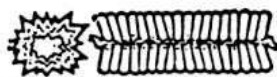
SOLUTIONS

From what has been said so far, it must seem to the reader that good size uniformity is difficult to impossible to obtain. That is simply not the case as I can routinely prepare 1 - 2 lb. batches of stars by hand in which 90% of the stars are within \pm 1mm of the average diameter. Much of this success has come about through familiarity of the properties of various compositions, and lots of practice.

The idea is to keep the stars in continuous motion in the pan while going through the dampening/dusting cycle. In addition to imparting a tight circular motion to the pan, it is necessary to switch to a back and forth motion and even gentle bouncing-type motions from time to time. This technique keeps the stars well mixed by bringing the bottom layers of stars to the top. Star rolling machines cannot impart such complex motions to the batch of stars and as a result, size uniformity is very hard to obtain.

I do not spray the stars with solvent all at once. I spray and dust in increments separated by 5-10 seconds of rolling time. Spray, roll 5 seconds, spray, roll 5 seconds, spray, roll 5 seconds, dust, roll 5 seconds, dust, roll 5 seconds, etc., is a much better technique than spray, dust, spray, dust, etc.

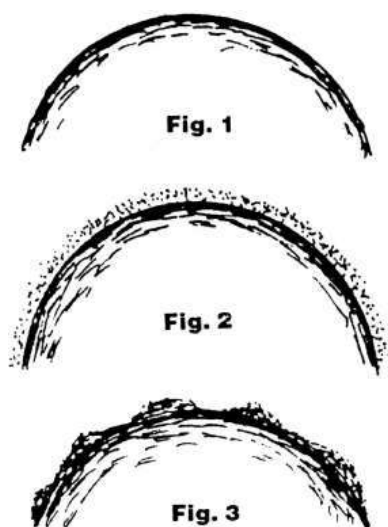
Naturally if all else fails and inadvertently a batch of poorly sized stars has been created, the best recourse is to pass the cores through the appropriate size hardware cloth screen to separate out the undersize stars. The undersize stars are returned to the pan for enlargement. This is the common practice with rolling machines. DB



ROUND STARS - THOSE UGLY BUMPS!

I often get mail from readers who are frustrated by their initial attempts at round star making. One of the most common problems is the difficulty of keeping the stars round while growing in size in the rolling pan. The stars develop bumps that grow into spikes, looking like little land mines. Eventually the spikes will break off in the pan, creating even more problems. This problem plagued me years ago when I first started rolling stars. It took me many months to find the solutions after much trial and error.

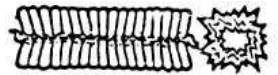
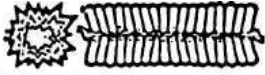
The fundamental driving force creating bumps or spike formation is shrinkage of the newly applied layers of damp composition over the dry star core. Even if one starts with a completely round core, improper rolling technique can result in spike formation, as shown in the illustration. (The degree of spike formation during one cycle of dampening and dusting has been exaggerated for clarity.) Figure 1 represents a large round core which has been just sprayed with solvent. The solvent diffuses into the dry interior slowly with time. Then composition is sprinkled on the star, forming a loosely bound layer as shown in figure 2. Almost immediately the solvent migrates from the damp layer underneath to moisten the dust on top. This causes shrinkage of the newly applied layer, forming gaps and lumps as shown in figure 3. These lumps will be enlarged on the next cycle of dampening and dusting unless steps are taken to prevent it.



Although you cannot stop the lumps from forming, you can "roll them out" so the stars return to a round shape. The trick is to spray with enough solvent while the stars are moving in the pan until the stars are so damp they are in danger of sticking together. This softens the outside surface so the lumps can be rolled "flat". Dry composition is sprinkled on slowly, in increments, until the star cannot pick up any more dry powder from the pan. It may take several repetitions of the process to get the stars back to round again. Beginners are tempted to only dampen the cores slightly with solvent for fear of the cores sticking together. During the early stages of star rolling when the cores are quite small (less than 4 mm diameter) I am careful not to apply too much water as the stars are most liable to clump up in the pan. If some spiking occurs it can be corrected when the stars get larger and more manageable.

A second helpful hint is to decrease the surface tension of the solvent by increasing the percentage of alcohol. I have used up to 70% alcohol/30% water as a solvent or dampening spray for some particularly troublesome stars without disturbing the dextrin binding system. Stars rolled using 95% alcohol or 2% NC lacquer in acetone exhibit no spiking whatsoever but tend to grow slowly in the pan.

A third technique is to control the particle size distribution of the star composition. Extremely fine powder such as bentonite clay and mixes containing high percentages of fine lampblack are very difficult to roll without spiking as the degree of shrinkage is high with a fine, wettable powder. It is sometimes necessary to wet granulate the mix and then pass the dried 10-20 mesh granules through a 50 mesh screen. The larger particle size distribution of the screened granules will be much less likely to cause spiking problems. You can imagine each 50-100 mesh particle to be "pre-shrunk" by the wet granulation process. I have found that the stars will grow in size faster when using a composition with a 50-150 mesh particle size distribution than with a fine composition with most of the particles 200 mesh or smaller. Realistically though, because of the added step of the granula-



tion procedure I only use this technique if the first two techniques fail to give satisfactory results.

Pyros experienced in rolling a large variety of star compositions will discover that the degree of spiking can vary from zero to nearly unavoidable depending on the specific composition used. I have tried to summarize here the relevant properties of various compositions used to make round stars.

I. CHARCOAL STREAMER COMPOSITIONS:

The extent of spiking with compositions of this type is moderate at low charcoal percentages to high in compositions such as willow with high charcoal percentages. If these compositions are made in a tumbler (Chrysanthemum 6 or 8 for example) it is advisable to wet granulate and sieve for better performance in the air and lower spiking potential.

II. ALUMINUM FLITTER COMPS:

Compositions containing over 25% aluminum are extremely easy to roll round without any spiking. The hydrophobic nature of aluminum totally prevents the shrinkage that leads to the problem.

III. GLITTER

Most glitter comps exhibit a moderate amount of spiking. It is necessary to use a high percentage of alcohol (50-70%) in the solvent spray. One must not allow round glitter stars to remain very damp after making them or the glitter effect can be diminished or ruined. I allow the finished glitter stars to stand in a tray for 15 minutes or so to allow the interior water to work its way fully to the surface, then redust with dry glitter comp. For best results I dry them in a cool room under a current of cool air from a fan.

IV. COLOR COMPS (low temps)

The fine red gum yacca fuel in many color mixes can aggravate the spiking problem depending on the percentage in the mix. Compositions with

high percentages of red gum can be troublesome if too much alcohol is used in the solvent spray. The composition powder will form a scum layer on the bottom of the pan that can be annoying to remove. I keep the percentages of alcohol less than 25% on mixes with over 12% red gum and dampen the cores well to prevent and control spiking.

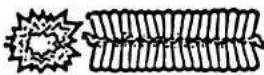
V. MAGNESIUM/MAGNALIUM "MAG" COLOR MIXES:

Spiking is not a problem with these compositions, especially if they are rolled using 100% alcohol or NC lacquer in acetone. DB

PASTA CORES FOR ROUND STARS

A suggestion was offered by J.H.B. to use one of the various pasta products which come in small ball shapes as cores for making round stars. They would have the advantage of producing no fallout from the sky after star burnout. Stars made with lead shot cores have the potential of landing in a spectator's eye.

Also the surface of pasta when wet is tacky, which makes star composition adhere to them easily. Previous experimentation with some pasta products sent to me by S.B. gave disappointing results. Pasta grains or spheres are light and sticky when wet with water and tend to stick together unless the solvent/powder application process is carefully controlled. Also the star uniformity came out quite poor which was not unexpected as the pasta spheres had poor uniformity to begin with. I will continue to use lead shot, but I certainly welcome comments from readers who have worked first hand with this material and obtained good results. I do not consider fallout to be a serious problem because I don't fire shells directly over the heads of spectators. Naturally, this rule is followed in commercial displays as well; the amount of unignited stars falling to the ground is rather high. DB



A NEW BLUE - PREPARING COPPER BENZOATE

Always a believer in simple star formulas, I recently came up with a blue star formula containing only two ingredients. Most color formulas require at least 4 components: 1. Oxidizer 2. Fuel 3. Color producing metal (strontium, barium, sodium or copper) 4. Chlorine donor for color enhancement. The purest colors often result from the combination of more than one of these components in one ingredient. For example, the well known exhibition green formula, Barium Chlorate 90%, Shellac 10% has only two ingredients and gives an excellent, albeit slow burning, green color. The barium chlorate serves as the oxidizer, chlorine donor, and color producing metal compound.

The simplest published blue composition that I have been able to find is one by Joel Baechle in *Pyrotechnics* which uses ammonium perchlorate (about 70%), copper oxychloride (about 9%) and the fuel hexamine (about 17%). The ammonium perchlorate functions as an oxidizer and chlorine donor. This mixture burns at moderate speed with red tipped blue flame.

To combine the fuel and the copper in one molecule I prepared copper benzoate and determined the optimum ratio of this color fuel with ammonium perchlorate. The result is the following formula:

New Blue	
Ammonium Perchlorate	82%
Copper Benzoate	18%

PREPARATION OF COPPER BENZOATE

The synthesis of copper benzoate is extremely simple. Since copper benzoate is nearly insoluble in water, it can be prepared by precipitation from mixing solutions of copper sulfate and sodium benzoate. The use of 4 parts copper sulfate to 5 parts sodium benzoate gives the correct stoichiometry to the reaction. I simply dissolve both salts separately in the smallest volume of hot water necessary to solubilize them. The two solutions are combined and a beautiful blue precipitate of copper benzoate forms instantly which is filtered after cooling.

It is important to wash the precipitate several times with cold water and refilter to remove traces of soluble sodium sulfate which can easily foul up the blue color production. Then I spread out the precipitate in a pan and allow 3-4 days to dry at room temperature. The material should now appear turquoise blue in color.

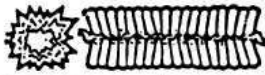
The copper benzoate is further dried for several hours at 90 to 100°C in a temperature controlled oven. The copper benzoate will begin to decompose above that temperature, giving off a distinctive odor which warns to reduce the temperature. This final drying step removes the water of hydration, turning the color of the benzoate to a much deeper blue.

PROPERTIES OF THE BLUE COMPOSITION

When finely powdered ammonium perchlorate and copper benzoate were mixed in various ratios it was found that the 82/18 mix given above was nearly optimal in color and burning speed. The mix seems quite insensitive to shock and friction but its complete safety profile remains to be investigated. The loose powder burns very fast but not as fast as benzoate whistle mix. Small pumped stars (3/16"x5/8") were made using 1% nitrocellulose binder in acetone. Their burning rate was measured on the ground to be 3.8 mm/sec which is quite fast, as normal color compositions burn around 1.5-2/5 mm/sec. The small stars burned with a beautiful blue large flame with no red tip and darted around the pan they were burning in.

FAILURE OF OTHER BENZOATES

Curiosity drove me to prepare the benzoates of strontium and barium to see what their properties would be when mixed with ammonium perchlorate. These salts are much more difficult to prepare as they have considerable solubility in water but are not hygroscopic. Both salts burned very poorly with ammonium perchlorate in various ratios, with little or no color production. This is not to be unexpected as the high performance of the copper salt is related to the well known catalytic behavior of copper and copper salts with ammonium perchlorate. Copper, cop-



per oxide, copper oxychloride, copper sulfate and other copper salts all readily catalyze the breakdown of ammonium perchlorate.

A PRETTY PURPLE

This new blue composition can be combined with a red star composition in the proper ratio to make a purple. I must emphasize that I do NOT use a red star composition containing chlorate, as ammonium salts should not be allowed to get anywhere near chlorate because of the danger of explosion. I used Sam Bases Crimson composition shown below from *Pyrotechnica TV*. I found a ratio of 2 parts blue mix to 3 parts crimson gave a beautiful purple composition of moderate burning speed. The crimson mix itself burns rather slow.

Crimson (Sam Bases)

Ammonium Perchlorate	30
Potassium Perchlorate	35
Strontium Carbonate	18
Red Gum	15
Hexamine	3
Charcoal	2
Dextrin	4

Primer Coat

Potassium Perchlorate	75
Red Gum	12
Charcoal	8
Potassium dichromate	5

PRIMING

Like all ammonium perchlorate star compositions, priming with potassium nitrate based primes is not possible. Hygroscopic ammonium nitrate will form to prevent ignition. Blue stars made from this composition should be well dried and will turn from light to dark blue when fully dry. I dampen the stars with 95% alcohol and dust with the primer composition given above. The primer coat should be put on at least [mm thick. Then I let the stars dry again and apply a final prime coat of meal powder or glitter mix using 2% nitrocellulose lacquer to a thickness of 1/2mm. DB

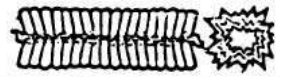
MORE BLUES

This is further to my article announcing a new blue composition using ammonium perchlorate and copper benzoate. Readers have asked what binder to use. I routinely make them with 3 - 4% dextrin added to the composition. In this consolidated form, the stars' burning speed is almost the same as a chlorate blue star. Tests have shown the intensity of the blue to be about the same as a chlorate blue star but the flame size is much larger, allowing for the use of smaller stars. A short but nice streamer tail can be created by adding 10-15% ferrotitanium alloy (100 mesh). Adding too much ferrotitanium will whiten the blue head too much.

A similar blue composition has been submitted by T.M. He uses an aqueous solution of ammonium thiocyanate mixed with a copper sulfate solution to produce a precipitate of copper thiocyanate, CuSCN. Copper thiocyanate is a tan colored light powder. He and I independently determined that the composition with the best color and burning speed was ammonium perchlorate 55% and copper thiocyanate 45%. Reducing the percentage of copper thiocyanate increases the burning speed but whitens the color. The deepness of the blue color produced is about the same as that of the benzoate blue despite the fact that the percentage of copper in thiocyanate formulation is much higher than the benzoate. The chief problem with this composition is the difficulty of obtaining the ammonium thiocyanate starting material.

I discovered that mixing copper thiocyanate with potassium chlorate produces an extremely fast burning powder which is **very sensitive** to shock. Its sensitivity seems comparable to that of a mixture of potassium chlorate and sulfur. Its extreme sensitivity, plus the fact that no usable blue color is produced, renders the composition unsuitable for pyrotechnic use.

The ammonium perchlorate/CuSCN mix seems to have very low sensitivity and I could not easily make it detonate from shock. The sensitivity to shock of the chlorate composition is, of course, related to the oxidation state of the sulfur in the thiocyanate radical. DB



NEW ELECTRIC PURPLE

Most of the so-called "electric purple" formulas I have tried in the past have turned out to resemble electric reds rather than a true purple. The difficulty in achieving a true electric purple arises from the bleaching out of the CuCl blue molecular emission bands at the high temperatures present in metal fuel stars. If an "electric" star is defined as a color star containing a metal fuel to increase the brightness of the flame, then adding metal fuel to an existing purple formulation suggests itself as an approach to the problem. I have found that standard perchlorate and chlorate based purple formulations give a whitish purple which rapidly lose their delicate color with the addition of even small amounts of metal fuel. These failures led me to investigate more fully the ammonium perchlorate based purple compositions.

Ammonium perchlorate purples, while clearly superior to the chlorate/perchlorate purples, suffer from slow burning rates which make them difficult to use in stars which must stay lit at high ejection speeds. Often, part of the ammonium perchlorate is replaced by potassium perchlorate to increase the burning rate, at the expense of some color purity. It turns out that if a small amount of metal fuel is added to a purple composition containing only ammonium perchlorate as an oxidizer, the burning speed will increase along with the brightness and still give a very acceptable purple color.

The formula given below is an example of the additive approach where magnalium was added to a very good, but slow burning purple. Magnesium CANNOT be substituted for the magnalium as it is much too reactive with ammonium perchlorate and will produce a composition that will rapidly decompose, giving off ammonia fumes and presenting a real hazard even if the stars are bound with nitrocellulose lacquer. The magnalium must be as fine a mesh as possible to minimize the production of white sparks. I used 200 - 400 mesh magnalium obtainable from KSI. The flame size and brightness is very good, but the burning rate is still less than that of a chlorate/resin or lactose based purple. Increasing the percentage of magnalium will start bleaching out the blue color component with only

a moderate enhancement of the burning rate. I believe that the burning rate is high enough to keep the star burning at all but the very highest ejection speeds.

ELECTRIC PURPLE

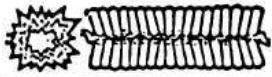
Ammonium perchlorate	68
Copper benzoate	8
Strontium carbonate	12
Magnalium 200-400m	5
Hexamine	7
Dextrin	additional 4%

The copper benzoate in the formula functions as a color imparter, fuel, and oxidizer catalyst. Copper oxide could be used, but it will not function as a fuel and another fuel would have to be substituted. Copper carbonate would produce a very slow burning mix as it cannot function as a catalyst or fuel.

PREPARATION OF COPPER BENZOATE

I simply dissolve equal amounts of copper sulfate and potassium benzoate in the smallest amount of hot water in separate containers. I combine the two solutions and let the blue precipitate cool. I then filter through a paper towel in a funnel. When most of the water has passed through, I add fresh tap water to refill the funnel on top of the precipitate. This will help rinse away the solubilized potassium sulfate. I repeat this washing step once or twice more. Then I remove the filter paper from the funnel and allow the precipitate to dry.

When I make up this formulation, I make sure that the ammonium perchlorate and hexamine are finely ground. I find that milling is necessary for these two ingredients to bring the mesh size to 200 or finer. I make sure to mill the hexamine and ammonium perchlorate separately to avoid a nasty accident. A mixture of equal parts of alcohol and water is recommended for a binder, but up to 70% alcohol can be used to speed drying. It should not be dried out in the hot sun as we want to minimize the chances for decomposition of the magnalium.



It would be nice if the purple stars could be primed with meal powder, but that will fail for two reasons:

1. Not hot enough burning;
2. Makes the star so hygroscopic as to prevent ignition.

Chlorate primes are completely out of the question because of the explosion hazard, so we are left with potassium perchlorate primes. A good prime to use would be a potassium perchlorate/resin fuel purple mix. A large number of such formulas by Dr. Shimizu can be found in *Pyrotechnica VII*. I layer at least a 1mm coating over the dried purple cores. When the primed

cores are finally dry, I apply a final prime of meal powder, or, if necessary, a 50/50 mixture of meal powder and the potassium perchlorate purple, followed by a final thin skin of meal powder. A glitter to purple star is quite attractive and the glitter mix is plenty hot enough to ignite the potassium perchlorate purple prime. If ignition difficulties present themselves, I would try applying the final potassium nitrate based prime coat with NC lacquer to prevent leaching of the potassium nitrate through the intermediate prime.

Finally, I should mention that stars should not be made too big. In round peony and chrysanthemum shells, stars over 12mm diameter will burn too long for most applications. DB

PROTECTING ELECTRIC PURPLE DECOMPOSITION

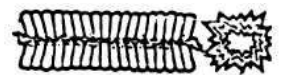
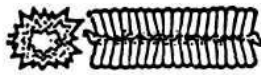
The electric purple formula given in the *New Electric Purple* article contained magnalium powder. Magnesium powder was eliminated from consideration on account of its high reactivity in the wet state with ammonium perchlorate. The first couple of batches I made with the formula, rolled up quite nicely into round stars, using 70% alcohol and dextrin as a binder. Then an attempt was made to increase the burning rate by reducing the ammonium perchlorate to a very fine powder in the ball mill. This material was screened with the other ingredients and made into stars using 70% alcohol. The stars grew in size very slowly and began to give off fumes of ammonia which was not immediately noticed because I was wearing a dust mask which adsorbed the ammonia vapors. Then I noticed the pan was warm on the bottom. The stars were rather warm, not hot, to the touch. Here was a classic case of reactivity being dependent on the particle size of the fuel or oxidizer. The stars had to be discarded and water was liberally poured on them in a dirt pile.

This reaction can be prevented from occurring by the addition of 5% of finely ground potassium dichromate and 1% boric acid. The potassium dichromate is toxic and a dust mask must be worn. It will effectively stop the decomposition and maybe even speed the burning rate up a bit while degrading the flame color slightly. The boric acid is insurance as the reaction rate proceeds the slowest in a weakly acidic environment.

II. Influence of Particle Size on Burning Speed

This is a good time to review the effects of particle size on the burning rate of round stars. When dealing with relatively slow burning compositions like the electric purple mix, the temptation is to increase the burning rate by reducing the composition to a fine powder. The way this is usually accomplished is by ball milling the composition in a rubber lined tumbler using ceramic grinding media. Ammonium perchlorate mixtures seem to be quite safe to tumble for 12 hours or so, providing that absolutely NO metal fuels are present. To remain on the safe side with this mix, it would be best to mill only the ammonium perchlorate, dextrin, and strontium carbonate in a tumbler. The hexamine and copper benzoate, potassium dichromate, and boric acid can be ground separately. These separate batches can then be screened together with the addition of the fine magnalium powder.

If this well incorporated fine powder is rolled into stars, several unanticipated problems will result. Unless the alcohol percentage of the solvent spray is kept very high, bumps will form on the star surface, which can break off into detached spikes, if the process is not brought under control. A high percentage of alcohol helps by reducing the surface tension. The stars will grow very slowly, only a fraction of a millimeter in each damping-dusting cycle. The composition will accrete on the star in a very densely packed



layer. This will actually decrease the burning rate for the same reason that flare stars are usually highly compressed - to increase the burn time.

The best, but unfortunately the most labor intensive procedure, is to granulate the finely powdered mix by incorporating 5-7% water to the powder. Addition of more than this amount of water will result in a mud pie, because the oxidizer and the hexamine are very water soluble. The dampened mix can be pushed through a 10 mesh screen and the granules allowed to dry in the sun. These granules will burn quite rapidly if you ignite a small pile, for the same reason that granulated meal burns faster than meal powder - the flame rapidly rushes through the interstitial air spaces around the granules. The resulting 10 mesh particles are too large to be rolled into size, so it is necessary to place them on top of a 36 or 40 mesh screen. The composition passing through the screen will contain a mix of sizes, from less than 400 mesh up to 36 mesh, fines below 80 mesh can be screened out, but that is not necessary nor desirable, as they help congeal the stars' larger particles. The resulting star will roll much quicker, catch fire much more easily and burn much more quickly than a dense star of fine particles. This is a fundamental consideration and can be applied to almost any other pyrotechnic mixture.

III. Changing the Color

The electric purple composition can be adjusted to give a different flame hue, if the ratio of strontium carbonate to copper benzoate is altered. I would keep the total percentage of the two ingredients the same as the original. A somewhat bluer purple can be achieved by making the percentage parts of copper benzoate and strontium carbonate equal. In this case the burning rate will increase as the strontium carbonate tends to decrease the burning rate in higher percentages.

DB

TIPS ON GLITTER CROSSETTES

Readers who have made charcoal crossettes with success and you are going to try glitter stars, might like to read my findings.

Typical glitter compositions burn slower than charcoal mixes. When rammed for crossettes, glitter burns 2 to 4 times slower. All else being equal, a charcoal star that burned 3 sec. before crossing, would be 6 to 12 sec. for glitter stars. Normally, stars will hit the ground in 5 to 7 seconds.

Some ways to correct this are:

- Make stars shorter
- Use final increment of gunpowder or spider mix
- Drill center hole deeper
- Use commercial meal for basic star
- Significant reduction of fuels and inhibitors

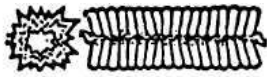
OK GLITTER

Potassium nitrate	50
Charcoal	20
Metal (Al or Mg/Al)	12
Antimony sulfide	8
Magnesium carbonate	4
Dextrin	

EQUIVALENT CROSSETTE

Commercial meal	76
Metal (Al or Mg/Al)	12
Antimony sulfide	4
Magnesium carbonate	2
Dextrin	

Also remember that ignition of glitter is more difficult than charcoal stars so I like to use meal prime on igniting surface. HF



ROUND STARS AT HOME

After reading how others make round/color changing stars I decided to come up with a more practical method for small, quick batches. I start out with a few necessities. A 4 to 8 quart kitchen mixing bowl, radish seeds, spray pump bottle of appropriate solvent, pre-mixed star comp. (dry powder) and dust mask for toxic chemicals.

My latest and nicest round, color changing stars start with a fast burning aluminum star mixture as the central core. I put about two teaspoons of radish seeds into the large mixing bowl and spray them lightly with (in this case) a 50/50 mixture of alcohol and water. Next I sprinkle a little aluminum star comp. onto the seeds. I shake the bowl in a circular motion until the seeds pick up most of the star composition.

I repeat the light spray of solvent and dusting with star comp. - each time the stars pick up all the star comp. sprinkled in. It may be necessary to spray solvent or dust with star comp. out of sequence to keep the procedure in balance. It is a good idea to periodically scrape off the dampened star comp. that sticks to the side of the bowl. There should not be too much excess unless you're over-doing something.

When the average size of the stars is about 5/16th-inch in diameter I change star comp. In my case, I changed to a red star comp. I go through the spraying/dusting procedure until the stars average 3/8-inch diameter. If the second star comp. needs priming I will use a prime that will not react with the chemicals in the star comp. Instead of a gunpowder prime I often use glitter star comp. I put it on a little thicker than needed. This gives added beauty to the burning star.

Two teaspoons of radish seeds should make about 1 to 2 lbs. of finished stars. Be sure not to handle the stars much because they may be fragile. I never touch them and only one or two fall apart in the process of coating with star comp. Spread them out to dry in a plate or pie pan.

That's all there is to making my own round stars. Now here are some hints.

I buy radish seed in bulk from a wholesale seed company for \$2.50 a pound. Any seed about the size of a radish seed will work. I might try a health food store for bulk seeds. There may be trouble with some binding agents and their solvents when rolling stars this way. I recommend using Red Gum as a binder and a 50/50 alcohol/water solvent in a spray bottle. Dextrin as a binder is OK providing some alcohol is added to break up surface tension. The best way to perfect technique in star rolling is to have lots of patience and don't give up! It works!

I stumbled across a novel effect while I was experimenting with different star formulations. This particular star was Shimizu's potassium perchlorate/copper carbonate blue. When the star of this formula burns, it leaves a heavy ash. When I put the blue star comp. over a central core of fast burning potassium perchlorate/sodium oxalate yellow star (Chemlit), the stars fall blue but suddenly the "jet" effect is quite pronounced and is a real breath-taker. The ash from the blue star confines the yellow star comp., forcing the flame out one direction. The star will actually squirm around in the air like a serpent!

One final note. Although not everyone will agree, I think that to prevent cracking, round stars should be dried in the sun if possible or at least in a low humidity area. MB



THE DARK SIDE OF PYROTECHNICS

Dark compositions are sought by pyros for use in compositions known as changing relay. A color changing star can be made by layering one color directly over another color. The difficulty is to achieve the aesthetic effect of all the stars changing color simultaneously. This is difficult to do even if the thickness of the color layers is closely controlled. In the expanding flower, some stars will always change color slightly before or after their neighboring stars. The use of an intermediate layer of changing relay between the two colors will cause the first color to dim briefly before brightening to emit the second color. The effect is to elicit the illusion of simultaneity in the eyes and mind of the observer.

Dark compositions are also used in state of the art Oriental shells. Those who were fortunate enough to see the Austin shoot at Montreal in 1987 witnessed some fancy "Saturn" shells. These shells deploy an expanding sphere of inner petal stars known as the "planet" and an outer ring of stars circling the planet. Before the stars expand to their greatest extent the planet stars extinguish nearly simultaneously and the previously invisible outer petal of stars containing the ring turns on, producing a huge sphere of a completely new color. This expanding outer petal was not seen because the color cores of the stars were coated with a dark composition that emitted very little light.

Shimizu in his book, *Fireworks, The Art, Science and Technique*, gives two formulas for changing relay. The simplest formula uses a mixture of potassium perchlorate and red gum. The other formula contains some potassium nitrate but is otherwise similar in type. Potassium perchlorate, whether it is mixed with red gum, shellac, or other resin fuel will produce a white flame when the ratio of oxidizer to fuel is near the optimum 5:1. Because the white flame is not bright and is perhaps somewhat dimmer than the light produced by color compositions, it will function as a marginal changing relay. The output of white light is too brief to be perceived. Yet these relay compositions Shimizu gave us leave a lot to be desired for our quest for a good composition.

Shimizu also gives us two "dark fuse" compositions which he states emit no visible sparks in the air. The dark fuse compositions are simply black powder formulas with the addition of a lot of realgar. I have not made these compositions as realgar is not available in this country for pyrotechnic use. Realgar is also very dangerous to experiment with as when mixed with potassium chlorate it is almost as friction sensitive as a red phosphorus-chlorate mixture.

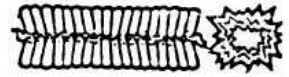
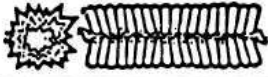
An improvement over the changing relay compositions that Shimizu gives can be achieved by changing the fuel. A fairly good low light composition uses sulfur as a fuel:

Potassium perchlorate	80
Sulfur	20
Charcoal	1

This produces less light than a similar composition with red gum or shellac but still far too much white light to be considered as a workable dark composition. The light seems to derive from the spectra of incandescent particles of potassium salts in the flame.

Another approach to dark compositions is to examine smolder compositions. The balance of fuel/oxidizer in smolder compositions is skewed to produce a composition that produces a glowing ember with no accompanying flame. Strobe compositions smolder just before they flash. The problem with smolder compositions is that stars made from them tend to go out at high speeds by the action of a stream of cool air.

I have had little success with smolder compositions using potassium perchlorate and metal fuels. I have also tried various mixtures of potassium perchlorate with antimony trisulfide and found it difficult to escape the white light produced by antimony even in small concentrations. Some impure silicon gave an excellent composition when mixed with potassium perchlorate, charcoal and sulfur. The same mix produced white light when I ran out of the old silicon and replaced it with a purer gray product. DB



STAR TESTING DEVICE

The following ideas and tips may be practical for the hobbyist who may not have access to expensive tools, supplies, etc.

Want a simple, reusable device to test stars in flight? Here's what I do...

Materials needed:

(1) -14" length of PVC or ABS plastic pipe (1/2" or 3/4" i.d.),

(1) - 18" length of wood dowel rod (same diameter as ID of plastic pipe),

(2) -1 1/2" 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 degrees 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 3/32" 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.

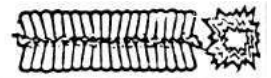
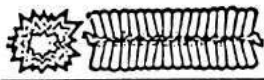
I cut off a 4" length of green visco fuse, tie a knot at one end, remove the plug, insert the fuse

through the hole so that the knot is at the top end of the plug and there is about 1 inch 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 two foot length of cheap grape stake alongside the mortar, and tape 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 sky 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.

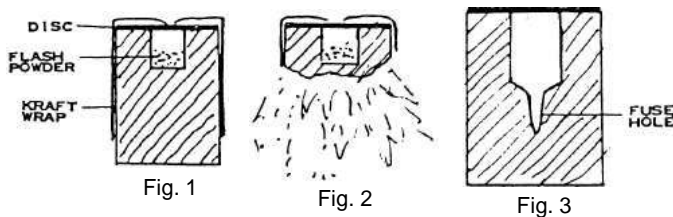
To reuse, I pull out the nails, replace the fuse and reload the components. Between test firings, I am always cautious to push the "comet rammer" completely through the entire tube in order to flush out any remaining hot dross, just in case. I have used this set-up dozens of times over before the mortar tube and plug needed to be replaced. Total cost: under two dollars. SC



THE CANTANKEROUS CROSSETTE

The popular crossette is a comet star made of streamer composition that explodes into fragments at the end of its trajectory, for a pleasing secondary effect. Very little has been written about their construction which is in a form that novice pyro's can obtain consistent results from. In this article I'll briefly cover some general principles and offer a specific design which should prove successful.

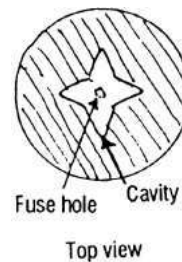
Figure 1 shows a crossette star design suggested by Rev. Lancaster in his book *Fireworks, Principles and Practice*. The crossette star is produced from a cylindrical star pump that ejects a star with a cavity on top. Flash powder is put in the cavity, covered with a disc and kraft paper wrapped as is shown in the diagram. Only the bottom end of the star is uncovered.



This design is prone to failure. The star is ignited from the bottom and burns in the direction of the cavity. Figure 2 shows the burning surface advancing near the bottom of the cavity. When the burning surface breaks through and ignites the flash powder in the cavity a strong explosion cannot occur, as there is no bottom wall left to maintain confinement. A bright flash might be seen at the top of the trajectory and the star may spin or jet off to one side as it behaves more like a rocket. Star fragmentation can occur only when the flash powder is ignited while there is still sufficient thickness of unburned star composition at the bottom.

The Orientals circumvent this problem by installing a small firecracker in the hole called the "hole shot". Rich Wolter of PYRO TOOLS studied this problem years ago and came up with an elegant solution which many readers are already familiar with. He designed a special crossette star pump which produces stars with a "fuse hole" built in as shown in figure 3. Now when the

burning surface advances, it encounters the fuse hole first, which allows the flame to flash through the hole to the cavity, which ignites the flash powder. The cavity that the pump creates has a cross shape as shown in the top view of a



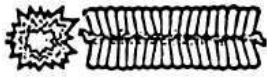
star as shown in figure 4. This allows the star to break into 4 pieces of equal size instead of shattering into minute, poorly visible fragments of varying size. The pump is available in two sizes, $\frac{3}{4}$ " and 1-1/8" diameter.

My own experience with stars made with these pumps has been one of erratic performance. Some star compositions worked OK, but others fizzled. Stars made with glitter compositions were particularly prone to failure. I improved the success rate considerably by taking a $\frac{7}{64}$ " drill and deepening the fuse hole until it stopped only $\frac{1}{8}$ " from the bottom of the star. Some compositions, especially slow burning ones, still performed erratically.

The solution to these difficulties was found by installing an actual fuse instead of relying on a fuse hole. After the pumped star is dry, I set it down on a piece of wood and drill a $\frac{7}{64}$ " hole directly through the star, using the existing fuse hole as a guide. It is not advisable to use an electric drill with compositions which contain chlorates or perchlorates because of possible friction sensitivity.

Then I mark a 1" piece of safety fuse $\frac{3}{8}$ " from one end. I insert it into the fuse hole up to the mark so that the $\frac{5}{8}$ " long end is on the outside. I take a toothpick and apply a fillet of Elmer's Titebond Glue around the fuse hole, then let it dry. When dry I use a razor blade to cut off the excess fuse so that it is flush with the bottom of the star.

It is important that the star have the correct length. A $\frac{3}{4}$ " star should be 1-1/8" long and a 1-1/8" star should be 1-3/8" to 1 1/2" long. Too short a star will have insufficient delay. A proper functioning crossette star is always longer than its diameter.



Now the star can be finished off as Rich Wolter recommends in his instruction sheet that comes with the pump. I smear Elmer's Titebond Glue on a piece of 60-70 lb kraft paper that is 1/2" wider than the length of the star and just long enough to wrap it one turn. I tightly wrap the star with the excess length of paper protruding above the end with the open cavity. I fill the cavity one-half full of flash powder, then drop a cardboard disc in and press the excess glued paper firmly down on the disc with my thumb. After drying an hour or so it is ready to shoot.

For those individuals who have never made crossettes it is strongly recommended that only potassium nitrate based streamer compositions be used such as glitter, willow and aluminum flit-

ter. Colored compositions are dangerous and inappropriate for crossettes. The use of the safety fuse helps assure the ignition of compositions which normally would require priming. However it is possible that a star can loudly explode at the end of its trajectory without producing visible fragments. This is usually caused by the flash powder being unable to ignite the refractory star composition that surrounds it. Another problem that occurs is the fracturing of the star into many small fragments instead of four large ones. This is easily cured by cutting down the flash powder.

The crossette star, by being encased in a strong, glued paper wrap, is ideally suited for use in shells. It can withstand a hard break better than an uncovered pumped star. DB

HOMEMADE CROSSETTE PUMP

An excellent "field expedient" crossette pump can be quickly produced using a 390 trial size stick deodorant plastic can and some stuff from your junk box. This design can be improved upon. I offer it only as a tool for the amateur who makes small quantities and has limited funds. The size limits the application of this tool. When the editor of CMFN returns my sample tool, I intend to try them in comets. Regular size Old Spice stick deodorant cans are 1-1/16" and might make an exhibition comet.

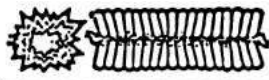
Before giving details for constructing the pump, I think you should know that my prototype was made from a Right Guard 1 oz can. I wrote to The Gillette Company, asking about availability of this item and was told that only limited production had been made as they considered it a promotional item. On the other hand, I've seen them recently in stores so it might be possible to pick up a few by careful shopping.

To make the comet star pump, I simply remove the remaining deodorant from the can and find a flat plastic follower piece. This piece initially formed the bottom of the can and when using, you placed your finger in the hole in the bottom of the can and pushed against this piece, forcing the deodorant up. I cut a handle from 1/2" wooden dowel, about 6" long, and fastened the follower

piece to it with a screw, then simply inserted the handle in the can and pushed it down until the follower is in its old location. It looks like a WWII German potato masher grenade. To use, I simply press the can into the wet star mix, or pack the mix into the can, invert it over a sturdy surface and by pushing the handle down, compress the mix. Brief experience shows how much composition to use to obtain the desired compression and thickness of star. When the proper thickness/compression is reached, the device is taken away from the sturdy surface and, with continued pushing on the handle, the star is ejected.

To make a crossette star using the device, it is necessary to make a suitable base. The base shown here would produce a crossette as described by LSO in *American Pyrotechnist* of 9/77. In use, again the pump is filled with an appropriate amount of composition and inverted over the former and compressed. By altering the shape of the 1/4" dowel, as shown, various experimental shapes could be produced, with, perhaps, various breakups as the star burns.

I want to impress that this is a strictly experimental design that should be improved upon. But as food for thought, it's a good idea and deserves looking into. KNJ



SIMPLE CROSSETTES

After trying several publicized glitter formulas in my crossette comets, I settled on one. My crossette comet formula is very simple and cheap. The effect gives a "yellow" more than a gold, glitter shower.

Although I have 40+ pounds of airfloat charcoal in my pyro shop I will not use any of it in my basic meal powder-type formula. Commercial brands of coarse charcoal also have no place in my formula. The desired effect can only be done with a dense, "compressed", type of charcoal. Where do I get it? I use my old crunched up charcoal brickette method.

First off I find an old metal five gallon bucket and dump in three to four pounds of charcoal brickettes. Next I repeatedly drop an eight pound sledge hammer on the brickettes until most of the large chunks are broken up. I sift the contents of the bucket thru a 20 mesh screen, using the screenings "as is" in the following formula:

Potassium nitrate	30
Charcoal	50
Sulfur	7
Titanium, 20-60 mesh	7
Dextrin	6

To make the comets it is necessary to buy or make a comet pump. Pumps are available specifically for crossette comets, but if you're like me you can afford just so many \$10. to \$20. tools. I made my own 1-1/8" comet pump from a 1" PVC pipe coupling and a wooden dowel. The inside of the coupling is 1-1/8" or so and should have a 1/16" center inside ring divider in the middle of the coupling. This makes a convenient stop for the dowel and gives a comet about 1 1/4" high. I use a 1-1/16" o.d. dowel about 4" long. One half of the dowel I sand to approximately 13/16" o.d. This allows for one side of the dowel to be placed in the PVC coupling half way. The other, narrow, half of the dowel is used to push the comet out of the coupling. It's not complex at all. I've made dozens of comets this way.

I prepare the dry comet formula, then dampen the mixture until it sticks together when squeezed. I pump out a number of comets and let them dry for a week or two, then take a 5/16" drill bit and wrap some masking tape around the bit so the bottom edge of the tape is about 1-1/8" from the tip of the bit. This tape is a depth gauge. I need to carefully drill in the center of comet down to within 1/8" of the bottom. This creates a delay so the comet rises from the mortar and then splits at its maximum height. The drilled space is filled with "Hot" flash powder. The depth of the hole may need adjustment for proper delay. Caution is advised while drilling into titanium comets. I use a drill press outside my shop. A portable drill will work with extra care.

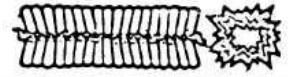
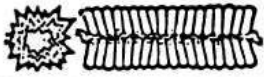
To finish the comet I fold two 2"x2" pieces of masking tape over the top of the comet and fold down over the sides. Next I wrap very tightly a 6" long strip of 3/4" masking tape around the side of the comet so the top of the tape is level with the top of the comet. I leave bare the bottom edge of the comet.

To fire the comet I secure a 6" long by 1 1/4" heavy wall tube to a base and put in a teaspoon of 3Fg commercial gunpowder, then put a fuse in the side near the base. I place the comet in on top of the lift, exposed side down and fire away.

The effect should be a long glowing trail of yellow/gold sparkles. MB

TIP OF THE MONTH

Hot Glue, I love it, but keep in mind it's hot glue: it melts when exposed to heat! Don't glue your rocket sticks on with it. If you do, well what can I say? There goes the engine, here comes the stick, then UH OH, here comes the engine again. Don't take chances, hot glue should not be used to attach drivers, etc., that generate heat that gets hotter and hotter as it burns. BGD



MORE ON CROSSETTES

Crossettes are spectacular and appealing effects and a great deal of information about them has appeared in the pyro literature. As will be quickly learned by anyone examining the recent articles about crossettes, there are many ways to make this item and I think that publishing specific methods just makes people think that particular way is the only way to do it.

If a "standard" crossette pump without splines is used, it is possible to tie a wad of string around an awl, shove a washer up against it (chipboard disc) and press a small pointed cavity into the bottom to perform as the fire transfer. It can also be used to speed up a comet mix that goes a little too long before hitting the shot.

Many pyros contrive one way or another to attach the hole shot to the top disc (some don't use a top disc at all) or the paste coat, so the shot doesn't go flying merrily out the hole while its short delay burns. Maybe just gluing the capsule to the disc will do.

Why do we see that chlorate/sulfur flash mix? Perchlorate and German dark aluminum work quite well, for instance, Lancaster's formula: 67/33 or 70/30. 1/10% by weight of chemite or Cab-O-Sil is added, and the perc and Cab-O-Sil are sieved thru 100 mesh over and over until the Cab is pretty much disappeared. Then the aluminum is added via a 16-20 mesh screen. I have successfully broken 3/4" cavity stars (FeTi mix) and they looked like crossettes. For accuracy, I weigh the flash and don't fill over 1/3-1/2 full.

FERROTITANIUM COMETS

All the FeTi formulas keep showing up with Meal D which is OK if you can get it and can afford it. Here is "The Poor Man's Palm Tree":

FerroAlTanium Comet

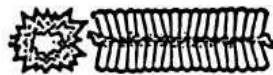
Potassium nitrate	20
Aluminum "bright" (#810)	3
Ferrotitanium	3-6
Sulfur	1V ₂
Antimony sulfide	P/2
Airfloat charcoal	5
Dextrin	2

The charcoal doesn't have to be all dust or the best. With under 10% aluminum, it can still be rammed, but it is a little on the light side. It catches very easily and burns fast. The tail is thick, does not last as long as charcoal, but it does crackle and the aluminum fills it in, while the FeTi adds the duration. I make no claims for this being better than another formula, it just is cheap and it works.

FALLING LEAF STARS

Just a comment on the Falling Leaf Stars article. In some Onda shells I have looked at, the falling leaves were made by cutting stars in small rectangular slabs (1/2 x 1/2 x 1 1/2"), which were then wrapped with a turn of Gampi, about 3" long. One end was left exposed and primed, and the other had a twist of paper, left bent at an angle. These stars then spun as they fell through the air, much as maple seeds do. Those I examined were not strobe compositions.

Another method being used by the Chinese is to coat the strobe composition on thin chipboard and cut it into 1/4" x 1" strips. Many of these are then held together and dipped into a blob of strobe composition on one end. The effect is of several large colored stars, which break up into many smaller, floating, flashing lights. The big Tiger Head Rockets use them. JHB



STAR IGNITION FAILURE

Novice shell makers frequently find the problem of star ignition failure facing them soon after they solve the problem of flowerpotting. It's been said that professional shell makers are usually satisfied if they achieve 80% star ignition. The ignition problem is complex because of the many different shell configurations and star compositions in use today. Literature on the problem is rather sketchy. Most sources simply suggest dusting the stars with meal powder and then let you worry about the complications. The problem is discussed in greatest detail in Takeo Shimizu's *Fireworks, the Art, Science and Technique*. The novice usually obtains successful star ignition of the common star varieties and shell configurations only after a careful reading of the available literature is coupled with extensive testing over a period of years. Having done my share of littering the ground with blind stars I will try to present in this article some general theoretical considerations and practical rules of thumb for specific applications gleaned from my own reading and observations.

The reasons for star ignition failure can be reduced to three separate problems: 1) Improper burst charge; 2) Improper shell wall hardness or thickness; 3) Inadequate star priming.

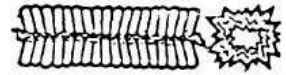
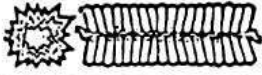
When the time fuse sends a spray of flame into the burst charge, the flame front rapidly expands and the internal gas pressure rises at a rate determined by the burning speed of the burst and the quantity of the burst charge. The shell breaks open when the gas pressure equals the force required to tear open the shell wall. The shell may burst before the flame can reach all the stars. That is why it is important to use a burst charge composition that burns rapidly. If one were to use home made, slow burning black powder as a burst, the shell will break open prematurely, ejecting many unignited stars ahead of the flame front. Making the shell wall thicker will increase the percentage of ignited stars only up to a point. Since the speed of burning of black powder is not a function of pressure, increasing the shell wall thickness will not increase the expansion rate of the flame front. Experiments I have performed with round shells have shown that with a given burst charge, star ignition increases with in-

creases in wall strength and then drops to nearly zero above a critical point. That point marks the region of pressure above which star destruction occurs. I learned this lesson the hard way when a 4" round shell filled with labor-intensive box stars detonated with no star ignition. I had glued 16 layers of 70 lb. kraft on the commercial Japanese (thick) hemispheres. The correct number of layers is about 7.

The use of powerful burst charges such as flash powder in flash bags can also lead to star detonation if the wall strength is not reduced. That is why flash bags can be used in "stringless" canister shells. The internal pressure rises much faster than a black powder burst. Consequently, stringing is not necessary nor even desirable for good star ignition. But it is necessary to carefully regulate the amount of flash powder and wall thickness as the region of good performance is in a very narrow range of these two parameters. The right values are found through experimentation as pyrotechnics remains a largely empirical science. Flash bag shells made properly often have good symmetric breaks. Small irregularities in wall thickness and strength in various regions of the shell become unimportant if a very rapid burning burst charge is used.

The selection of the proper burst charge and wall strength becomes critical in the Japanese Warimono shell. Powerful burst charges such as H3 (3 parts potassium chlorate and 1 part charcoal) are needed for shells 4" or smaller to give a suitably large radius. The larger the shell the less energetic the burst charge required. Twelve inch warimono shells use a thin coating of black powder on large cork chips as a burst. The wall thickness must increase with shell radius to maintain equivalent wall strength. Star ignition in a properly designed warimono shell approaches 100% as the burst charge is in contact with every star in the shell.

When George Plimpton's 40" "Fat Man" canister shell exploded with a horrific detonation over Merritt Island, Florida a few years ago, only a small percentage of its stars ignited. The cause of the problem can probably be traced to the use of too large a black powder burst charge (about 100



lbs). If a slow burning, hand mixed black powder had been used, less star destruction would have occurred. Not only does it take less lift charge per unit weight as the shell size increases but the burning speed and quantity of burst charge per unit weight must be reduced. Mathematicians would call it a "non-linear relation"!

The round Japanese Poka shell seems to violate the principles outlined above. The shell is constructed from thick strawboard hemispheres. Only a VERY SMALL black powder burst charge is used which is often present in a small bag attached to the end of the time fuse. The shell is wrapped with only a few layers of kraft paper so that it breaks very easily. Willow shells incorporate the Poka design which dump an umbrella shaped load of willow stars with long tails. The stars are placed only in the bottom hemisphere with the fuse. The top hemisphere is filled with a noncombustible material. This configuration puzzled me for some time until I realized that the Poka was more of a mine than a shell. The bottom half of the Poka serves as the mortar containing the stars and burst charge. The top half serves only as a dome shaped "lid" for the "mortar bottom" which is designed to blow off easily. Star ignition is good in mines because the flame produced by the lift charge is concentrated in a long directional jet that easily ignites the column of stars in its path.

STAR PRIMING

The pyro literature currently available contains hundreds of star formulas. Information on the optimal priming methods for each particular star composition is usually lacking. This article will attempt to fill that gap with an explanation of the theory and practice of star priming.

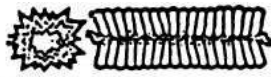
The maximum ballistic velocity in which an unprimed star, or for that matter, any combustible object, is capable of remaining ignited can be termed the critical wind velocity. At the critical velocity the rate of heat production from exothermic combustion on the star's surface is equal to the rate of heat loss from contact with the ambient air blow.

BLACK POWDER TYPES

In a hard breaking shell such as a Japanese chrysanthemum, the initial star velocity is so high that only a few types of star compositions have a high enough vertical velocity to sustain ignition. Black powder-type compositions are often used as the surface prime of stars in these shells as its critical wind velocity is very high. Potassium nitrate and charcoal are the key ingredients in black powder-type composition which allow for ease of ignition at high speed. Potassium nitrate has the unique property of undergoing a crystal phase transition (rhombic to trigonal) at the very low temperature of 135°. This change "loosens" the molecules in the crystal lattice, making them more available to rapid thermal decomposition. Charcoal, in addition to being an excellent, fast burning fuel, has the well known property of maintaining "smoldering embers" even at very high wind speeds. This property of charcoal can keep micro-embers, or hot spots, on the star's surface which allow it to ignite the star composition when the star velocity has slowed down at some distance from the burst. It should come as no surprise then that McLain (*Pyrotechnics*) reports that the most ignitable (from a hot wire radiative source) prime was sulfurless meal (90% potassium nitrate, 10% charcoal). The message here is to add charcoal rather than sulfur, to aid in star ignition, to your formulas. Usually as little as 2% charcoal can make a significant difference in burning speed and ignitability.

The star compositions which require no prime in hard breaking shells can be seen to contain one or both of these two key ingredients. The following is a list of general star compositions which require NO prime at high ejection speeds.

- **CHARCOAL OR WILLOW STARS** containing mixtures of meal powder and/or potassium nitrate with charcoal. This would include all the formulations on p.88 of Lancaster's text: *Fireworks, Principles and Practice*.
- **GLITTER STARS** which do NOT contain a large percentage of barium nitrate.



- **FLITTER STARS** which contain a large percentage of meal powder such as Ferrotitanium 30%, Meal 70%.

- **ZINC STARS**

CHLORATE TYPES

Compositions containing potassium chlorate have a high critical wind velocity because of the low decomposition temperature of potassium chlorate. Chlorate color stars can be adequately primed with just a thin coating (about 1/4mm) of meal powder on the surface. Green star formulas employing only barium chlorate as the oxidizer will require a thicker (1/2mm) coating of meal powder on the surface because of the higher decomposition temperature of barium salts versus potassium salts. Lancaster uses a small percentage of charcoal in all his chlorate color formulas and uses the highest percentage in his all-barium chlorate cut green formula on p. 91.

PERCHLORATE TYPES

With potassium perchlorate color formulas, ignition becomes more difficult to obtain because of the high decomposition temperature of perchlorate. Meal powder alone will not be able to transfer sufficient heat to a perchlorate based star to insure ignition at high speeds. For this case I use an intermediate layer of ignition mix made up of one part perchlorate color mix and one part meal. This layer is applied to the star until it is about 1/2mm thick. Then another 1/2mm layer of meal powder alone is applied, usually with about 2% dextrin added as binder.

For ammonium perchlorate color stars, a meal powder ignition layer is completely out of the question, as potassium nitrate and ammonium perchlorate form the double decomposition product ammonium nitrate, which is hygroscopic. Some pyros use a hot slag producing prime such as a lead oxide/silicon mix, but I feel the mixture is too sensitive to friction and too poisonous to fool with. I use Shimizu's "Strobe Igniter" without the aluminum. *[Formula in next column].*

I apply the igniter mix to round ammonium perchlorate color stars by using 95% alcohol as the solvent to spray on the stars. The red gum

Ammonium perchlorate prime

Potassium perchlorate	74
Red Gum	12
Charcoal	6
Potassium dichromate	5

serves as the binder. After this coating has completely dried to a thickness of 1/2mm, I apply a mixture of 2 parts meal to 1 part charcoal (henceforth called prime "A" or top prime) to the star, using a 5% solution of nitrocellulose lacquer in acetone as the solvent/binder. This non-aqueous system insures that the potassium nitrate will not leach through the intermediate igniter layer to react with the ammonium perchlorate. Needless to say the use of large amounts of NC lacquer is not practical from a commercial standpoint.

MAGNESIUM TYPES

I also use NC lacquer to ignite magnesium stars, both large ones, and for magnesium cores in color-changing stars. For example, Lancaster lists a red mag formula on p. 93 which is given below:

Red Mag

Strontium Nitrate	55
Magnesium, 100-200 mesh	28
PVC	17
Red Gum	5
	addition %

I added 5% red gum to serve as an alcohol-soluble binder. Using a mist of 95% alcohol, I form round mag cores about 6 to 8mm in diameter. After drying overnight, I make up a small amount of a mix of 2 parts red mag mix to 1 part prime A. This "hot" prime is sprinkled on the cores using 4% NC lacquer until the thickness is about 1/2mm. Then another cooler prime consisting of 1 part red mag mix to 2 parts prime A is applied Vimm thick. After drying, this igniter layer will prevent water-bound compositions applied over the cores from getting the magnesium damp. If a potassium nitrate/charcoal streamer mix is applied over these treated cores, the ignition will be certain and there is no problem of potassium nitrate leaching into the core and turning the color to orange.



THE BEST OF AFN II



If one wanted to go from a hot burning aluminum flitter mix (such as the ones on p. 90 of Lancaster) to a red mag core, no mixed or graded igniter layer is necessary because the heat produced by the outer layer is more than sufficient to insure ignition of the core. However, a thin intermediate coating of NC lacquer is advisable to prevent the leaching and core dampening problem.

ALUMINUM TYPES

Aluminum flitter stars containing 40-50% aluminum, can be ignited with a meal coat prime,

provided that potassium chlorate is the oxidizer. With potassium nitrate, it is necessary to add about 10% sulfur and some meal powder or charcoal. A lot depends on the mesh of the flake aluminum used. When aluminum brite flakes 200-300 mesh are used with potassium nitrate, it is necessary to use a graded igniter system like the ones described above. Aluminum stars using potassium perchlorate as the oxidizer, can be reliably ignited using the gradation system, even if the percentage of aluminum in the core is 65%! The whole idea here is to gradually increase the heat output of the igniter layers until it is sufficient to ignite the core. DB

"A" BLASTING & FIREWORKS BLACK POWDERS

"A" Blasting Powder (potassium nitrate) is available in seven standard granulations. Fireworks Powder is available in ten standard granulations. All except Meal granulations are manufactured glazed or unglazed. Unless specified, glazed powder is supplied. Meal granulations only are manufactured unglazed.

GRANULATIONS		GRAIN SIZES			
"A" Blasting	Fireworks	Through (inches)		On (inches)	
		Sieve	Opening	Sieve	Opening
FA	FA	20/64	0.3125	No.5	0.157
2FA	2FA	No.4	0.187	No.12	0.0661
3FA	3FA	No.10	0.0787	No.16	0.0469
4FA	4FA	No.12	0.0661	No.20	0.0331
5FA	5FA	No.20	0.0331	No.50	0.0117
6FA	6FA	No.30	0.0232	No.50	0.0117
7FA	7FA	No.40	0.0165	No.100	0.0059
	Meal D	No.40	0.0165		
	Fine Meal	No.100	0.0059		
	Extra Fine Meal	No.140	0.0041		

Tolerances: 3% maximum on "Through sieve; 12% maximum through "On" sieve.

UNCONVENTIONAL SHELL CONSTRUCTION

Here is a method I have developed of getting nice, big, symmetrical breaks every time! The secret is the burst charge. My method uses potassium perchlorate and sodium benzoate in proportions that are normally used for whistles, yet its power almost equals aluminum flash. Mixed well and preferably milled to dust, it burns like flash powder.

To begin, I roll the shell casing paper around a former (which has a 1/4" or 3/8" hole bored in one end) and tape to hold. I withdraw the former about one inch and fold the paper over the end of the former about 2 sheets at a time. The last turn may be pleated around the center to make punching the fuse hole easier. After the paper is all folded down, I bang the end on the bench a few times to set the folds and then I tape it shut with two pieces of masking tape, crossed over the top. Now I punch the fuse hole, starting with a nail, then 1/4" or 3/8" pointed dowel to get the proper size for the fuse.

	3"	4"
Burst	200 grains	500 grains
Paper	3 strips 36x6", 60#	4 strips 36x8" 60#
Former	2 1/2"	3 1/2"
String	8 vertical	16 vertical

I take the shell case off the former and start the time fuse into the hole. Now I run a bead of white glue around the fuse base and twist and push the fuse in until it enters the bottom of the case. I hold my fingers against the hole inside the shell to prevent the fuse from pushing the paper so as to close the hole.

Now I turn the case upside down (I make up a jig consisting of a block of wood with a hole drilled in it so the fuse fits in the hole and won't be disturbed by further operations). Now I fill the shell up with stars until about one inch from the top. I add burst according to my chart and then fold the paper over the stars as I did when making the other end. I try to keep it as round as possible, which is rather difficult without an end

disc. Now I tape it closed and string as usual. I make sure to have put plenty of glue around the fuse. After the string is in place, I wrap one layer of masking tape around, starting at one end and spiraling down to the other end. (All this does is keep the string in place and smooth the surface a little). Now I add quickmatch, wrap it in two turns of 30 lb. kraft paper, add the lift charge and it's finished.

Multi-breaks can be made by having all breaks ignited by the lift at the same time. First break should have the shortest fuse, second break should be a little longer, etc. I tape a good, thick piece of black match to each time fuse, letting the bare end run down the side of the shell about 3/4" and wrap (or string) the breaks together. I make sure the match will be exposed to the lift flames.

Stars	Red**	White##	Blue***%	Green***#
Potassium chlorate	66	7	65	15
Stront. carbonate	15			
Red gum	12	2		15
Copper oxychloride			12 1/2	
Lactose			12 1/2	
Dextrin	5	1/2	5	5
Barium chlorate				40
Barium nitrate				25
Hexachlorobenzene	1		5	
Stearin	1			

Note: All formulas use water.

* = don't prime. + = from Pyrotechnica #1

** = prime. # = from author

% = from Lancaster

Stars for this type of shell should be fast burning and easy to light. Most black powder types will work, but perchlorate or those with high aluminum content should be rolled in prime. I like the star formulations that are shown in the table, but they are very sensitive and I make and use them with caution! MV "&



"CHEAP"(?) DAYLIGHT SHELLS

A short while ago a friend asked me if I could put together a few daylight effects for him. I said I'd try.

"SMOKE" SHELLS

After taking apart a quantity of smoke items and trying to make acceptable smoke stars or inserts, none of which worked, and only succeeding in staining my hands various colors of red, blue, puke green, jaundice yellow, etc. I gave up on a pyro mix. I remembered that the various police and military organizations of the world use tear gas in exploding grenades, so that is the approach I decided to take. I went to a local store that handles art supplies and bought dry tempera paint in three colors. I decided on blue, yellow, and magenta and could thus custom blend them to make green, orange and purple. I gathered a quantity of 3" plastic round shells and fitted them with a small flash bag. I then filled them with the dry paint, and sealed, lifted and leaded as usual. Not bad, if I say so myself, but not as good as real smoke. They are most visible in dim light just after sunset and in the eastern sky. They are also very sensitive to strong wind, and dissipate too fast to be really appreciated. But tempera is only \$3.50/lb and will fill 5 or 6 shells. Have you seen the price of smoke dyes lately? Wow, no wonder you don't see many daylight smoke shells these days!!

CONFETTI SHELLS

I then got the idea that a confetti shell would be nice and built them the same as the smokers, putting colored foil, streamers etc. into them. Also not a bad effect if the shell isn't too high when it bursts.

PARACHUTE SHELLS TOO!

How about a day parachute shell? Also easy, but not so cheap. I take apart Class C parachute items. I leave them in the inner tube and prime the fuse end. I fill the empty space with cat litter (fresh only!) and add the burst at the primed ends only. I found that a 6" shell will hold 5 mammoth day, 6 American flag, and 10 double day 'chutes when properly arranged. JC

2" DISPLAY SHELLS IN A HURRY

Are you like me and don't want to wait around for glue to dry when you're dying to test your latest stars out? I saw some egg shaped plastic containers in a department store last Easter that I just had to buy in the hopes of making 2" display shells out of them. Many stores sell the plastic eggs at Easter time for use as candy containers (they are sold empty). I finally got down to business and came up with a workable technique (it worked the first time and I had never made a display shell of any kind before).

First thing I do is drill a small hole in the pointy end of the egg and stick a 1 1/2" piece of 3/32" green visco fuse half way through. Then I mix up a half teaspoon of 5 minute epoxy and pour it into the shell half so that the fuse will have a puddle of glue 1/4" deep around it. After the glue sets up I fill the *egg* with stars and burst charge.

With the two halves of the egg together I squeeze a little model airplane glue in the joint. Next I wrap the egg with masking tape (just enough to cover the egg and a little at the base of the protruding fuse). Now I wrap the egg vertically with fiberglass-reinforced tape. Being careful not to put too much tape on, I wrap the egg horizontally. Obviously the egg cannot fit tightly into the mortar.

I use a 2" i.d. tube, 12" tall, mounted on a board with a fuse hole near the base. I pour about 1/3 to 1/2 oz. of 2FA into the mortar, place fuse in hole at base and finally drop the shell (fuse end down) into the tube. I split the fuse attached to the shell slightly to insure ignition.

This technique is very simple and quick although someone may want to go fancier, e.g., piped match, exterior effects, etc. MB



THE ASCENT OF PLASTIC

As judged by the results of the shell building questionnaire in the July '87 PGI Bulletin, the users of plastic round shells constitute a minority of the sample. Only 27% (the Bulletin erroneously reported 47%) of the 108 respondents admitting making any plastic round shells. Only 6% of the sample reported that round shells constituted a majority of their shells made in 1986. Yet I have not been receiving a great deal of phone calls and letters from pyros experimenting with 3 and 4 inch plastic round shells. These individuals also tend to be avid users of RSI's R.A.P. canister shells. We are all pursuing the same goal - to produce round, symmetric breaks as good as the paper shells.

The advantages of plastic hardly need repeating. They can be assembled in a fraction of the time of paper shells and the cost of plastic shells is considerably less than the imported strawboard hemispheres from Japan. 3" plastic hemispheres can be purchased in quantity for about 15-cents each.

The chief stumbling block of plastic shells is the difficulty of achieving a good symmetric break from them. The key to the solution to this problem lies in three areas: 1. The arrangement of stars in the shell, 2. The type of burst charge used, 3. The method of joining the hemispheres. I'll describe below methods that have worked well for me and throw in some alternate ideas I have received from others.

I. Loading the Stars

The most perfect burst symmetry will occur when the stars are loaded only one layer deep against the inside wall. This arrangement assures that each star will be given a nearly equal velocity as in a paper chrysanthemum shell. A greater star density can be achieved by filling both hemispheres full of stars. In that case the stars in the center will have a very low outward push and will tend to dump downward if the shell bursts at the apex of its trajectory. The overall effect will still look basically symmetric if the proper burst charge is used. An uneven distribution of stars in the shell will nearly always produce a nonsymmetric "spray" type burst.

Figure 1 shows an unevenly filled shell with the stars occupying only one hemisphere (the burst is unspecified). The explosive compression begins at area A, causing the shell to fracture at its weakest point, which will be along the wall unoccupied by stars. The explosive energy of the burst is largely wasted with only a fraction of the energy delivered to the stars, resulting in a spraying or dumping type burst.

II. Burst Charges

A great deal of burst charges have been mentioned to me: H3, flash powder, flash powder on rice hulls, benzoate whistle comp, used alone or on rice hulls, KP burst, etc. It is wise to experiment with different types and quantities of burst charge to get some familiarity with the properties of various compositions. The general rule to follow is to increase the energy of the burst charge with decreasing shell diameter. I have listed various burst charges in the table below in the order of decreasing burst energy.

Whistle comp appears to be the optimal burst for 3 and 4 inch shells, giving the most consistent results. It can be used as a fine powder or coated on rice hulls. I prefer simply dumping the powder on the cross matched fuse and packing the interior with meal coated rice hulls as shown in figure 2. I use two teaspoonfuls of benzoate burst or about 10 gm in either a 3 or 4 inch plastic shell.

Whistle comp must be well mixed to burn properly. I pass the mix through a 40-50 mesh screen 5 times before using, then I test its burning rate by packing in a cardboard spoollette. It should burn at 6.4-6.6 mm/sec. In humid climate I would use potassium benzoate instead of the sodium salt.

III. Joining the hemispheres

Now we come to the trickiest part of the plastic story. Two schools of thought exist in the finishing process of plastic round shells. Over half of the plastic shell builders in communication with me glue the hemisphere together, then wrap with various kinds of tape to various thick-



THE BEST OF AFN II



nesses. For example, A.K. uses Duco Contact Cement which he applies to the seam with the shell almost closed and then squeezes tight - holding for about 60 seconds. Then he wraps with two layers of masking tape. He buffs the tape down with a hardwood block sander to smooth it out. Al says the shell breaks symmetrically and when recovered only a ring consisting of the glued joint is left.

My feeling is to do away with the tape entirely in the interest of speed and efficiency. I assemble the two halves using a thin plastic sheet covering the hemisphere that is flipped upside down. I align the halves and pull out the plastic sheet and snap them almost together. Then I dip a cotton swab in methylene chloride and apply to the joint quickly. The shell is snapped together and held tight for 30 seconds. If the shell is a 3" plastic I grab it by the fuse and dunk it into a large glass of solvent so that the shell is covered to within 1" of the top where I am holding the fuse. The shell is rotated for 30-45 seconds and pulled out. I stand it up carefully on a plastic sheet until it is dry. This process fuses the joint together, very effectively reducing the inherent weakness of the joint in an effort to obtain nearly uniform wall strength. If the shell is 4", which comes with a convenient plastic ring which is glued to the top, I rotate the shell horizontally in a bath of solvent as shown in figure 3. After 1.5 minutes I pull the shell out and hang it up to dry. A shell is not fully dry until you can not scratch it with your fingernail on the seam.

After crossmatching the fuse I put the lift charge in a paper cup, trim off the excess height of the cup with scissors and swab a circular area around the fuse with solvent, then I glue the cup down. The shell leader is passed through the loop and into a hole or slot in the lift cup and taped down.

My results so far have been encouraging. Over 80% of my breaks have been perfectly round. Occasionally I get "jets" of stars streaming out at some angle and disturbing the symmetry somewhat. I don't plan to use paper anymore except for specialty shells such as palm trees.

A final note of warning: One cannot allow solvent to soak the fuse or get into the shell (which is easy to spot as air bubbles form at the seam

when wet with solvent). If this happens the shell is ruined and should be taken apart or safely destroyed. DB

BURST CHARGE	
Perchlorate based flash powder	3" or smaller plastic shells
Pot. perchlorate 70%/ Pot. benzoate 30%	3" - 5" plastic shells
H3 on rice hulls	4" or larger shells
KP burst $KClO_3/C/S$	6" or larger shells
Meal pwdr on rice hulls	Filling center of shell

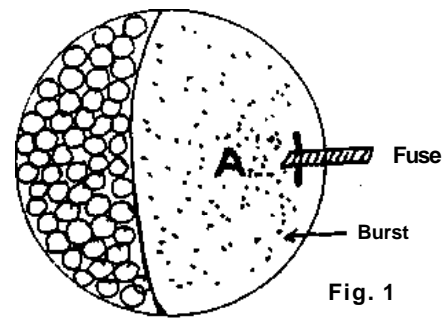


Fig. 1

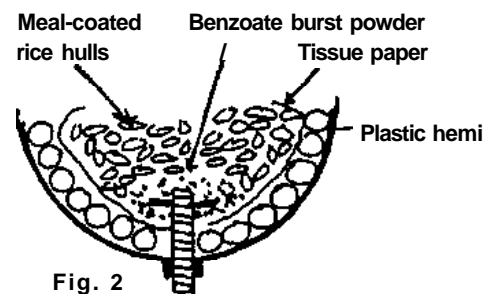


Fig. 2

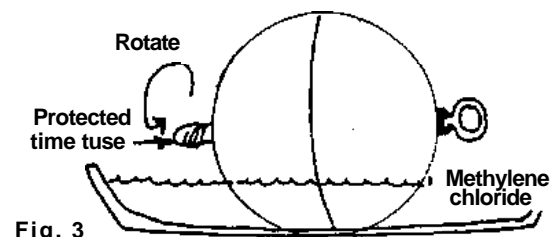
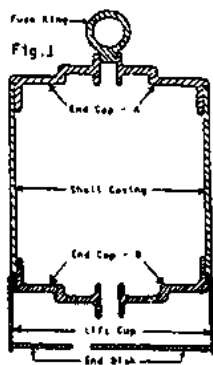


Fig. 3

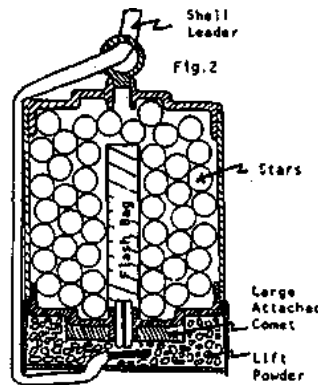


RAP* SHELL ASSEMBLY TECHNIQUES

We (KSI) and many others have had a high degree of success using RAP shells. Assembly times for RAP Shells are a small fraction of that which is required for Italian-style construction and nicely symmetric breaks can be achieved when the proper techniques are employed. This article is a summary of successful methods used by us and reported to us by others. However, no attempt will be made to give detailed step-by-step instructions, nor will the information in our "Guidelines for Assembling RAP Shells" be repeated here. (That information can be requested for free and is included with copies of our price lists.) While the information presented below is particularly relevant for RAP shell assembly, much also applies to assembling other types of plastic and plastic/paper shells as well. To assist those readers who may not be familiar with RAP Shells, two figures have been included. Figure 1 shows the various RAP shell components and how they are assembled, and Figure 2 shows a typically completed RAP shell.



Break Charge



Solvent Bonding

It is certainly possible to apply the solvent for bonding the plastic components with a wool dauber. However, high quality breaks cannot be reliably attained in this way. It appears that only by dipping one of the components into the solvent before assembling can high quality breaks be reliably achieved. Dipping is usually accomplished by filling a shallow tray with about 1/2" of solvent. Then one or more of the components are placed in the tray so that the surface upon which bonding is to be achieved becomes wetted by the solvent and starts to dissolve. The

* RAP means Rapid Assembly Plastic

length of time the components should remain in the solvent depends on the temperature and on the type of solvent used. (For methylene chloride, about 15 seconds is usually sufficient.) The dipping method has the added advantage of being easier and faster when assembly line techniques are employed. The disadvantage is that a larger quantity of solvent is initially required to fill the tray used for dipping. With a solvent such as methylene chloride, the rate at which solvent is used when dipping is not much greater than with the dauber. This is because methylene chloride vapor is about three times denser than air. Thus, after the tray fills with vapor, relatively little continues to evaporate. (Note that because good results seem to require dipping, and because dipping requires more solvent, we have doubled the amount of solvent we put into our RAP Shell Kits. Also, we are now using metal cans for the solvent which allow it to be stored for much longer periods without evaporating.)

Caution When Using Thickened Methylene Chloride (TMC)

In the past we recommended the use of TMC when attaching the ring on the top of the shell that holds the quickmatch leader. (TMC is made by dissolving about 10% by weight of scrap polystyrene in methylene chloride, until it has become as thick as a heavy syrup.) However, one person has reported having an unfortunate accident when using TMC. On opening the container of TMC, the contents effervesced, frothing up to overflow the container (much like what sometimes happens with soda pop). When this happened, his hands were covered with TMC. The methylene chloride caused a burning irritation of his skin, which was made worse by having to peel dried polystyrene from his hands after the solvent had evaporated. We have seen TMC effervesce slightly at times, although we have not had it froth up. We still use TMC but are considerably more careful in its use.

Break Charge

Only through the use of high energy break charges have symmetric and broad spreading RAP shell breaks been reliably achieved. Flash



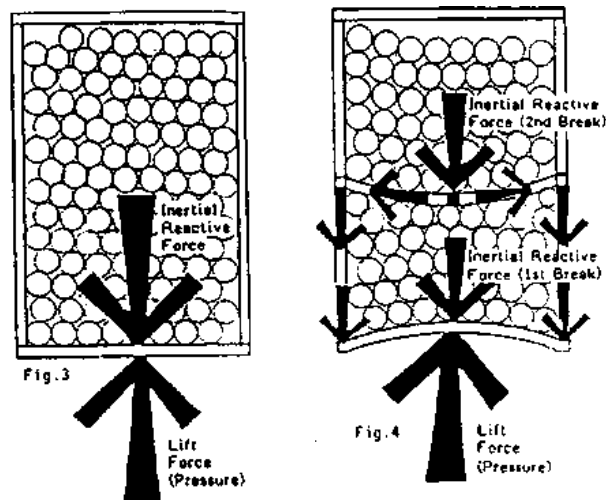
composition, whistle mix and perchlorate H3 powder have all been reported to generate high quality breaks of shells containing stars. Black powder and pulverone have only been useful in breaking RAP Shells containing small components. Some of the formulations used for making the compositions which work well when used in flash bags have been revealed to me, but I was asked not to pass them along. I can say that what is needed is a slower and drossier mix than would be used to make salutes. (Some guidance on the use of flash bags can be taken from the Oglesby article *Igniter Flash Bags*, appearing elsewhere in this book). Whistle mix (70% potassium perchlorate and 30% sodium benzoate) has been reported to produce breaks as effective as with flash bags when the whistle mix was contained in a larger version of a flash bag in the center of the shell. When whistle mix is used but is dumped in loose, good breaks are obtained but not as reliably as when it is contained in a centrally located bag. When loose whistle mix is used, it is important that the sodium benzoate be the type that is quite finely ground so that it tends to coat the stars well and remains stuck to them. Perchlorate H3 powder (70% potassium perchlorate and 30% air-float charcoal) either granulated or heavily coated on rice hulls, has also been reported to produce good breaks.

Contents Loading & Break Symmetry

Because RAP Shells do not derive their strength from the careful loading of their contents, the stars and/or components can be dumped in loose. It is not necessary to attempt to consolidate them, nor even to fill the shell completely. However, one user reported that he was able to achieve improved break patterns when care was taken to fill the shells completely full. Another user reported that improved breaks were more easily obtained when the length of the shell casing was reduced by about 1/2" before use. (This also saves on the use of stars.) Finally, as with other types of shells, break symmetry is improved when the stars are loaded around a centrally positioned break charge.

Multi-Break Shells

Several people have reported the successful launch of multi-break shells (2- and 3-break color



shells and color/color/report shells). However, I can not recommend this. In the material we supply with RAP Shell Kits, we do describe the possible use of a small (light weight) salute as a second break on a RAP shell. This places much less strain on the bottom end cap than does a second (or third) star shell. In a conventional shell, much of the compressive strength of the shell is derived from the careful packing of its components. This is not the case for RAP Shells where the strength is derived primarily from its plastic case. On the one hand, this has the advantage of not requiring careful packing of the shells. On the other hand, it means that RAP shells will not function very well to launch additional breaks. The reason for this will become clearer by examination of Figures 3 and 4. Figure 3 is a sketch of a single break shell being propelled upward while inside the mortar. There is a large upward force created by the high lift pressures. This force is exerted uniformly across the bottom end of the shell, but to simplify the drawing and help illustrate the multi-break problem, it is shown as a single large upward arrow. This lift force is opposed by an inertial reactive force (Newton's Third Law of Motion) in a downward direction. In essence, this force is created by the stars' inertia (if at rest, the tendency to remain at rest) in reaction to the acceleration they are undergoing. These two forces are both acting on the lower end cap of the shell and to large measure, as far as the end cap is concerned, they balance each other. (They do not completely balance because there is also a small outward component of the inertial reactive force that is coupled to the shell wall by friction. However, for the purpose of this discussion, this

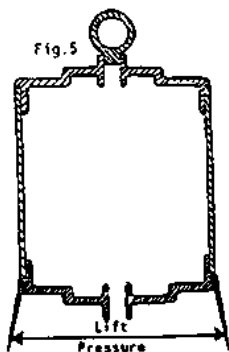


can be ignored. Thus, for a single break shell, since the end cap has almost completely balanced forces applied to it, there is relatively little stress on it. Accordingly, the end cap can easily adjust to the lifting process.

Figure 4 is a sketch of a two-break shell being propelled upward inside a mortar. In this case, the forces on the end caps are definitely not balanced. The inertial reactive force from the first break's stars acting downward on the lower end cap only balances about half of the upward lift force acting on the end cap. In addition, the inertial reactive force of the stars in the second break are not properly balanced across the middle end cap. The stars push downward across the entire cap but are not opposed by a balancing lift force. It is the shell wall of the first break that communicates the inertial reactive force from the second break downward to encounter the lift force. The net result is that the bottom end cap experiences an unbalanced force in the upward direction, while the middle end cap experiences an unbalanced force in the downward direction. Accordingly, much more strain is experienced by the end caps and there is a much greater chance of their breaking. RAP Shells were designed for a single break to have a good chance of surviving being 200% over lifted (three times the normal lift). However, they are not intended nor designed to operate as multi-break shells.

Lift Powder

Because of the design of the RAP shell lift cup, less lift powder can be used than is necessary for conventional shells. (See Figure 5, which illustrates how the lift cup expands to close the space between the shell and mortar, much the



same way as the wadding acts in a shotgun shell.) We use 0.6 and 1.1 ounce of powder to lift 3-inch and 4-inch shells, respectively, which contrasts with 1.0 and 2.0 ounces for conventional cylindrical shells. Also, there is no difference in the lift achieved when using 2F powder as compared with

using 4F powder. (Small shells normally are propelled more efficiently with 4F powder.) This means that there is no cost advantage in using 4F powder, and the more gentle 2F powder can be used. Some amateurs, for whom it is difficult to obtain commercial black powder, have reported success using granulated perchlorate H3 powder. Success has also been reported using granulated homemade meal powder (75% potassium nitrate, 15% air-float charcoal, 10% sulfur, and +5% dextrin) mixed with a small amount of sporting grade black powder (to speed up the burn of the homemade powder).

No RAP Salutes

We have had reports of people using RAP Shells to make salutes. We strongly recommend against this practice. While RAP shells are made of high impact polystyrene, they are still somewhat brittle and when shattered (broken explosively) sharp fragments will be produced. We very strongly recommend against using RAP Shells to make salutes and will not knowingly sell them to people intending to use them in that manner.

Accessory Products

When RAP Shells were introduced, it was indicated that eventually a series of accessory products would be made available. Some of these items (shell labels and leaders) are now available. Accessory tubes should be in stock by about the time this article appears. (Accessory tubes are a series of different sized tubes designed to mate with the various convolutions on the end caps. Their use will allow the easy attachment of flash bags, comets, colored cores, and small salutes to RAP Shells.)

Easy Damage to Fuse Ring

The small ring attached to the top of the RAP shell to hold the small leader in place can be easily damaged shortly after it is installed. There are two reasons for this. First, the fuse ring often becomes coated with TMC when being prepared for attachment to the ring. The methylene chloride dissolves into the ring and while present, results in a substantial weakening of the ring. The solution to this problem is to allow the fuse ring to dry thoroughly before attempting to



thread the shell leader through it. Second, the fuse ring originally was made too thin to provide sufficient strength. This problem has been solved by redesigning the ring so that it is now twice as strong.

Caution with Paper Mortars

In our testing of randomly selected, normally lifted RAP shells, we have fired 136 three-inch shells and 61 four-inch shells, and have never experienced a flowerpot (shell failure inside the mortar). However, when using RAP shells in our commercial displays, we observed several percent of the shells to flowerpot. These events were puzzling because the same shells never failed during tests. The problem was traced to our paper mortars, which had seen a moderate amount of use and were slightly torn on the inside surface. They were still successfully launching spherical shells but were causing cylindrical shells to occasionally jam when fired from them. (In our testing, only steel and high density polyethylene mortars, with smooth interiors, were used.) RAP shells do have a rounded upper edge, but not nearly so rounded as a spherical shell. Thus, if paper mortars are to be used successfully, they must be inspected and damaged mortars must not be used.

Conclusion

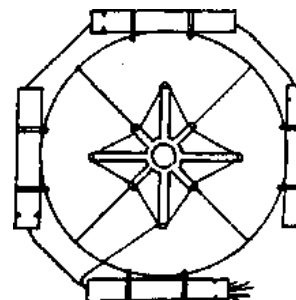
I have been surprised by how quickly and effectively people have learned the new technology of plastic shell construction. RAP shells can be assembled in a small fraction of the time required for paper/string shells and they can be made to perform approximately as well. We have had a good deal of feedback on the RAP Shells and while some have expressed concern about plastic debris, there has been only one person expressing a strong preference for using traditional techniques. I am certain that, of the shells made in this country, plastic shells will become the most frequently made shells in the very near future. Amateurs can easily make effective shells and professionals can significantly increase their all-too-narrow profit margins. In fact, because of improved fire safety (the lack of burning fall-out), some countries (e.g. France) are reported to have banned the use of any aerial shells that are not made entirely of plastic. KK

MORE ON WHISTLE MIX BURST

In a previous article on plastic shells (*The Ascent of Plastic*) I discussed how the whistle comp burst charge was placed in the shell. The method I suggested placed the whistle comp burst load on top of the cross matched fuse and then packed with meal coated rice hulls.

I made up a series of 10 shells in which a small piece of kleenex tissue was placed over the whistle comp powder and then meal coated rice hulls were packed on top. The tissue prevented any mixing of the rice hulls with the whistle comp. This slight modification, which is essentially a flash bag filled with whistle comp., changed the burst drastically. All the shells opened with a very weak pop with very poor star ignition, especially the stars in the hemisphere not containing the fuse. It appears to be essential to have the quick lighting meal hulls ignite the slower igniting whistle comp and not vice-versa. It doesn't seem to make a great deal of difference in the break if the whistle comp is premixed with the rice hulls before loading or just dumped in near the fuse. The whistle comp will naturally distribute itself throughout the shell interior.

I found that 10 gm of potassium benzoate whistle comp is fine for 5" plastic but 7 gms seems more appropriate for a 4" plastic shell to keep it from breaking too hard. One reader told me that he uses many teaspoonfuls of whistle comp in his six inch plastic shells to good effect. As usual, one must try various burst strategies to produce the desired effect. DB





AN EASY 4-INCH CHRYSANTHEMUM SHELL

Pyrotechnicians interested in achieving a round burst usually employ the ready made yellow strawboard pressed hemispheres imported from Japan. The preparation of these shells is quite straightforward. A piece of time fuse is glued in, stars and burst charge are added to both hemispheres, and the two hemispheres are joined. The shell is finished by wrapping with kraft paper soaked in wheat paste. This type of shell cannot create the perfect radial symmetry obtainable with a chrysanthemum. The shell always breaks along the line joining the two hemispheres because that is the weakest part. The result is a "donut" shaped spherical burst with the two hemispheres falling to the ground. The hemispheres used with a chrysanthemum are much thinner than the Japanese hemispheres and more layers of pasted strips are used on the outer wall. This causes the shell to break into many small fragments. The "secret" of the chrysanthemum's symmetry resides in keeping the thickness of the unpasted hemispheres a small fraction of the total outside wall thickness of the shell.

The construction methods for single-petalled chrysanthemum shells have been published previously. The following description entails modifications which should make it easy for the beginner to achieve a quality shell the first time.

To make the outer hemispheres, I start with two 4" Japanese strawboard hemispheres. I stretch a piece of thin, clingy plastic wrap over them, then tape down or twist the wrap tightly to keep the surface of the wrap as wrinkle free as possible over the spherical surface of the shell casing. I cut a medium weight grocery bag into strips 1" wide by 4" long, and brush with white glue (or soak in wheat paste) and paste on the surface in parallel rows so that the edges of the strips extend over the edges of the hemisphere slightly. I keep the strips close together to cover most of the hemispherical area but without excessive overlapping of the ends. Now I apply a second layer of strips at an angle to the first, then repeat with a third layer. I smooth the surface by rubbing the hemisphere on a hard surface. When dry, I pull the plastic wrap from the hemisphere. Then I put the thin hemisphere back on the Japanese hemi-

sphere and press it down for a good fit. I trim the excess strip ends around the edge of the hemisphere with a sharp razor blade so that the two hemispherical edges are flush. Then I drill a hole in the bottom of one hemisphere and glue in a piece of time fuse with epoxy.

The hemispheres are filled with stars on the inner wall surface only. Contrary to popular belief shell makers CAN use pumped stars that are 5/16" in diameter and 5/16" long provided they are placed standing up on their ends. I use pumped or 5/16" to 3/8" diameter round stars made by the technique outlined by M.B. elsewhere in this book.

Now a set of inner bag hemispheres can be prepared. Some workers just push a circle of tissue paper in the filled hemispheres and load with meal powder-coated rice hulls, but the excellent fit obtained by using an already formed bag keeps the stars in their place more securely. I simply take four 3" Japanese shell hemispheres and tape them together at their joints to make two spheres. I stretch a piece of plastic wrap completely around each sphere, twisting it tightly together at the bottom. Now I take a circle of quality tissue paper and brush a thin coat of White glue on it. Good tissue paper will not rip to shreds during pasting. Then I stick this down over the plastic wrap, making it conform to the spherical shape so that 2/3 of the surface is covered. I let it dry and peel off the bag. The inner bag will now fit inside the large filled hemisphere perfectly. Then I cut the top of the bag into strips, fold them over the stars and tape to the outside of the shell with thin tape. One bag will need a hole punched in the bottom so it can slide over the fuse. I cross match the fuse and fill both bags with meal-coated rice hulls to the top.

To assemble the shell, I place a 4"x4" square of thin cardboard over one hemisphere and flip it upside down. Then I place it carefully over the other hemisphere, lining up the edges and slowly pulling the cardboard out. A piece of masking tape can be used to seal the joint.

The shell at this point is thin and must be handled carefully. I cut some 1-3/8"x4" strips



from extra heavy paper bags or kraft paper and brush white glue on six of these strips and paste them symmetrically around the shell in a vertical fashion. Wheat paste can be used but Elmer's glue dries faster and is more suitable in the author's very humid climate. I gently roll the shell on a hard surface to smooth the strips down, then allow to dry completely. Then I apply three more layers of strips, changing the axis of the strips by 90° with each layer. The object is to create a wall of uniform strength in every direc-

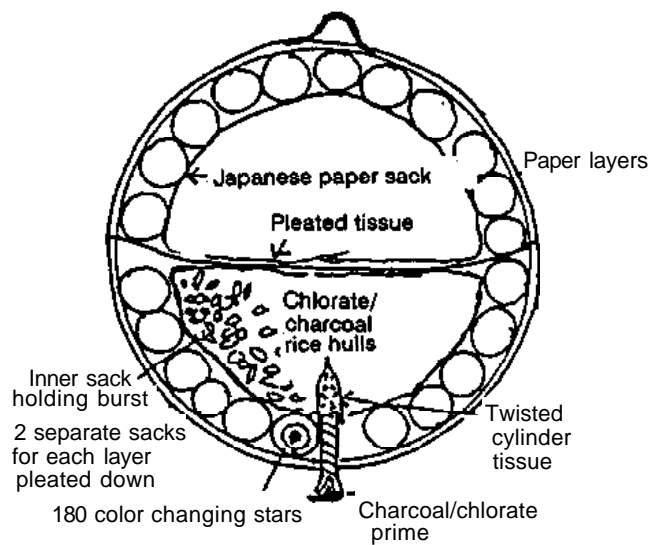
tion. I let it dry again and apply another five layers. The exact number of total layers will depend on the thickness of the kraft paper used. The finished diameter should be about 3 3/4". I usually put a loop of string on the top and attach a thin cardboard cone holding the lift charge to the bottom in the usual manner.

This technique produces a less expensive product with increased performance so I don't mind the small amount of extra effort at all! DB

JAPANESE SHELL DISSECTION

An AFN reader, M.L., took apart a Japanese 5" Round Reddish to Gamboge Green Flickering Chrysanthemum shell and asked me to report his results. The paper thickness used in the final wrap was 30 lb. Japanese paper strips measuring 2 x 4 1/2" in roughly 16 layers. The base hemispheres were the usual 4 1/2" Japanese paper hemis. The burst consisted of rice hulls heavily coated with a chlorate/charcoal (H3) mix. The round stars were 1/2" in diameter. M.L. dissected them and they appeared to be nitrate based red and green comps with a common flitter core. Cross matching was the common Japanese split fuse and primed with chlorate/charcoal instead of the common BP prime!

When opened, each hemisphere had its own separate bag of burst which was wrapped in fine Japanese tissue. Each wrapper was 8x8". The lift was apparently 3FA. The total weight of stars was 10 oz., with 6 oz. of burst. Length of time fuse was 1 1/4" with a bag of 2FA at the end (see diagram). DB



ONDA BRAND 5" shell



THE CHARCOAL BALL SHELL

This unusual shell was first brought to my attention in Dr. Shimizu's book, *FIREWORKS, The Art, Science & Technique*. The shell is composed of a small Japanese round shell which is coated with a thick layer of a fast burning charcoal or willow star composition. As Shimizu states, the effect produced is very pretty indeed. The shell functions as a huge charcoal-tailed comet star which breaks with a spherical burst near the apex of its flight. Its close relative is the comet shell which is familiar to most western pyros. The comet shell consists of a canister star shell fitted to a large comet star. The effect is different from that of the charcoal ball shell. The spark trail of the comet shell spirals upwards from the rotation of the combination.

The tricky part in the construction of these shells is the process of layering the comet composition which uses starch as a binder and water as a solvent. The coating has a tendency to crack when drying and the shell must be wrapped with twine during the coating process to help prevent this problem. Also the shell fuse can easily fail from water soaking into it during the process. The method presented here avoids these difficulties by using nitrocellulose lacquer as the binder (NC lacquer).

I started small with a set of 2" Japanese shell hemispheres. I cross match one end of a 1 1/2" piece of Japanese time fuse, then mark the fuse 1" from the cross match and glue it in the bottom of one of the hemispheres. I make sure the 1" mark is on the outside of the shell about 1/8" from the wall. I fill each hemisphere with stars and about 5gm of meal burst. I join the two halves with a piece of masking tape, then uniformly paste three layers of 3/4" x 2 1/2" strips of 60 lb. kraft paper on the shell and allow to dry.

The selection of a streamer composition coating is the next consideration. It is highly recommended that compositions with a total metal fuel content over 12% be avoided because their very high combustion temperatures are capable of burning through the shell wall. I like to use the following modification of Weingart's comet star mix:

COMET STAR MIX

Potassium nitrate	6
Meal powder	6
Sulfur	1
Charcoal	3
Antimony sulfide	3
Titanium (50 mesh)	1

I take a 12" length of thin strong twine and tie a knot around the fuse between the wall and the 1" mark. I cut the excess length of fuse off above the knot with a sharp razor blade. I find a wide-mouthed jar of at least 3" diameter and about 4" deep. I fill about one-half full of NC lacquer. I try not to get the string wet with lacquer as I lower the shell into the lacquer. Then I raise the shell out of the lacquer and allow the excess to drip back into the jar, then drop the shell into a ceramic mixing bowl, while holding the string. The bowl contains about 50 grams or so of comet composition. I roll it around until completely coated with dry comp. I don't let the string drop in or it will coat itself to the shell! I pull the shell out by the string and give it a 30-second treatment with a hair dryer set on LOW heat, being sure the area is well ventilated. Then I repeat the whole process again for the next coating, stopping when the shell gets about 2" in diameter. I allow it to dry overnight. I don't try to coat the shell all in one operation as the coating may sag too much during drying. The next day I bring the diameter up to about 2-5/8". The end of the fuse is now buried under the composition coating and the end of the shell is likely to be somewhat pointy-shaped around the fuse. I usually take a hack saw and carefully saw around the string until I cut off a slice that exposes fresh fuse. A coping or jeweler's saw may be best for this job. I allow the shell to dry for a week.

I should mention that the trouble taken to expose the fuse is necessary to achieve proper burst timing. The coating itself is capable of igniting the fuse but the shell would burst after the coating burned out. Naturally, with this shell one cannot attach a lift charge and it is easy to overestimate the lift charge because of the added contribution of lift gases from the shell itself. DB



MULTIPLE BREAK SHELLS

CONSTRUCTION OF A 4" 3-BREAK COLOR SHELL WITHOUT RAMMED TIME FUSES

The story that follows is not a how-to-do-it recipe but a detailed story of how one shell maker produces multi-break shells for the trade. The author specifically discourages others from experimentation with this technique.

Three shell casings are made on a 3 1/2" casing former. The casings are all made with four or five turns of 75-lb. paper. The paper is cut wide enough so that each can be 3" tall, with enough paper to pleat down at least 1" on each end of the can when it is closed. The first casing is made on a solid end disc. On the second and third casings, the casing is formed on a disc with a 1" center hole. The paper is glued and pleated so that no paper obstructs the 1" center hole opening.

Two turns of either .025 or .035 thickness chipboard are placed inside the casings. The chipboard is 3" wide and is backspun tightly into the casing. Chipboard in an aerial shell serves three important purposes. It gives the shell better overall structural integrity, and it prevents the inner shell wrap from catching fire when the shell bursts. I don't know how many times I've seen shells made by the Eastern shell makers (who advocate no chipboard) spew forth great myriads of burning 75-lb. paper when they burst. One of the basic characteristics of a high quality aerial shell is that it has no burning fallout of any type. For multiple break shells, .035 chipboard seems to give the best overall performance, although the .025 chipboard is a little easier to work with.

The first casing, with the solid end disc, is placed upright on the workbench. A thin wall tube, with an outside diameter of 1 1/2" is centered in the shell casing. Stars are placed around the outside of the tube. Star size for a 4" shell is not generally more than 3/8" in diameter. The sides of the shell casing are tapped gently to consolidate the stars. 2FA unglazed powder is then poured into the center tube. The tube is lifted from the casing, forming a central core of gunpowder in the stars. Great importance is placed on the tight packing of the individual components in each casing. Discretion is advised when compacting certain types of stars. Par-

ticularly sensitive are chlorate stars mixed with glitter stars that contain antimony sulfide. The stars should be well consolidated and should be packed slightly higher than the chipboard liner. An extra measure of 2FA gunpowder is poured over the top of the stars to fill in any space between them.

There are two types of end discs available: light and heavy. The light discs run between .035" and .080" thickness. The heavy discs run about .120" thick. The best end discs to use with Japanese time fuse are the light ones. Thinner discs allow the Japanese time fuse to be crossmatched at short intervals. This is important as the Japanese fuse has to be crossmatched at intervals between 1/2" and 3/4" between the breaks in a multiple break shell. This results in timing intervals of between 1 1/2" to 2 seconds. Timing intervals closer to one second are preferred but this is achieved only with rammed time fuse of spoolettes. Spoolettes are time consuming to produce and seem to require a certain amount of acquired skill so they will be omitted in this article. Three pieces of 1/4" Japanese time fuse are cross punched approximately 1/4" from one end. The fuses are about 1 1/4" from the cross punched hole for a timing reference. A piece of 4-ply match is placed in the hole and the fuse is lightly crimped down onto the blackmatch, with a pair of pliers. The time fuses are threaded through end discs that are no more than .080" thick and have center holes of 3/16-inch. The center holes have to be reamed slightly. The fuses are pulled through the discs until the blackmatch is touching the disc. A disc and fuse assembly is placed onto the stars with the blackmatch facing stars. The disc is tamped down on top of the stars to consolidate the contents. One turn of paper is sometimes torn from the inside of the shell casing. This is the portion of the paper above the top disc only. This technique is done to minimize the layers of paper between the breaks. The paper is then glued and pleated down over the disc. Extra glue is applied around the fuse to prevent gas leaks. Another disc, no thicker than .080 is placed over the fuse and onto the pleated paper. The disc is tamped down to keep the shell



THE BEST OF AFN II



compacted and to compress the discs and paper. The shell is then strung with two pieces of 8/6 Long Staple Twine. Twelve vertical strings are placed on the shell. Care is taken to minimize string build-up around the time fuse. For best results, the time fuse is cross-matched below the 3/4" timing mark. The string is tied off around the fuse with a reverse close hitch.

The time fuse is cross punched just above the string. The length between the blackmatch, on the inside of the shell, and the new fuse hole should be no longer than 3/4". Half-an-inch between the cross matching is even better. A 3/4" piece of 4-ply match is inserted in the fuse hole and the time fuse is lightly crimped onto the blackmatch. A piece of 8-ply blackmatch that is 6" long is bent in half to form a V shape. The 8-ply match is placed next to the time fuse with the crotch of the V under the 4-ply cross match at a right angle to the cross match and parallel to the time fuse. The 8-ply match is then tied firmly to the time fuse. These two pieces of 8-ply match protrude up into the next shell to help insure fire transfer to the small 4-ply cross match. The 8-ply match also effectively increases the surface area of the cross match, exposing more match to the flame inside the shell. Fire transfer between shell breaks is most important and sometimes two pieces of V shaped match are tied on either side of the time fuse.

The second shell casing with a 1" hole in the bottom disc is placed over the top of the completed shell. The blackmatch extends upwards through the 1" hole. The casings are aligned and taped together. The second break is then loaded, closed and strung individually to the first break. A second set of twelve vertical strings is layered between the twelve vertical strings on the first break. The first break now has twenty-four evenly spaced vertical strings and the second break has twelve. The time fuse is cross matched at less than a 3/4" interval, and the 8-ply match is tied on to the time fuse like the procedure for the first shell break.

The third shell casing is then positioned on the top of the first two breaks, aligned and taped. Again, the last break is loaded similarly to the previous breaks with two exceptions. On the last break, a smaller tube is used for the blackpowder

core. The outside diameter of the final core tube is 1 1/4". The last completed break is the first to burst. The first break of a multiple break shell is the only break that gains strength from the pasted paper. After the first shell break explodes, the pasted paper is partially torn off the remaining breaks. The remaining shell breaks rely on the string and strength of the shell casings only, to maintain a large bursting radius. Consequently, if the 1 1/2" size core is used for all the breaks, the first break will be unusually powerful and sometime will result in poor star ignition.

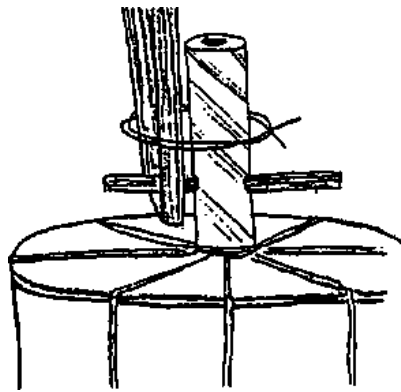
The last break is strung with eight vertical strings. Instead of tying the string off around the fuse, the string is passed down the side of the shell in an arc towards the bottom. Two complete turns are made around the bottom. The string is wound upwards, making squares. Extra string is layered at the joints, between the breaks. The theory is the extra string at the joint, keeps the string from tearing past the joint when the previous break explodes. The idea is to keep as much string around the secondary breaks as possible. The string is tied off at the top of the shell.

The shell is now ready to be paste-wrapped. The paste-wrapping is done in two stages. Four turns of pasted 40-lb. paper are wrapped around the shell. The paper is cut so that when the paper is torn and folded down over the ends of the shell, it folds all the way across the bottom of the shell, but only halfway across the top or fuse end of the shell. This is done on the first four paste-wraps to prevent the build up of paper around the time fuse. After the shell is dry, four additional paste-wraps are applied. The width of the paper for the second paste-wrapping is wide enough so that the paper will fold down across the entire length of both the top and the bottom of the shell. Five additional tears are made in the paper on the fuse end of the shell to layer the paper around the fuse. The ends are smoothed and the shell is thoroughly dried.

After the shell is dried, the time fuse is cross punched at the 3/4" timing mark and a four-ply piece of match that is approximately 1 1/2" is inserted in the hole. The blackmatch is set in the time fuse with a light crimping. The shell is now ready to be lifted. At this point, the shell can be lifted with the fuse end of the shell either up or



down. Despite information to the contrary, shells constructed in this method are usually lifted with the timed fuse directly in the lift. This saves time in the finishing process and I have seen many thousands of shells lifted in this manner that have functioned flawlessly. However, I do not advocate this technique as the only way to lift a shell. If the shell is poorly pasted, it would be better to lift it with the fuse facing upwards, in the traditional style. Please note that the word traditional should by no means be confused with the word functional.



Multiple break shells made with Japanese time fuse take a larger lifting charge than shells made with rammed time fuse. This is because the duration between the shell breaks made with rammed fuses are generally short (about one second) and the overall time the shell is in the air is short. Multiple break shells made with the Japanese time fuse have the limitation of having a relatively long duration between breaks (about two seconds). This is a result of not being able to get timing intervals of less than 5/8" out of the Japanese fuse. The longer the interval between shell breaks, the longer the shell has to stay in the air, thus more lift to send the shell higher. Three to 3 1/2" ounces of 2FA unglazed powder is used to lift a 4", three break shell employing Japanese time fuse. This lift is on the generous side and is calibrated to be fired from a 24" long steel mortar that is exactly 4" i.d.

Multiple break shell manufactured in the style I have described function surprisingly well. They are simple to construct, reliable and function well without the use of rammed time fuse. The bursting radius of shells made in the this style is large and consistent. The performance of these shells is definitely exhibition quality. WP

TIPS FOR PASTING ROUND SHELLS

B.V. has submitted to me some of his improved pasting methods for round shells that I will pass along. They produce a professional looking round shell.

He uses the thin walled kraft paper hemispheres made according to the method I have previously described. I usually paste my shells with strips of 50 lb kraft with slightly diluted white glue smeared on them. I have avoided starch or wheat paste because the high percentage of water soaks through too much, making the shell almost mushy to the touch. He solves this problem by brushing Thompson's Water Sealer on the outside of the shell before pasting. He allows the shell to dry overnight and then applies strips pasted with a starch paste containing a little white glue. After slapping on 3 layers he puts the shell in a thin plastic bag and rolls it on a table to smooth the layers out. The use of a tightly wound plastic bag avoids getting paste on the table during the smoothing process and prevents strips from sliding or peeling off the shell as it is rolled. Then for a professional appearance he sands the outside of the shell with 80 grit sandpaper after each series of 3 pasted wraps has dried.

I recently made a pair of intersecting ring shells, one by his method and one using my white glue method. The shell made using his method was very round and smooth indeed. I hated to fire it! Unfortunately the rings produced when the shell broke were more distorted than my shell for some reason! More testing is required over a long time period to determine the importance of wall uniformity in round shells using whistle comp break charge. B.V. and other pyros feel that white glue is not a good paste for shells as it does not dry as hard and brittle as the customary wheat or starch paste. The use of rapid burning whistle comp burst charges may tend to offset these negative factors. DB

BURST CHARGES FOR ROUND SHELLS

I. HULLS OR NO HULLS?

The common practice in designing burst charges for round shells is to coat the burst composition on the rice hulls. It is important to bear in mind that the use of rice hulls is not essential. The burst composition (containing 3-5% dextrin) can be granulated by adding 12-18% water and pushed through a 12-15 mesh screen. It takes a little practice to find the correct percentage of water to add to the burst comp. Too much water will result in sticky, rod-like masses coming through the granulation screen. An underdamped mix will push through the screen with ease but will contain too many small, easily crumbled particles after drying.

The main reason why I don't use granular burst charges is that they are inefficient compared to rice hull burst. Compositions with a slow to moderate burning rate made into granules will continue burning after the shell breaks. This is because the thickness of the composition is too great in the granule. The thickness of the burst composition can be better controlled by pasting it on rice hulls. The thickness of the coating is controlled by adjusting the ratio of the weight of the hulls to the weight of burst composition.

The importance of the use of rice hulls becomes apparent as the shell size increases. For example, a 4" shell will perform very well with granulated H3, giving a more powerful burst than with rice hulls. A 5" shell employing the same burst would likely shatter the stars as the large quantity of H3 in it would make the device resemble a salute more than a shell. A granulated perchlorate-/charcoal burst would perform better in the 5" because of its slower burning speed but much of the burning would continue after the shell breaks, thus wasting part of the burst charge.

II. FIRST BURST

H3, the chlorate/charcoal burst pasted on rice hulls, is a good place to start. It is cheap and easy to prepare. But many readers seem to be perplexed on the correct procedure. Here's how I do it. It is possible to add the dry hulls to a slurry of burst composition and water or to add dry

burst comp to the wet hulls. Being more comfortable with the latter method I will discuss it in detail. The first thing to determine is the ratio of H3 composition to hulls. For a 4" shell I recommend using a ratio of 4 parts H3 to 1 part hulls (by weight). Then I dump the weighed quantity of rice hulls in a plastic cake pan and fill with water. After allowing 15-20 minutes for the hulls to become thoroughly wet, I dump the hulls in a colander and drain the excess water and letting them stand for a few minutes. Then about one-third of the weighed quantity of H3 is added to the hulls in the cake pan. The top is snapped on and I shake, rattle and roll for a minute or so. Then I open the cake pan and scrape the sides with a spatula to break up any lumps.

Then I add another 1/3 increment and repeat the procedure. After I add the last increment I usually will note the presence of loose or partly damp powder around the hulls. I spray water from a plant mister directly on the hulls in the pan and continue stirring and shaking. The object is to keep spraying and stirring until the hulls have a shiny black smooth appearance and the individual hulls will still separate from each other with no large clumped masses. The hulls are then dumped in a large shallow tray for drying. If the hulls are properly prepared the coating of H3 will adhere easily with a minimum of dust and powder falling off the hulls when they are shaken.

III. MEAL HULLS

Meal powder, homemade or commercial, can be used to coat rice hulls, giving a burst that is somewhat effective in 5" shells with a greater than usual wall thickness. They perform best in shells 6 inches or larger. Meal hulls should have a ratio of 5 parts meal to 1 part hulls. If the previous procedure is followed it is not unusual to find that after addition of the last increment of meal powder, an unusable slurry of overwet hulls has resulted. The high solubility of potassium nitrate in water is the culprit. The best thing I can do in this situation is to allow the hulls to partially dry over a day or so with occasional stirring until the desired dampness is achieved. To prevent the problem from happening, I find it



best to allow the damp hulls to drain for a longer time before adding the meal powder.

think about adding flash powder to H3 hulls) when they are placed in the shell hemisphere before final assembly. The mix:

IV. PERCHLORATE BURST

For 5" shells or larger, a burst charge using perchlorate is recommended. It has a slower burning rate, so shell detonation is less likely. Here is the rule: as the shell size increases the burst density and the burst burning rate should decrease rapidly. For 5" and 6" shells I have used a simple burst mix using potassium dichromate instead of sulfur to increase the burning speed. This formula is what Shimizu calls #44 burst:

Potassium perchlorate	7
Aluminum bright	3
(never alum, dark or German alum.)	
Sulfur	1

I find that about 4 to 5 gms of homemade, ball milled black powder on the rice hulls is needed for a 4", and 10 to 12 gms in a 5". This makes for a very cheap flash burst system.

#44 BURST

Potassium Perchlorate	75
Charcoal, air float	25
Potassium dichromate	5
Dextrin	3

I think that the best method is to apply the flash powder directly to the rice hulls using a rather slow flash comp that will moderate the burst energy and prevent making salutes instead of shells. My tests of flash hulls indicate that I can get a wide symmetrical burst while reducing the number of pasted layers by 30%. The maximum ratio of powder to hulls is about 3:1. It will take a little practice to achieve the correct amount of dampness of the pasted hulls before drying. My first hulls were nearly dustless and a joy to use but they did not burn completely before the shell opened. Still, the burst intensity was greater than #44 or H3. However, the glowing rice hull particles hanging in the center of the burst were unacceptable. Properly finished hulls should be somewhat dusty, with up to 10% of loose flash powder which can be sifted out before using. I recommend allowing the water soaked hulls to drain for about 4 - 5 minutes before addition of flash. Particles of aluminum bright fly around when packing the burst so I make wearing a mask mandatory.

D.Z. FLASH BURST

Potassium Perchlorate	3
Potassium Nitrate	3
Barium Nitrate	1 1/2
Antimony Sulfide	1 1/2
Sulfur	2
Aluminum bright	3
Dextrin	1

V. FLASH BURST

Recently advances have been made in the use of flash powder as a burst charge in round shells. Flash bags in canister shells have been in use for many years. A properly designed round shell employing a slow burning flash as a burst charge can give a good, wide, symmetrical burst with a significant reduction in the number of pasted layers used in the shell wall. Flash powder can be applied directly to the meal hulls (don't even

In the table below are my suggestions for burst charges in small round shells. I do not use standard strawboard hemispheres but use homemade, kraft paper hemispheres (4 layers of 40 lb paper in 4"; 5 layers in a 5" set). DB

RATIO OF BURST COMPOSITION TO HULLS AND # LAYERS OF 40 lb. PASTED WRAP.

Shell Size:	H3	#44	Meal	Flash Hulls
4"	4-5:1 /4-5 wraps	don't use	don't use	3:1 /9 wraps
5"	3:1 /5 wraps	4-5:1 /17 wraps	4:1 /17 wraps	3:1 /13 wraps
6"	don't use	4:1 /20 wraps	4:1 /20 wraps	2.5:1 /15 wraps



USING BRIGHT ALUMINUM FOR BREAKING SHELLS

Bright aluminum is often overlooked as pyro's head for the scales. But it can be used to make flash bags just as with dark or pyro aluminum. I picked up several pounds of this aluminum quite inexpensively and wanted to put it to use. It is pretty messy stuff for stars, so I decided to experiment with flash. I mixed quite a bit for use last year and did find it useful. Just as with flash, the formula is very forgiving as to percentage of ingredients. My formula was (approximately):

Bright aluminum	20%
Dark german aluminum	10%
Potassium perchlorate	70%

It is possible to go with a typical 70/30 mix and leave out the dark aluminum and it will burn just fine. I think that titanium may be added to this mix as desired; I use a lot. As the dark is added, a more potent formula develops. My desire for this mix was to generate some good flash bags, but not create the noise of salutes. Note that as the volume is scaled up, the dark aluminum can be decreased. What is fine to break a festival ball-sized item may be much too powerful for the desired effect in a tightly wrapped 3" or 4" shell.

My first use was as a burst in 1 1/2" small plastic shells with some small stars that needed a gentle burst. I used a single layer of the all plastic version of duct tape to seal the shells. These were launched inside a standard 4" shell with a mild 2FA burst. When these break they give a flash and will ignite the stars.

I rolled some light paper tubes about 1/4" i.d., sealed them on one end, filled them with this mix, and fused with an inch or two of bare quick match. These were stuffed in a long 4" shell along with some crackers for packing. I got a bright flare heading toward the ground. Coarse Ti in this will help the trail. I found that this is best launched over water, or something that won't

burn! I experimented with the tubes on the ground to get the mix correct.

I constructed some 4" shells using some less than spectacular meal powder-based stars as a filler and then added a lot of this mixture, and a handful of coarse titanium. This is about as cheap and easy as a salute to construct. I got a really nice flash along with some noise, but, of course, nothing like a 4" salute would produce. This may represent a good compromise when trying to keep peace with the neighbors.

A few cautions: This stuff is messy, ranking right in there with lampblack. A small amount is all that is necessary to become airborne and cover everything in sight. Like all flash comps, it is very powerful, so I use great care. DM

CHEAP-CHEAP STORAGE CONTAINERS FOR SMALL BATCHES OF STARS

How's about a storage container for each of those different batches of stars you've just made? A container, say, big enough to hold a few pounds? Water tight? Transparent? Easily labeled? Lightweight, preferably plastic with a snap or screw-on lid? And you say you want a dozen of them — for free? Well, OK then. Take a trip to your friendly neighborhood liquor store and ask if they wouldn't mind setting aside the empty plastic beef jerky jars for you. I did, and when I came back a week later, I had over a dozen "field expedient star containers" waiting for me. They were only too glad to get rid of the things. The lightweight jars work great for temporary storage of stars. The labels come off easily when soaked in hot water. SC



WHAT ARE FLASH BAGS

Flash bags (ugly words but quite descriptive) are used by shell makers to blow their shells apart. There are several methods of bursting shells and this is one. It is by no means universally accepted. Use of this method usually requires heavy cases and thick end discs. Shell makers are still working out flash bag systems and we should see a lot of experimentation before the method is fully accepted.

I am convinced that one is wasting 2FA and his time by making small shells without flash bags. Practically every flash bag maker has his own method and filling. I've done a lot of experimenting and this is the method that has worked best for me. After much testing of compositions, I found that:

Potassium perchlorate	70
Dark aluminum	30

gives me consistently good results. Now to the bag.

My method seems time consuming but it works. Here's what I do. I take enough 30-lb. kraft paper to wrap around a 3/4" dowel three times, pasting only the last turn. For a 3" shell I make a mark every 3 1/2" along the paper tube, while it is still wrapped around the dowel. This is where I will cut it off later. I cut a piece of 1/4" Jap time fuse about 1 1/2" long and crossmatch one end. Then I push the dowel so that about 3/4" of paper is above the dowel. I insert the fuse and tie it in with waxed twine about 3/8" from the top, then smear some white glue on the paper and twine, after trimming the twine.

I pull the dowel down enough to cut the bag at the mark previously made at 3 1/2". I repeat this process until I have enough bags made with fuse tied in. The next step is loading the composition. I place 1/2 teaspoon of rice hulls (coated with Meal D) into the bag, then 1/2 tsp of flash, a tsp of hulls, a final 1/2 tsp of flash and then fill to within 1/2" - 3/4" with rice hulls. I then close the bottom by twisting shut and tying or taping the bag closed. Finally I shake the bag gently to mix the flash and rice hulls together. The flash bag is complete but how is it used?

Flash bag shell bursting requires a strong case - that's the secret of flash bags. Starting with a very strong case and loading from the bottom up, I insert the bag in the case with a few stars on the bottom and then add stars in whatever sequence is needed. I don't put a disc on the bag until it is resting in the shell casing on top of, surrounded by and covered with stars. While pasting liberally, I put the disc on the fuse, close the casing over the disc, paste the paper, cover with another disc and complete by taping that disc to the casing with filament tape. It is not always necessary with 2", 3", and 4" shells but you can paste in now with at least two turns of heavily pasted 70-lb. kraft. Match and finish as usual. That's all there is to it and think of all that 2FA saved.

Here are some random thoughts about flash bags. I have found it much better to use rice hulls coated with Meal D. In very dry climates one might get by with sawdust but it is more dangerous with sawdust because it will suck moisture out of the air. Some experienced flash bag makers use bran. I find rice hulls very cheap and easy to obtain.

To coat them with Meal D, I soak them in water for about a half hour, drain and shake off the excess water, then spread the wet hulls on newspaper and sprinkle with Meal D. I shake the paper and sprinkle more Meal, and shake and sprinkle until the hulls are heavily coated. I dry them in the sun.

There is as much variety with flash bags as there are pyro users. I know one shell maker who uses a 1" bag for a 3" shell. Another just dumps flash composition in with the stars and the entire shell becomes a flash bag. Another uses whistle composition instead of flash. Another experienced operator just reported that he has settled on a uniform 7/8" bag using several nitrates, aluminum and sulfur, with no perchlorate.

I don't know if any one way of making flash bags is better than another way. All I know is that this method worked for me and it has improved my 3" and 4" shells greatly while saving me money on black powder burst. JCB

FLASH BAG SHELL CONSTRUCTION

There are many variations of formulations and manufacturing techniques for making flash bag type shells, all of which are of particular interest these days because of the high price and diminishing availability of black powder to burst shells. The technique offered is not necessarily the only way to achieve a good effect from a flash bag. This is but one method currently being employed to manufacture shells in several shops across the United States.

It should be noted at this point that there is no safe way to manufacture fireworks. One can only limit his or her exposure to such dangerous devices. Terrible accidents have happened with seemingly harmless mixtures and devices. There are recorded incidences of finely divided aluminum powders detonating or catching fire without the aid of any oxidizer, other than the air surrounding them. Firework plant explosions happen, even under the supervision of trained experts. The only absolutely safe way to handle fireworks is not to handle them at all.

Anyone experimenting with pyrotechnic mixtures and devices is taking his or her life into their own hands! They should realize this and accept the responsibility.

The material that follows is not a "how-to-do-it" article. I am merely relating in detail, observations I have made and take no responsibility for the material contained herein.

Hopefully, most readers will be at least vaguely familiar with some of the basic materials and construction techniques involved with aerial shell production.

There are several things to take into consideration when making flash bag shells. One thing is that a flash bag shell emits an initial bright flash when the shell opens. This is of no consequence if the right type of stars are used. The shellmaker must pick stars that are heavily primed and fast lighters. Glitter and Streamer stars work particularly well with flash bags. Perchlorate color stars work well if they contain at least 3%

airfloat charcoal and are heavily primed. Chlorate color stars work very well but I *adamantly advise against the use of chlorates by anyone who is not fully aware of the properties and handling techniques.*

One of the other considerations when making flash bag shells is that the materials involved may vary between different manufacturers. Variations may also occur between different batches from the same manufacturer. So it is sometimes necessary to modify the manufacturing techniques or formulations to accommodate the situation at hand. For instance, with unusually coarse chemicals or crude mixing techniques, the flash bag will be weak. To compensate for this the shellmaker must either increase the volume of flash powder or make the shell casing stronger. The casing can be made stronger by additional string or more layers of pasted paper. If the flash bag turns out to be particularly strong, the opposite is true; less string, less pasted paper, or less powder in the flash bag.

Included in this article are two charts showing formulations and dimensions for flash bags.

FORMULATIONS

Please remember that any pyrotechnic mixtures containing finely divided metals and any type of oxidizer is considered extremely hazardous. The hazard is increased with the addition of sulfur. Don't dismiss these formulations as innocuous simply because they have nitrate oxidizers. They can be quite devastating even in small quantities. Flash powders should ideally be mixed by remote control and handled as little as possible.

SOME BASIC FLASH BAG FORMULAS

	#1	#2	#3
Potassium nitrate	29	29	31
Barium nitrate	29	29	31
Aluminum, #809	28	~	19
Sulfur	14	14	12
Antimony sulfide	~	~	7
Aluminum, German Dark	~	28	~

Formula #3, with the addition of antimony sulfide, seems to have slightly better star ignition than Formulas #1 and 2. Formula #2 will often work well if #1 is found to be too weak.

The barium and potassium nitrates are passed through a 40-mesh screen by themselves onto a sheet of paper. The screen is then removed and shaken to free any remaining coarse particles of oxidizer. The sulfur and aluminum are then sifted onto the oxidizers and mixed thoroughly with the hands. On successive screenings, after the fuel and oxidizers have been combined, the last remaining particles left in the screen are thrown out rather than forced thru the screen. The mixture is then passed through the 40-mesh screen two additional times. It is important that a thorough mixing takes place to insure consistent performance.

THE BAG

The bag itself is made by rolling two turns of 30 basis or 30 pound kraft paper around a suitable size former. A thin disc is dropped into one end of the tube formed by the paper and the end is glued down over the disc to form the bag. The bag is then loaded approximately 3/4 full with flash composition and a time fuse is glued and tied into the open end of the bag.

Flash Bag Dimensions		
Shell Size	Flash Bag Size	Charge Weight
3"	3/4" x 3"	10 - 12 grams
4"	1 x 3 1/2"	25 - 30 grams
5"	1 1/4 x 3 1/2"	50 - 60 grams

There are a variety of time fuses and techniques that work well. The duration of the fuse should be between 2 and 3 1/2" seconds, for the best results. One-quarter inch Japanese time fuse is the easiest and most reliable to work with. One method is to split and prime one end of the fuse with a slurry gunpowder prime, made with the addition of 8% fine titanium and 4% dextrin. The primed end of the fuse is allowed to dry completely before it is tied into the flash bag. Another method is to crossmatch with 4-ply black match or High Speed Ignitercord.

The complete flash bag should run the entire length of the shell unless the shell is taller than prescribed standard lengths set forth under Shell Casings. In the event that shells are made longer than usual, a full length flash bag may cause over burst, resulting in blind or irregular star patterns.

SHELL CASINGS

The shell casing is made by rolling a number of turns of 75 pound kraft paper around a casing former. A disc is dropped down onto the end of the casing former and the bottom paper glued down onto the disc to form the casing or bag. Two turns of .025 chipboard are rolled up and placed inside the casing. The chipboard is back-spun tightly into the casing and should rest squarely on the bottom disc.

Shell Casings		
Casing Size	# turns of paper	Width of Chipboard
3"	3 - 4	2 1/2"
4"	4	3"
5"	5 - 6	3 1/2"

The shell casing is placed on a flat surface, open end up. The flash bag is centered in the casing, fuse end up and the stars are placed around the flash bag. The stars should be well consolidated all the way up to the edge of the chipboard. A well packed shell is less liable to flowerpot, or break unevenly once it is in the air.

A disc, with a center hole 1/8-inch dia. larger than the diameter of the time fuse, is then dropped down over the fuse and onto the stars. The disc is tapped down until it rests on the edge of the chipboard. The edges of the paper are glued down, one layer at a time, onto the top disc. When all the paper has been folded down, another disc with a center hole the same size as the fuse diameter, is placed down on top of the paper. Plenty of glue is used around the fuse. The second top disc center hole should fit snugly around the fuse to prevent gas leaks. The shell is then ready to be strung in.



STRINGING IN

The best results can be obtained by using a single strand of 8-ply or two strands of 6-ply cotton wrapping twine. The double strands of 6-ply give the stronger burst patterns and need to be used accordingly. All the manufacturers of cotton twines catalog their strings differently, so it is sometimes confusing when trying to obtain a specific string. Wrapping twines seem to be the best suited for stringing in aerial shells. They tie well and absorb paste correctly. Polished cotton twines are sometimes used in situations where an extra strong casing is needed but this is not common practice because the polished twines don't absorb paste very well.

Number of Vertical Strings	
3" shell	8 - 12
4" shell	12 - 16
5" shell	16 - 24

The easiest string patterns are multiples of eight. The string is first brushed with thin wheat paste, and tied on to the shell in bisecting quarters until the desired number of vertical turns are obtained. After that has been achieved, the shell is turned on its side and the string is curved around the shell, like a barber pole, to the bottom. One complete turn is made around the shell at a 90° angle to the vertical strings. The string is then wound upwards to form squares. When the top of the shell is reached, enough extra string is needed to go around the shell one more time. A reverse loop is made of the extra string, and wrapped around the top of the shell, so it forms a cinch knot. When this is done correctly, it ties off the string and actually becomes part of the grid pattern. When stringing multiples of twelve, the shell is first quartered. The string is advanced approximately 30°, and the quartering pattern is repeated. There should be four small sections and four large sections when the shell is examined. The four large sections are then bisected with two additional loops of string, resulting in twelve

vertical strings, spaced at approximately 30° intervals. The shell is then completed in the same manner as with multiples of eight. The shell is now ready to be pasted in.

PASTING IN

When pasting in, the easiest paper to work with is 40 pound Natural Kraft, although 50 pound kraft also works well. The paper is cut across the grain. An easy way to determine how wide to cut the paper is to measure the length of the shell and add twice the diameter of the end disc minus 1/4".

Example: a 4" shell is 3 1/4" long and is made with a 3 1/2" end disc.

So $3 \frac{1}{4} + (2 \times 3 \frac{1}{2}) - \frac{1}{4} = 10$ " paper width.

The grain of the paper runs from end to end of the shell when rolled up. The paper is then rubbed well with wheat paste which has been made with fairly warm but not hot, water. The paper is then picked up and worked with the hands to soften the grain, so that the ends of the shell will lay down smooth. After the paper is spread back out on the table and the shell is placed in the center of one end, the shell is then wrapped up with equal amounts of pasted paper extending from each side. The shell is then placed, fuse end down, on a short collar with a diameter one-inch less than the shell (PVC tubing works well). The pasted paper extending off the fuse end of the shell hangs freely around the collar. The pasted paper extending upward off the bottom of the shell is torn vertically into five sections. The paper is torn down to just off the bottom of the shell and folded down, one section at a time. The pasted paper stretches all the way across the bottom of the shell. When the five sections have been folded down and across each other, the bottom is smoothed and the shell is placed upright. The tearing procedure is repeated on the fuse end of the shell, with additional tears being made to layer the paper around the fuse. The shell or shells are then set out to dry.



IGNITER FLASH BAGS

The flash bag is really an ancient device. In one old Italian book it is illustrated as a tubular bag of black match tied to the Roman fuse of a cylinder shell to act as a pass fire between the time delay and the contents of the shell. Theoretically, it bursts suddenly, releasing a well developed combustion, uniformly, inside the shell. In modern use, it is filled with a high energy, high temperature mixture capable of properly rupturing the shell hull and igniting the contents. It is a nice, simple idea that is capable of beautiful results after much trial, many errors and is, I promise, worth the time and travail.

Now, before I get to the technical parts of this article, let me pull out my trusty and well worn soap box and issue two admonitions. At a properly regulated fireworks display, the aperture of the eye remains open or very nearly so, for almost the entire performance. Extremely bright illumination is intimidating and should be used only for shock value. You cannot maintain shock for long and please an audience. The last thing a pyrotechnician wants is for the eyes of his audience to close while he is displaying his fine efforts. The most common symptom of a poorly regulated flashbag shell is a rather awesome initial flash that shows up on film and video systems, often to a disastrous degree. This is really disastrous for televised shows and promotional efforts.

The second most common fault is a result of using too much, too fast, too hot a flash bag. The tyro shows his new found joy; at best he is getting good breaks, wide spread, nice patterns, so he overdoses the flash bag. A shell must ignite and arrange the stars/effects carefully and artistically in the pattern and at the velocity best suited for the effect. Glitter stars, for instance, look like something did not really light correctly and are quickly so dispersed that the space they fill is not properly illuminated with the effect at all. Such shells leave one with the, "Blam ... he got some things lit, I think, boy what velocity, what was that supposed to do, sure was skimpy, does he ever put enough fire in them?" And "this is not the same as a piece of art". For mystery, for sensation of speed, occasionally these things

might be done, but not every shell; a few in a display will suffice.

Last, but not least by any means, is the fact that powerful flash bags can easily make the stars dangerous projectiles capable of penetrating the skin even through denim clothing. No shell ought to be so regulated without special warnings attached, so' that adequate protection, which would be extra-ordinary, could be taken.

To sum up, the goals are: first, good ignition; second, good break pattern. The most common faults are a blinding flash and overhard break.

One fine display I attended left a parking lot the size of a city block littered with unignited stars two feet apart, and two live salutes. There is no excuse for such failure. It is a hazard to the audience; it wastes chemicals, time and hard work. The shells are less beautiful than they should be. I have all of that shellmakers's secret formulas now, and they were very ordinary. He sure left me a lot of samples.

Ignition is simple, you need heat transferred, a fuel, and oxygen. The best way to transfer heat quickly in the shell is by splattering the priming of the stars with hot molten particles that stick to the stars and are large enough and hot enough to cause local ignition.

The priming surface should be rough enough to trap these hot molten particles in crevices. Such a rough surface also absorbs infrared and visible light energy better. The rough surface shelters the poorly developed early reactions from high velocity gasses of the shell break and the vacuum and high velocity gas effects produced by the star's velocity through the air. A good job of priming should look and feel about like a piece of 240 to 400 mesh wet or dry silicon carbide paper. Priming that looks slick or glazed will often fail. If the prime looks like 600 mesh SiC paper or finer, it should be done again. Priming can be too rough but I don't know how to do that trick. The primer must always be dusted with a loosely bound (or simply dampened, sieved, and dried) mix that has little or no binder at all in it.



Dextrin can leave a thin film over the mix that will cause ignition failure. Hand mixed chemicals hold the reaction in the early stages of a shell better than commercial black powder. There will be many who will doubt this last statement; it has been proven repeatedly, and I can prove it again at any time. This is the fuel.

To heat the fuel and oxygen and combine them, the igniter flash mix will be designed to produce a heavy spray of molten oxidizer and combustion products, with adjusted particle or droplet size. The heat will come from burning of aluminum with potassium perchlorate or potassium chlorate. What is most desired is a high count of molten droplets that are large enough that each is sure to cause an ignition event. The heat and speed of aluminum flash powders exceed our requirements. By using two particle sizes of the oxidizer, one very fine for speed, and another very much larger for the main mass of each droplet, it becomes a very simple task to adjust the mixture to perfect performance. Basically, a simple high speed flash with excess of fine flake type aluminum will be mixed with oxidizer which is much too coarse for rapid reactions. This latter material will be in heavy chemical excess of the oxygen required to burn the hot but incompletely combusted aluminum from the fast aluminum-rich base fire or heat mix. Thus the combustion products of the heat mix will be absorbed by the much larger and cooler molten heat sinks of the coarse material. Since the heat mix reaction products are in part impact-absorbed by the droplets, the intensity of the flash or light will be greatly diminished. At the same time, most of the gas in the shell will become oxygen which is in the red hot or better temperature range. The actual oxygen pressure in the shell may range from about 200 psi to about 2000 psi depending on shell construction. In this pressure range, charcoal, most oils, and many other fuels are spontaneously, explosively reactive with room temperature oxygen. Since the oxygen is very hot, chances of a fire starting are excellent. That's what we wanted. Since the molten droplets will still be very hot and still evolving oxygen, even more ideal conditions will exist under each splatter impact of the droplets.

Using a microscope to fine tune the particle sizes of the oxidizers makes it very easy to light 300

stars in a 3" shell. The speed adjustment is simple, the heat mix is fast, the coarse material impedes ignition mechanisms. More of the former - faster; more of the latter - slower. For shells 1" and below, chlorate should be used. For 3" through 8" shells, perchlorate should be used. Above 8", potassium nitrate should be used for the coarse material. By this simple, complex mixing, aided by wet sieving, a carefully adjusted igniter flash can be made exactly tailored.

Remember that the explosive power of the priming on the stars is more than enough to rupture the casing of a shell and, in fact, should be at least twice as thick a layer as would possibly be burned by the time a "breakless" shell would explode. Generally, if a star is still burning ten to twenty feet from the exploded shell, it will burn. The shifts in mechanisms of burning that occur at the tremendous pressure drop of shell rupture, the high velocity gasses blowing by the star, and the vacuum that forms behind the shock wave, are considerable problems to overcome with any system. The most common priming fault is too thin a layer of prime. Priming should be thick enough to still be burning at least one foot from the shell for every inch of diameter. This will assure protection from the vacuum that follows the pressure wave of any explosion. The priming, all but the outer hundredths of a millimeter, should be mechanically strong. I prefer starch binder to dextrin for that reason, and because starch does not bleed to the surface glaze over the composition, as can dextrin.

The endothermic reaction of generating oxygen and molten KCl with molten unreacted potassium perchlorate (or chlorate, nitrate, whatever) will help absorb the incandescent particles from the combustion of the heat mix by nucleated agglomeration processes. The temperature of the two stage reaction will be mitigated by the presence of the excess oxidizer which will act as a heat sink and then as an efficient heat transfer device. The evolution of oxygen by the oxidizer heavy blobs is not in thermal equilibrium in the short time of the break, and the equation:



is reversible theoretically, and in actual experiments can be prevented by very high pressure of



oxygen to a near theoretical nicety.

Now, how do you actually do this? If two crystals are in contact with a saturated solution of their material, the larger one or the more flawed one will grow at a greater rate as the solution deposits its solute.

Since all three of the oxidizers already mentioned are more soluble in hot water than in cold, we can grow the crystals to larger sizes with simple heating and cooling cycles. A stainless steel pot, one third full of oxidizer is filled to two thirds full with distilled water. It is heated to boiling, held at boiling for about one minute and cooled. Without stirring or with little stirring and with slow cooling, the particle size becomes much more random. The combination of these will produce a particle size distribution best described as a flat topped bell curve with a fat tail extending into the large sizes. Rapid cooling with rapid stirring will result in almost uniform particle sizes. With the microscope one will quickly be able to adjust the conditions to suit his experiments. If attempting this without a microscope, it is possible to try one or two heat cycles for nitrate or chlorate and three or four for perchlorate. I usually take most of the perchlorate to the size range 0.1 mm to 0.25 mm, but this is only a guide as changes in aluminum, fineness of the powdered oxidizer in the heat mix, shell size, flash bag construction and shell construction and, of course, size and type of stars and priming are all variables of some importance. You can easily adjust ignition flash for all of these variables with a little practice.

Since there are so many variables, I will describe what I look for during the adjustments. I find the mixes are usually between 50% and 80% coarse oxidizer (wt.) when they are properly adjusted for a particular shell igniter bag. I mix the materials wet and sieve through 20 mesh three times, with final sieving when almost dry through 40 mesh. This results in most of the finely powdered heat mix loosely coating the larger oxidizer particles. A large tube filled with the mix should mark paper and burn a few holes through the paper a foot from the tube. At three inches the paper should ignite instantly. An M-80 case with the ends glued in will make a soft bang or *bu* sound. With loose end caps, the same will

produce only a *whoosh*. With one end glued and one loose, a pop or *plop* will be produced, with 14" to 20" of fire from the loose cap end.

Loaded into the flash bags made of one turn of 40 lb. paper per inch of shell diameter with last turn fully pasted, the bag should make a *pu* or *chu* sound. In a shell forming bag or hull the sound will be much louder. The shell bag will move along the ground or launch into the air. An empty dummy shell hull will be torn into about four pieces with a good sized report. The inside layer of paper of this dummy shell will be thickly coated with blobs visible to the naked eye and burned through one or two layers of paper in much of the area. Now especially if one has not had much other experience with flash bags, it would be wise to make a dummy shell with inert stars - say salt and charcoal with dextrin, dusted with straight charcoal. The stars should be recovered from a ground burst, and all surfaces of each examined. I count anything that looks like a "well formed splatter" at 10 power as a hit. I get 100% ignition at one hundred hits per star (10 by 10 = 100), so I adjust the flash etc. until I find at least 200 hits on each star.

With a little experience one can make enough of this type of flash igniter mix for 500 shells in three hours, which is less time than almost any part of the shell's remaining construction. One should not expect to do that well on the first batch or so. When a good batch is obtained, a small sample should be kept as a microscope reference. I use an empty .22 brass as a scoop to do test shells, trying four to seven scoops for a 3" and only a little more for a 4". The properly adjusted ignition flash will not openly detonate in 2kg quantities, but the 50/50 heat mix will! I make at least a kilo at a time. It is not at all as powerful as a firecracker type flash and is a lot of trouble to adjust.

Is it worth all this work? Yes, 100% ignition is typical and the control over break pattern would be worth the work and time at 50% ignition. With this technique I can light more than 300 color stars in a 3" shell (photograph proven 100% ignition) almost perfect spherical break. I do not throw out the less-than-perfect batches. I mix with hand mixed black priming and use on anything that never ever lit before. LSO



OLD LLOYD'S IGNITER FLASH

The technique I gave in the previous article was deliberately vague about exactly how I make igniter flash for the simple reason that many things will work. When a wide variety of formulations that all employ a single concept will work, I try to emphasize the concept and not the application, but readers asked for further details so here's one system employing the principle:

HEAT MIX

equal parts by weight of:

- 1) very finely powdered potassium perchlorate
- 2) any flash powder grade aluminum which makes good firecracker powder.

I prefer the flake types aluminums (such as Al can 400, US Bronze 809, etc.) If you smear some on your hand and if it looks shiny and bright, it is the flake type; if you can't quite make out individual particles with the naked eye, it is a flake-pyro grade. I did not mean flitter when I said flake type. The bronzing powder type flake aluminum is a little easier to slow down and works fine at a reasonable cost. For more on aluminum, see *Glitter* [a monograph on the glitter phenomenon, available from AFN].

I mix the above until a fast flash powder results. This mix is dangerously powerful and explodes even in the open so as soon as possible I add Part Two, the coarse oxidizer. If the mix is dampened and sieved, the heat mix will, in part, coat the coarse oxidizer. This will help prevent separation of the coarse crystals in transit and handling. Commercial manufacturers might consider the obvious use of small quantities of binders.

I add at least an equal weight of coarse oxidizer to the heat mix. I will add less than twice the weight of the heat mix of the coarse oxidizer. The overall formula then might be written:

Aluminum	1
Potassium perchlorate, fine	1
Potassium perchlorate, coarse	2 --> 4

I damp sieve the mix and allow it to dry.

In the short time that the composition will be wet, the flake type aluminums will be protected from water by the stearin coating. Aluminum compositions must never be stored wet for protracted times. Most will show damage or heating up. This heating can occur in a few hours to a few days. Once they are dry, there is no hazard of spontaneous reactions. Wet flash powder is extremely difficult to detonate from ignition; damp flash powder is difficult to detonate, but both have higher velocities of detonation than the dry material. I dampen the sieve before I use it. It should be plastic or 304 stainless mesh and, naturally, must be chemically clean. I do not use steel, copper, brass or bronze sieves for flash. Dampened dacron sieves are the safest. By impact tests they are less sensitive with damp flash powder on them than the dry flash powder is alone, in all cases thus far tested.

This ignition flash mix is very much more effective at lighting stars, etc. than black powder. No single simple test is really adequate to measure this, but the number would be about 400 times the black powder "ignition quotient". By any system of ignition assessment, it is more than ten times as effective as black powder.

One fellow wanted to know if this was better than adding black powder to the flash mix. You bet your black powder it is! Adding grain black powder to an ordinary flash bag flash would help for the same reason the crystals help as the flash burns. It would serve to slow down the flash powder burning, but will not perform the remaining functions of the crystals.

One fellow mentioned using Chinese needle antimony sulfide in the flash bag to slow down the flash and help form hot splatter material. It is a good trick on both counts, but has the significant drawback of a large, white, glowing cloud of burning antimony sulfide vapor. This "glow cloud" is not as bright as flash powder but is still too bright and too big and burns for too long for general use [but put to very good use in Brock's White Duration shells!]. LSO

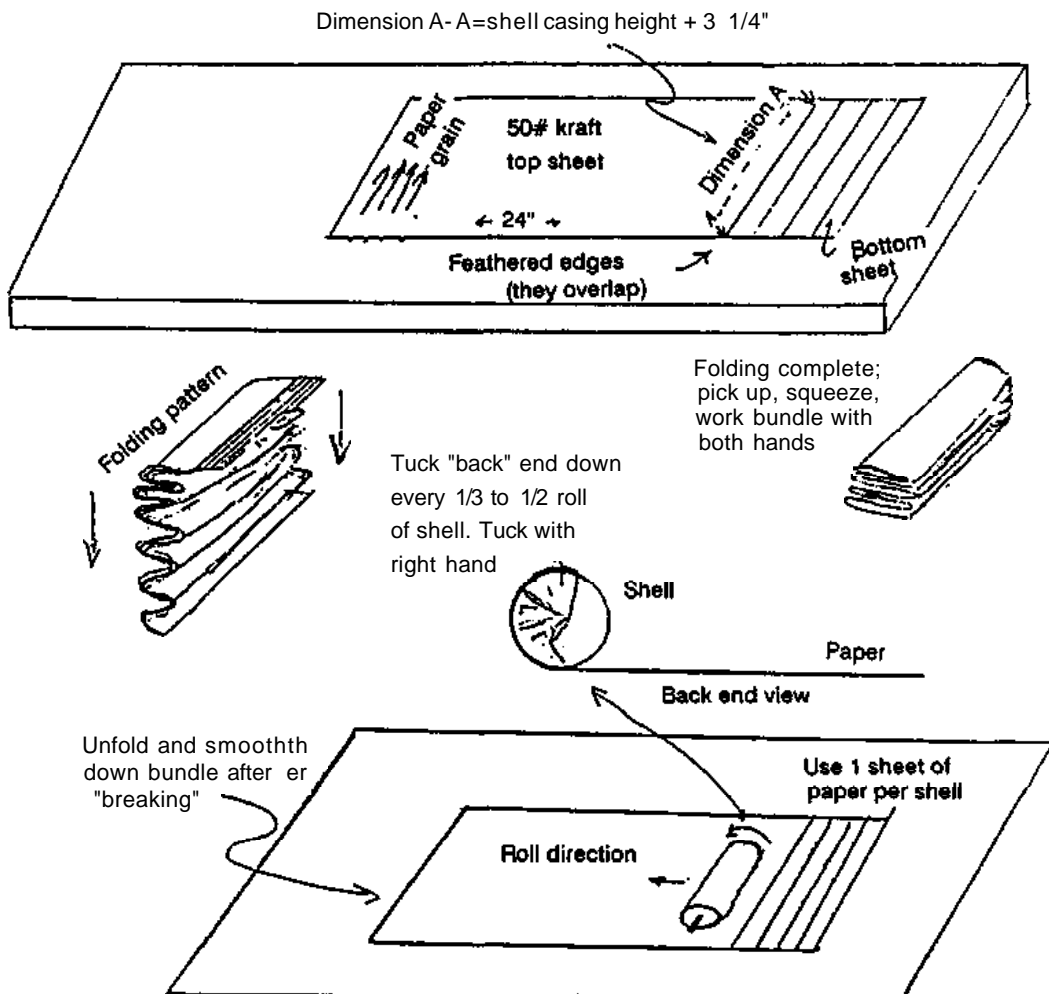


BREAKING PAPER

I am going to discuss an aspect of shell making that is little known and not widely practiced. Called "breaking paper", it's the act of soaking your shell wrapping paper with paste and working the paper until the stuff has lost its stiffness and has paste inside the grain. I can remember the time when I was pasting shells without the knowledge of breaking paper and my 4" shells could barely take 1 1/2 oz. of lift without flower plotting. After learning how to break paper I have fired 4" 3-break shells that required as much as eight ounces of 2FA lift with no problems! The process is critical to shell making.

Here is the technique:

1. Wallpaper wheat paste - mix thoroughly with water to thick but not runny paste, not too stiff.
2. Paste the table with sash brush.
3. Lay a sheet of 50 lb. kraft on table, completely coat with paste.
4. Lay 2nd sheet on top of 1st, feather edge as shown (only need about 1/2"); completely paste over top side.
5. Repeat step 4 for total of five sheets; completely coat top of 5th sheet with paste.
6. Break paper by folding as shown and squeezing and working paste into paper. Really abuse the folded bundle. If no paste oozes out ends of bundle, not enough paste was used or you are not squeezing hard enough.
7. Unfold and smooth down bundle on table; center shell on paper and roll, tucking down paper on end.
8. Rolling complete; pick up shell and spin with one hand while gathering and laying down paper around fuse with other hand. A well pasted shell will have no air bubbles under paper.
9. After fast drying in heated building, shell is ready for nosing paper, quickmatch leader and lift. WO



SPIKING IMPROVES SHELLS

Spiking is the term used by shell makers for binding a cylinder-shaped aerial shell with twine. The twine is usually wrapped around the shell from end to end (vertically) and then spirals down the side to where it is tied with a clove-hitch knot. Generally, most shells have at least eight or more equally spaced vertical spikes of twine. The number of turns spiraling down the side of the shell varies with the type and size of the shell. Spiking is always applied before a shell is pasted-in.

Spiking is the traditional method of "Italian" shell design. It comes from the days of making shells by first rolling a "bag" casing around a wooden former. Discs were inserted into the bag casing to form the casing ends which were secured by folded down, over-lapping paper from the ends of the rolled cylinder. After the shells were loaded and the last discs (with fuse) were inserted and secured, the shells were spiked with strong twine. It is obvious the spiking adds strength to the shell and improves the burst spread, but how significant is shell spiking to safety?

In recent years, most professional manufacturers have phased out labor intensive shell rolling in lieu of using inexpensive paper cans. The paper can walls are more ruggedly constructed than the rolled bag casings and have impressed many shell makers to the point of producing "stringless" shells. Those who remember their trials of designing stringless shells will recall compromises that had to be made to preclude extensive instances of flower potting when the shells were fired. The lift charge had to be reduced or heavier paper had to be pasted-in or internal as well as external discing had to be introduced, etc. For a light weight one-break shell, the problem of flower potting may not have occurred. However, with heavier shells of more complex performance, the problem was pronounced.

During the 1983 display season, I witnessed approximately 600 4" color with report shells perform flawlessly. Each shell was constructed identically, using paper cans, 1/8th-inch thick discs (one on each end), spiked with heavy twine, pasted in with four turns of 60# kraft paper and

lifted with 2 1/2 ounces of 2FA black powder. The shells traveled high, had wide symmetrical bursts and the reports ignited, timed out and detonated perfectly.

As an experiment near the end of the season, twenty more shells were made identical to the first 600 with only one difference: the twine spiking was left out. Out of the twenty fired, eight flower potted, one failed to ignite the salute after the aerial burst and all burst out the fuse end of the shell casing, driving the salute at high speed in the opposite direction.

I have concluded that the sudden occurrence of flower potting was caused by inertia of the shell contents. The shell is resting at zero velocity at the bottom of the mortar when at the moment of ignition it accelerates to 100+ feet per second muzzle velocity.

The "g" forces of the shell contents act internally against the bottom of the shell casing, causing it to separate from the shell walls. The shell casing tends to accelerate faster than its contents and perhaps (if no lift flame were present) would exit the mortar empty, partially empty or severely cracked. Without twine spiking, the shell would have to be "beefed-up" with extra pasted-in paper and/or have its lift charge reduced. While this would help get the shell successfully launched, it does not resolve the aerial burst and ignition problem.

The experiment left no doubt in my mind that shell spiking improves safety. This is not to say that all stringless shells are unsafe. There are many shell makers producing good quality stringless shells. However, most of the stringless shells I have come across were usually light weight single break color shells. The more complex "stringless" shells I have seen had rather heavy wall paper cans, had heavy discing inside and out on both ends of the shell and were burst with a flash bag or similar burst powder in a bag. The extra work to make burst bags, use extra discs and the extra expense of heavy wall cans leaves me wondering if the economics of successful performing "stringless" shells is worth the effort. WO



SHELL STRING

Anyone who believes in the older style of shell making knows you can't do anything without string. There are many types of string or twines available. The problem is sorting out the best string for a particular application.

Up until recently I had been using a popular 3-ply brown linen twine available from Ludlow Textiles. The characteristics of this twine are: thin overall diameter; high tensile strength; minimal stretching properties. This particular brown linen twine has been used in the fireworks trade for over 100 years. Over these years the price of the twine has (if you'll excuse the expression) sky rocketed. The current price is about \$9.50 per pound, purchased directly from the factory and in large quantities. This makes its use restrictive.

I contacted Blue Mountain Industries in Alabama. Blue Mountain is currently supplying regular cotton twines, commonly used for shell stringing. I asked if they offered any twines with the characteristics of the brown linen twine, manufactured by Ludlow. If so, was it reasonably priced? Blue Mountain was very helpful and promptly sent off a box of sample twines. I tried a half dozen samples and found a twine that came very close to the characteristics of the brown linen twine. The twine is a long staple cotton variety. It is very strong and thin. It is referred to as 8/6 Natural Soft Right Cotton Tying Twine. This long staple twine has ten times the strength of regular cotton twine in the same diameter. The 8/6 long staple twine breaks a bit easier than the linen twine of the same diameter, but is quite acceptable.

I find the 8/6 long staple twine very useful for a variety of different applications. I originally planned to use the 8/6 long staple twine for shell finishing and tying Sateens. I have subsequently found that it is superior for stringing large multi-break shells. The high strength and thin diameter of the long staple twine allows many breaks to be strung together without the overall diameter of the shell becoming too large. Shells made with the long staple twine appear to break larger and more consistently than similar shells made with the more common 8/8 ply cotton tying twine.

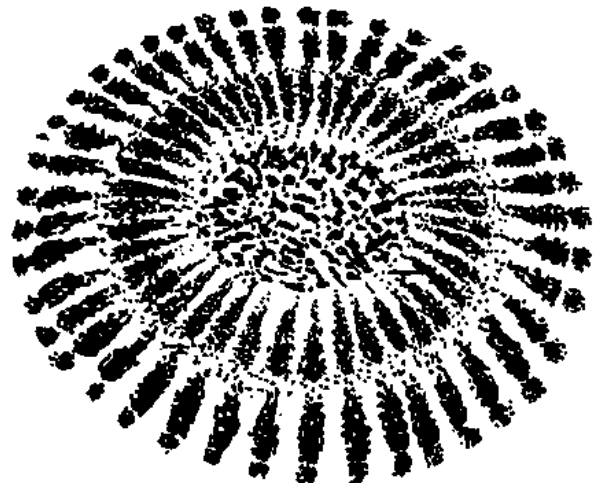
The long staple twine is available from Blue Mountain Industries in minimum 200-lb. lots, for \$5.50 per pound. The twine is put up in two-pound spools, containing about 6,200 feet. The standard two-pound roll of 8/8 ply cotton contains about 4,600-feet. The 8/6 long staple has the advantage of being stronger and thinner than the commonly used 8/8 ply cotton and a two-pound spool of the 8/6 long staple twine contains about 28% more string. The 8/6 long staple twine is about twice as expensive per pound as regular cotton twine, but is considerably cheaper than the linen twine.

Here is a breakdown of the strings, in price per foot, when purchased directly from the factory in case lots:

8/8 ply Cotton Twine	\$.00125/ft.
8/6 ply Lg. Stpl. Cotton	\$.00185/ft.
3 ply Brn Linen Twine	\$.00297/ft.

BOWLING BALL SHELL

One of my readers has informed me that he uses a bowling ball to make a set of hemispheres, first the bowling ball is covered with plastic wrap and five layers of 50 lb kraft are pasted on. An equatorial line is cut with a razor blade. After drying, the two hemispheres are popped off. The o.d. of the shell is about 8.7 inches, which is too small for a 10" mortar unless the correct amount of excess lift is used. Good luck! DB



DEVELOPING AERIAL SHELL CASES

After working with skyrockets, I felt that I would like to try making aerial shells.

In my research, the first thing I found was that the paper materials for the cases were extremely hard to find in the quantity and quality I needed. Then I tried what everyone tries: substitution. Results: disaster. There I was with all the time and money invested in star materials, watching all that work flower-pot in the tube. It was clear that I must have the proper paper materials for case construction. Thus began my trip into the world of industrial paper and my decision to offer 3" and 4" shell cases to my fellow pyros.

I first contacted a national brand paper products company warehouse and purchased an entire roll of 75-lb. kraft paper for shell casing. I also purchased an entire roll of 30-lb. kraft for final shell wrap. I thought, now I am in business with a 6-foot wide roll of paper, 1,625' long and another roll of paper 4-feet wide and 1,850' long.

So what the hell am I doing with a life-time supply of paper in sizes that I can't use immediately? I made up a machine to cut this paper to the sizes that I needed. WHOA! What about the chipboard for the inner case material and what about end discs?

Again the successful hunt was on. Chipboard for the inner case material is available in the proper thickness and width but it comes in rolls that weigh about 100 lbs.! Back to the drawing board to come up with something that will allow me to work with these huge rolls of material.

The end discs gave some success. The first discs were made of fairly thin chipboard. The first cases produced fine flower-pots. The cases were OK but the end discs were no damn good for what I needed.

Armed with kraft end discs which are twice as strong as chipboard, I re-designed the case to get the type of break that I should have when using a canister aerial shell case. I now have what I feel is the proper case that will do the job if the pyrotechnist will complete the work properly.

CONSTRUCTION FEATURES

75-lb. kraft for shell casing.
.025" chipboard for inner case.
.120" kraft end discs.
Double end discs for fuse end.
Fuse matched inside & out with igniter cord.
30-lb. kraft for final shell wrap.
Outside end disc applied to the case using a mechanical press and pressure of 100-150 lbs.

USING THE SHELL CASES

As received, the cases are ready for filling, stringing and final wrapping.

I feel that there are some basic rules that must be followed in the completion of any aerial shell. I will list these in the order I consider important for the completion of the shells.

1. Bursting Charge Powder Core Former: This is a thin walled paper tube of about 1 1/4" diameter. One end of the tube has slots cut in each side. These slots are about 1/8-in. wide and about 1-in. long. The slots make it possible to set the former over the fuse and igniter cord. With the former in place, Step #2 can proceed.

2. Star Charge: This is now placed in the case in small increments. Each increment of stars is compacted with a filler such as rice hull powder or granulated Black Powder. The case is filled and compacted to the level of the inner case chipboard material. For compacting the star charge, a screwdriver can be used as follows: I hold the screwdriver by the blade and tap the case with the handle. The star charge must be compacted completely. If after the bursting charge powder has been placed in the case and the powder core former removed and the top end disc set in place, I can hear the star charge rattle, the charge has not been compacted enough or I do not have enough stars in the case. Aerial shell cases will not perform properly if the star charge is loose.

3. Introduce the bursting charge powder into the case. Remove the powder core former, add more stars if necessary and compact again.

4. Set and secure the top end disc. Fold the shell casing paper over the top end disc and glue completely.

5. The properly filled case is now ready for stringing. This is a most important step if I want to have a good "break" from the shells. I use a waxed linen cord for stringing. This material is available at electric motor rewinding shops. I feel that the results justify the cost of the cord. Stout cotton twine can be used in place of the waxed cord. Whatever type of string, it must be applied very tightly around the shell case. Holding the case in one hand while wrapping the string with the other hand will not do the job. One easy method of stringing is to lay out enough string to cover the case and then to anchor the string to a firm point. I wind the case with the string stretched tightly against the anchor point.

6. After completing the stringing, the quickmatch leader is prepared and then laid along the case. The case and match leader are centered on the final shell wrap paper with an equal amount of paper on the top and bottom of the shell. I wrap the shell and leader with the final shell wrap and secure the end with glue. The top of the paper is gathered around the leader and secured with string. The lifting charge powder is placed in the bottom of the shell and the shell final wrap paper is folded down around the lifting charge and secured by gluing or with string. This completes the shell.

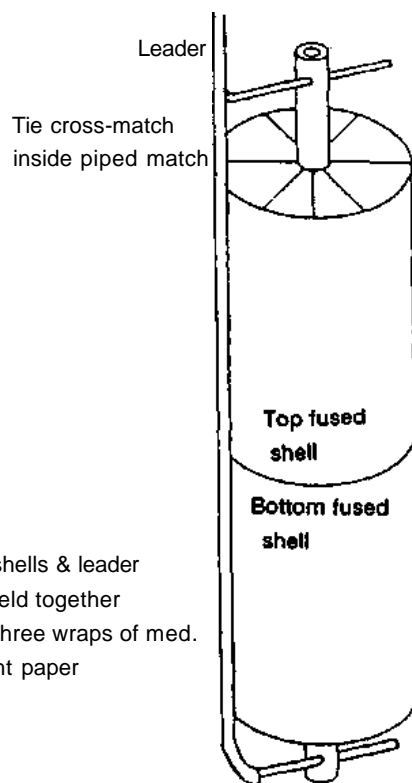
Important points to remember when constructing aerial shells:

- a) Fuse must fit end disc holes snugly and must be glued on both sides of the disc.
- b) Do not rely on a spaced glue joint to hold the fuse to the end disc.
- c) The star charge must be compacted properly.
- d) The case must be strung tightly and properly.
- e) The completed shell must fit the mortar tube properly. JET

DR. ZUFFY'S EASY TWO-BREAK SHELL

The Dr. had been bottom fusing 18" shells for some time with no problems so he decided the time had come for a little ("something extra") for these economical little beginner's shells. But he wasn't smart or patient enough to do it the real way so he did it like this. The upper Jap time fuse was cut for a 4 second delay and the lower one for 2 second. The Dr. liked to use colors that harmonize such as blue with green or blue and green with yellow. Or a color break followed with a 50 gram flashpowder 'surprise'. Flashmix was:

Potassium perchlorate	1
Barium nitrate	1
Sulfur	1
German dark aluminum	1



The shells & leader are held together with three wraps of med. weight paper

He never had a problem with it since he never mixed or handled more than a 100 gram batch, always wearing welder's gloves, long-sleeve shirt, and plastic face shield. And he always buried his mortars into Mother Earth before firing them.

LW

LIFT CHARGE AMOUNTS

One of the most frequently asked questions is "How much lift powder do I need for my shell?". Unfortunately, the answer is not an easy one. The foremost reason is a lack of consensus regarding the optimum height to which various sized shells should be propelled. Of course, it is a requirement that burning components must not fall to the ground, but that is where the consensus ends. For a 3" shell, is 250 feet high enough or is a height of 450 feet required? Another reason is that after deciding on the proper height, there is still a large number of other variables that determine the needed weight of lift powder. Among the variables are:

- Shell Type (cylindrical or spherical)
- Shell Weight
- Shell Size (diameter)
- Shell Length (for canister shells)
- Lift Powder Grain Size
- Lift Powder Quality (if it is not a commercial grade)
- Mortar Length
- Loading Space (volume between bottom of mortar and shell)
- Shell Clearance in Mortar

Our typical response is to refer the questioner to what others have reported and to recommend the use of those suggestions as a starting point from which further adjustments can be made as found to be necessary during testing.

Basically, there are two ways in which authors have reported their recommendations regarding shell lift. One is the *weight of lift per weight of shell*. The other is *weight of lift per shell size*.

LIFT VS. SHELL WEIGHT

As regards the *weight of lift per weight of shell*, there are at least three recommendations. The Westech(1) literature advises 1/5 ounce of black rifle powder for every ounce of shell weight, with the caution that actual weight must be determined by experimentation [Authors' note: Caution is advised because this is higher than the other recommendations by a factor of at least 3]. Fulcanelli(2) also provides a rule of thumb ~ 1

ounce of 2FA for each pound of shell weight up to ten pounds, then 1/2 ounce for each pound over ten pounds. Fulcanelli also notes that with very large shells, such factors as the fit of the shell in the mortar, the mortar length, and the length of the shell, assume more importance than for smaller shells. A PGI Bulletin Question and Answer(3) presented a chart of shell weight in pounds versus 2FA in ounces. Figure 1 is a reproduction of that chart with added lines for Fulcanelli and Westech weight ratios. Of these, the authors feel that the graph from the PGI Bulletin probably represents the best starting point.

LIFT VS. SHELL SIZE - SPHERICAL

With regards to *weight of lift vs. spherical shell size*, Table 1 presents the recommendations of Shimizu(4), Lancaster(5), Bleser(6), Tenge(7), and Weingart(8). Only Shimizu provided shell weight data. These same data are presented graphically in Figure 2.

LIFT VS. SHELL SIZE - CYLINDRICAL

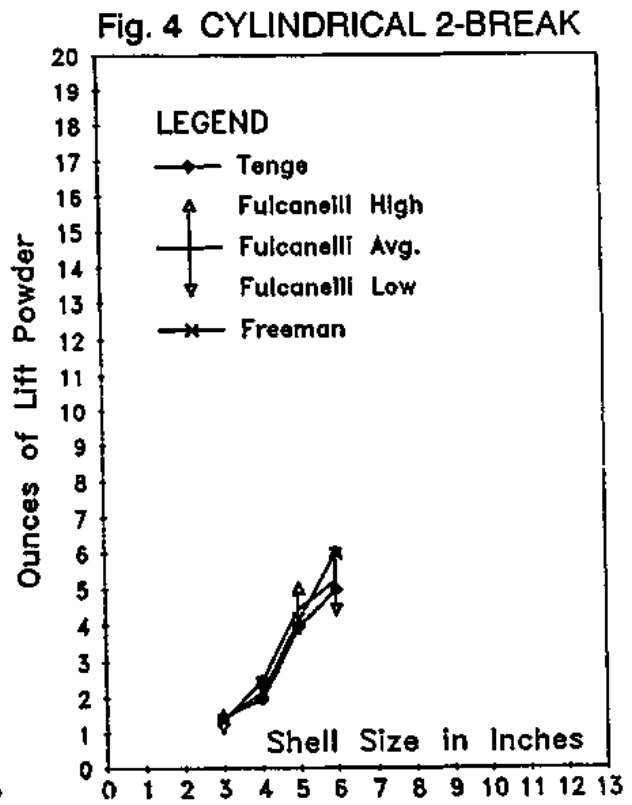
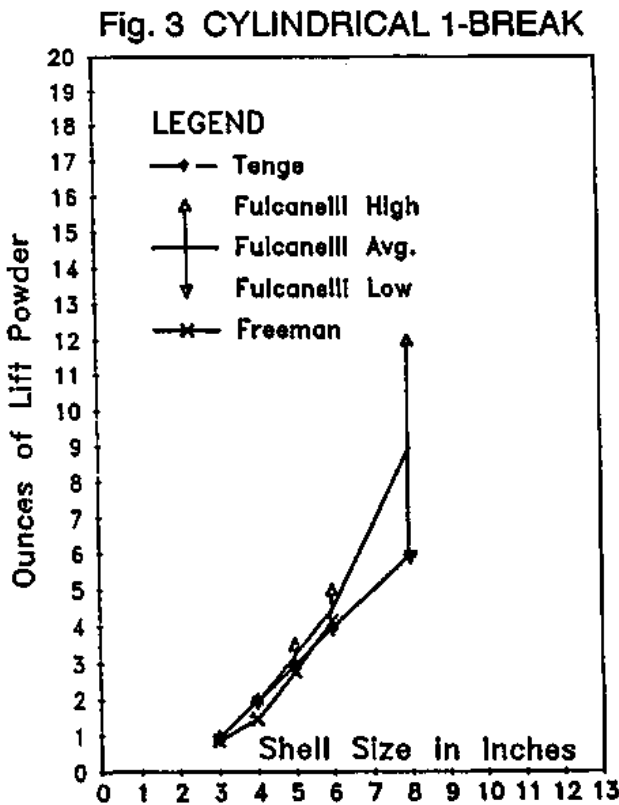
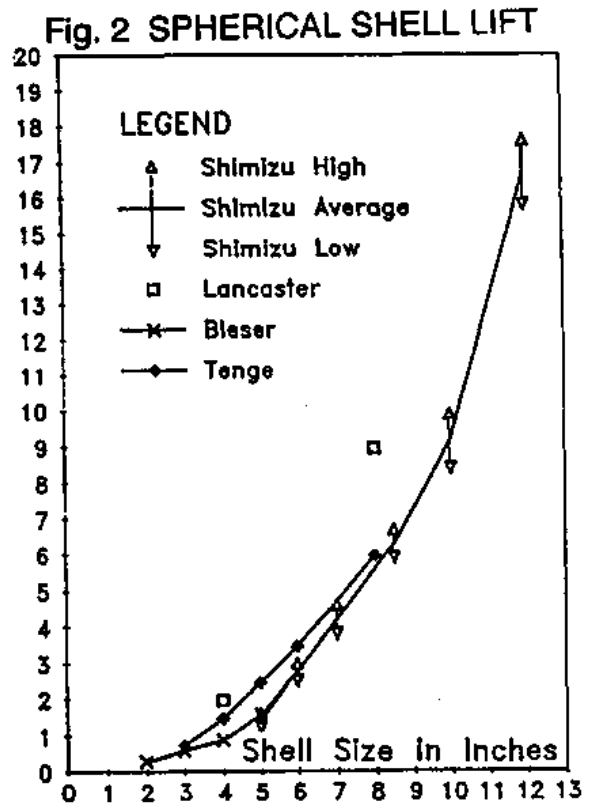
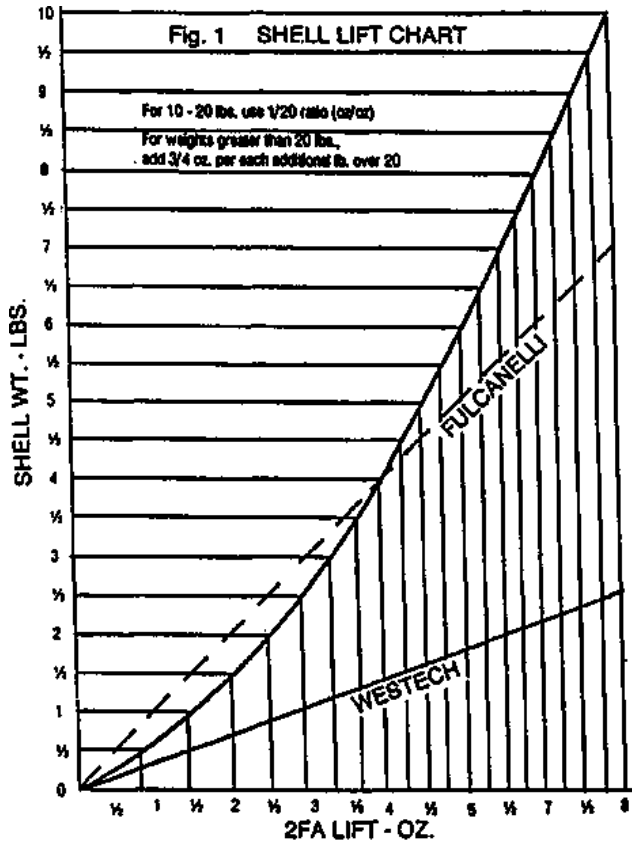
Cylindrical or canister shells are more difficult to deal with because: the shell length can vary greatly; the contents of the shell can be high density (stars with black powder burst), low density (flash powder), or anywhere between; and the shells can be single or multi-break. Nonetheless, Tables 2 and 3 provide suggestions for one- and two-break cylindrical shell lifts from Tenge, Fulcanelli, and Freeman(9). The data are presented graphically in Figures 3 and 4. All references suggest using 2FA powder.

Freeman also offers a chart of estimated shell weights and lift amounts for multi-break 4" shell. For long multi-break shells, Freeman notes that the mortar lengths should be at least half again the shell length. Example, a shell 32" long should be fired from a mortar at least 48" long.

Because of all the many factors mentioned in the introduction, these tables should be used only as starting guidelines; one MUST experiment to determine the correct amount of lift for any particular shell. BK/KK



THE BEST OF AFN II



THE BEST OF AFN II

References:

- 1) Westech. 1970. "Basic Aerial Shells." Westech Corporation.
- 2) Fulcanelli, A. 1984. "Traditional Cylinder Shell Construction, Part 1." Pyrotechnica DC. Pyrotechnica Publications, Austin, TX.
- 3) Unknown, 1981 "Questions and Answers." PGI Bulletin No. 22.
- 4) Shimizu, T. 1981. Fireworks The Art, Science and Technique. Pyrotechnica Pubis., Austin, TX.
- 5) Lancaster, R. 1972. Fireworks Principles and Practices. Chemical Publishing Co., Inc., NY, NY.
- 6) Bleser, D. 1988. Round Stars and Shells. American Fireworks News, Dingmans Ferry, PA
- 7) Tenge, Chuck. 1983. "Lifting Shells with Black Powder." PGI Bulletin No. 34.
- 8) Weingart, G.W. 1947. Pyrotechnics. Chemical Publishing Co., NY, NY.
- 9) Freeman, W.H. 1986. "Some Thoughts on Shell Lifting." PGI Bulletin No. 50.

Table 2.

Recommended Lift for 1-Break Cylindrical Shells

Shell Size (in.)	Tenge 1-break (oz.)	Fulcanelli 1-break (oz.)	Freeman 1-break (oz.)
3	1	1	.9
4	2	2	1.5
5	3	3-3.5	2.8
6	4	4-5	4.2
8	6	6-12	--

Table 3.

Recommended Lift for 2-Break Cylindrical Shells

Shell Size (in.)	Tenge 2-break (oz. Xb)	Fulcanelli 2-break (oz.)	Freeman 2-break (oz.)
3	1.5	1.25-1.5	1.4
4	2	2.5	2.2
5	4	4.0-5.0	4.2
6	4-5.5	4.5-6	6

Table 1. Recommended Lift for Spherical Shells

Shell Size (in.)	Shimizu (2Fg-3Fg) (a) (oz.)	Shimizu Shell Weight (lbs.)	Lancaster (Cannon powder) (oz.)	Bleser (2Fg) (oz.)	Tenge (2FA) (oz.)	Weingart (Unknown powder) (oz.)
2	--	--	--	0.3	--	--
3	--	--	--	0.6	0.75	--
4	--	--	2	0.9	1.5	1.5
5	1.3-1.6	.9-1.4	--	1.6	2.5	--
6	2.6-3.0	2.5-3.3	--	2.8	3.5	3.5
7	3.9-4.6	4.4-5.7	--	--	--	--
8	--	--	9	--	6	--
8.5	6.0-6.7	7	--	--	--	--
10	8.5-9.9	7.7-11.7	--	--	--	14
12	15.9-17.6	18.3-20.3	--	--	--	--
24	145.5-172	132.-149.	--	--	--	--

(a) This does not mean 2Fg but rather Shimizu reports using black powder with a wide particle size range, which encompasses the particle sizes of both 2Fg and 3Fg.

(b) Specifically color and report, or larger single break component shells.

Table 4. Weight Ratio for Multi-Break 4" Shell

Number of Breaks	Estimate of Shell Wt. in Lbs.	Recommended Lift in Oz.
1	1.2	1.5
2	2.4	2.2
3	3.6	2.8
4	4.8	3.4
5	6.0	4.0
7	8.4	5.0
8	9.6	5.5



LIFTING CHARGES

The article *Recommended Lift Charge Amounts*, is quite interesting and clearly illustrates the problems of handling more than one or two different powders. My book *Fireworks Principles and Practice* was compiled about 1970 and much of what is there is no longer useful for today. For example, the powder referred to was made by ICI Nobels (Scotland) and was called TP Cannon. However, it is no longer made by ICI and most powder used in the UK comes from Wano in Germany.

When the changes were effected, it was the change from TP Cannon to 4FA which was the most notable one. In fact we discovered that we only needed 75% of the weights that we had been using and so a 6" cylinder shell which had needed 8 oz. of TP Cannon required only 6 oz. of 4FA. At the time it was a good thing since we suddenly saved a lot of money. However, TP Cannon was a lovely regular powder and the fact that it was slower pleased many people including the gun enthusiasts.

Of course we went metric some time ago in the UK and 'miles' are about all that we have left of the old weights and measures. Using 4FA, the weights these days would be:

	<u>Round</u>	<u>Cyl.</u>
3"	20gm	35gm
4"	40	55
5"	60	100
6"	100	165
8"	225	
10"	375-450	

(We had 28gm/ounce).

If you buy shells from Spain it will be quite a different story and it will be clear that slower powders and larger and less dense granules have been used. This is mainly because Spanish manufacturers ball mill their own powder and granulate it themselves also.

The two most important issues are:

- **Lift Powder Grain Size**
- **Lift Powder Quality**

The reader should consult *Fireworks Principles and Practice* page 129, where the column test is explained. Powders can be compared by pressing them under identical conditions and then comparing the burning rates. The results can be quite illuminating, yet I never cease to marvel at unscientific and 'hit and miss' methods that are employed by some. But it works both ways in that however scientific one tries to be, there are variables which cannot be avoided and this is where the experience comes in. For example, the diameter and length of available mortars can change everything.

It would be so nice to be able to make everything oneself and have complete control of the situation, but I am afraid that life is not like that. RL

[The writer is the operator of a leading U.K. display and manufacturing company]

THE CROSSETTE SHELL

When properly executed, the crossette shell is one of the most beautiful known. Unfortunately, the crossette is a complicated and delicate pyrotechnic system that must be exactly right to properly function. Here is a construction method that has proven reliable and functional.

THE CROSSETTE

A crossette star is a large pumped star made of one or another type of streamer composition. It has a cavity in one end that penetrates rather deeply. It is wrapped in protective paper so that it burns progressively from one end. The overall effect of a crossette shell is to see a number of these tailed stars spreading from the break, and then they abruptly burst into fragments. The fragments themselves become tailed stars. The aim is for the fragments to burst evenly, in a cross shape, thus the name "crossette".

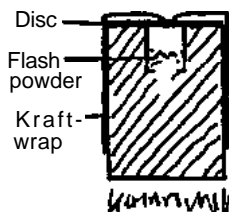


Fig. 1

The kind of charge used to fragment the star is critical and there are several methods of doing it.

The first method utilizes a special star pump. It is evident that the star relies on a small vent to transfer flame to the burst charge. This system of flame transfer has a shortfall in that the flame transfer vent is easily blocked, resulting in failure of the fragmentation process. A small piece of igniter cord folded in half and pushed into the vent was found to improve reliability. However, this system has shown to be an erratic performer.

The second method uses a small firecracker or "hole shot" to fragment the star (fig. 2). The hole

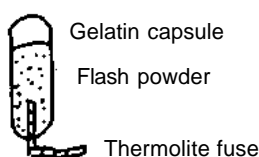


Fig. 2

shot has proven to be highly reliable and is the method of choice for many pyros. Ignition is via a piece of igniter cord or black match. Making the actual hole shot can be accomplished by one of several techniques. One method is to roll a tube and finish as a conventional Chinese firecracker. Another possibility is to use empty gelatin capsules as the casing. These are available from your friendly neighborhood pharmacist. Since the star composition is rammed hard and ignition surface area is limited, ignition may be a problem. A good way to ensure ignition is to tie a piece of blackmatch directly to the star surface.

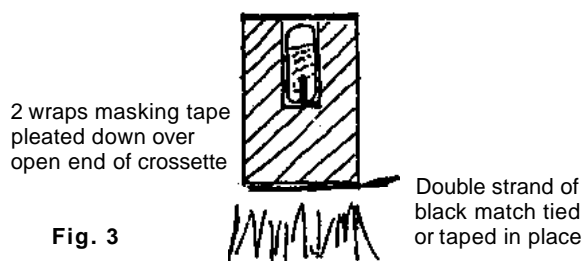


Fig. 3

Figure 3 shows a completed crossette. The star is finished by placing the hole shot into the cavity, then wrapping the star in a couple of turns of pasted paper or masking tape which overlap the cavity end. A chipboard disc is placed against the cavity end and the paper or tape is pleated down over the disc. The star is now completely wrapped in paper except for the solid end which is exposed for ignition. Upon ignition and ejection from the shell, the star will burn progressively with a streamer effect until the flame reaches the hole shot ignition area. When ignited, the hole shot will blow the burning star into what you hope will be four or more equal-sized chunks which continue burning until the material is exhausted.

SHELL CONSTRUCTION

A shell can is rolled on the appropriately sized former, first with chipboard and then kraft paper, allowing a 1" kraft overhang on each end. The kraft paper is pleated down onto the first solid disc, then the second solid disc is placed on top of the pleated paper and taped in place. The shell can is now removed from the former and readied for filling.



A thin walled tube (*canule*) is centered on the bottom end disc, then a ring of stars is inserted. The stars must tightly fit into the casing so as to form a circle (fig. 3). The triangular spaces between the stars and the shell wall are rammed with sawdust until the shell is very hard. Then another ring of stars is inserted and the ramming process is repeated. All successive rings are staggered half-a-star diameter to interlock the crossettes for added support. The normal number of rings is three per shell. When all rings are in place, the canule is filled with 2FA black powder, which is the shell bursting charge. When full, the canule is carefully removed by a twisting, pulling motion while pushing the black powder down with a dowel, finally, the disc containing the time fuse is pushed into place. The top paper is pleated over it and the outer top end disc is slipped over the fuse, down onto the pleats and held tightly in place while taped. The shell is now ready for stringing.

SPIKING

The shell is wound with string in a technique called "spiking". The string gives the shell structural integrity and insures a uniform burst, so special care is needed here. The best results are obtained using a double strand of 3-ply flax string, however a double strand of 8-ply cotton string will also perform well. All types of coated or waxed string are avoided because they will not absorb paste to any great extent.

Stringing the shell is one of those things that is infinitely more difficult to describe than to demonstrate. The spiker must bear in mind at all times that the string is to be wrapped around the shell with uniform tightness, otherwise an erratic break may result. An appropriate length of string is measured out, doubled, then tied to a secure object. A handful of thick wheat paste is worked into the string while it is drawn thru the paste. By doing this, the string will shrink while drying, resulting in string wrap unattainable by other means.

A good method to string is in multiples of four vertical strands. The paste-soaked string is tied onto the fuse with a clove hitch. The spiker then leans against the secured string and wraps the string vertically around the shell once, rotates 90

degrees and makes another complete wrap. The shell should now be divided on bottom and top into perfect quarters. From this point, it is a simple matter of subdividing each quarter until the desired number of strands have been added. When the vertical stringing is complete, the shell is turned on its side and a loop is wrapped around the extreme top of the shell to lock in the verticals. From this point, the string is wound down the entire length of the shell in "barber pole" fashion, making sure to form a pattern of squares with the vertical strings. At the shell's bottom, another loop is made to lock in the vertical strands and tie off.

PASTING-IN

The shell is now ready for pasting-in. Working with 70 lb. kraft paper has the advantage of requiring fewer turns to achieve the desired wall thickness but also has the disadvantage of being less pliable than the lighter weights of kraft. The choice of paper weight is therefore largely a matter of personal choice and the data listed in Table 1 can be modified according to other paper weights.

When pasting in larger shells, the wrapping is generally performed in a series of pastings so that no more than four wraps of wet paper are placed on at any one time. This is to ensure that the bottom layers completely dry. The operator must allow almost a full diameter overlap on each end for a positive gas seal.

The paper is cut so that the grain runs parallel to the length of the shell. The paper is then broken by brushing with wheat paste on both sides, crushed into a ball and set aside to soften. A detailed explanation of "breaking paper" can be found elsewhere in this book. After the paper has softened, a sheet is smoothed out, the shell is centered and then tightly wrapped, making sure to have equal amounts of overhang on each end. The operator now places the shell on a jig on his bench, which is a short length of pipe, so that the overhanging kraft on one end is unrestricted. The overhang on the shell top is torn into five or six equal strips and carefully smoothed down around the shell fuse to give a secure seal. The shell is turned over and the procedure is repeated on the other end. finally, the shell is set aside un-

THE BEST OF AFN II

til completely dry. A good way that the operator uses to test for complete dryness is to press the buildup around the time fuse with his thumbnail.

The dried shell is completed with quickmatch leader, outer wrap and lift charge the same as any other shell. My personal preference is to top fuse everything for the added safety. TG

TABLE 1 - SHELL CASING				
SHELL SIZE	# TURNS 70 LB. PAPER	# TURNS CHIPBOARD	3 VERTICAL STRANDS DOUBLED STRING	PASTEWRAF
4"	2 - 24" sheets	2	24	2 - 24" shts
5"	3 - 24" sheets	3	28	3 - 24" shts
6"	4 - 24" sheets	4	36	4 - 24" shts

TABLE 2 - CONSTRUCTION				
SHELL SIZE	# 1-1/8" CROSSETTES	2FA DIAMETER	V TIME FUSE DELAY	FFA LIFT
4"	3 rings of 6	1 ¹ / ₄ "	1 ¹ / ₄ "	2
5"	3 rings of 9	1 ¹ / ₂ "	1 ¹ / ₂ "	3 ¹ / ₄
6"	3 rings of 12	1-3/4"	1-3/4"	5

TABLE 3 - SUGGESTED FORMULAS					
	#1	#2	#3*	#4*	#5
Meal D				30	
Barium nitrate					17 ¹ / ₄
Potassium chlorate	43				
Potassium nitrate		44	40	35	38
Sulfur	26	5			9 ¹ / ₄
Charcoal, airfloat		12		10	9
Charcoal, 80 mesh		12			
Charcoal, 36 mesh		12			
Antimony sulfide		5	10		9 ¹ / ₄
Aluminum, German dark	31		20		
Aluminum, atomized bright			20		7 ¹ / ₄
Ferrotitanium alloy				20	
Titanium, 60 mesh			10		
Dextrin		10	6	5	9

Notes:

- #1 - "Hot" flashpowder for hole shots.
- #2 - Charcoal crossette - low intensity golden long tail.
- #3 - Aluminum crossette - bright/high intensity medium long silver tail.
- #4 - Ferrotitanium crossette - medium intensity gold/golden dense, long.
- #5 - Snowball crossette - bright white/med.long., sparse to med.density.



TIPS ON IMPROVING AERIAL SHELLS

Here are a few ideas on getting full, symmetrical breaks. While these methods are nothing new, they take on more importance with the advent of flash type shells.

A favorite of mine is the use of charcoal type stars mixed with colored stars. While lampblack is best, charcoal can give a much cheaper effect. Lancaster's crossette-comet mix works well, but in humid climates dextrin should be reduced to about 3% to help prevent moisture influx. Small ($\frac{1}{4}$ " to $\frac{3}{8}$ ") cut or pumped charcoals, mixed with red, green or blue (say about two color to one charcoal) can give an added fullness to color shells as well as slightly enhancing the colors themselves, via visual contrast. When these shells break, they frequently leave a gold spider inside a ring of color, especially if the charcoal is loaded in the center of the shell. Also, these stars burn much faster and are lighter than most color types which causes them to stay closer to the center, while the denser colors are blown a greater distance.

Another effective method is the reverse. Stack crossettes around the inside of a shell and fill the center with small colored stars, thus producing first a big gold spider with a colored center. Then as the colors burn out, the crossettes break, adding an additional effect!

Water can make a big difference in the performance of charcoal. Light damping will leave a full but short lived tail, whereas a heavy damping causes persistent sparks that can burn all the way to the ground! While this fallout is generally considered undesirable, it can be used for an interesting effect.

A spider shell made with over-damped stars will first form the spider, then the spark *trails* will blend together to form a ball of gold and finally will drop to form a curtain of gold mist with some of the sparks "dripping" smaller sparks. It's amazing how many people go for this effect!

Of course, other streamer-type stars (flutter & glitter) will also help make a full burst. This makes sense as a mass of glitter flashes gives an optical effect like many small stars burning. And the more stars, sparks or flashes you have, the denser the break will look.

Priming is my final tip. I use a meal dust with 2% each of barium carbonate and dextrin and sometimes 5 to 8% silicon fine powder (for hard-to-light types). In flash-type shells, it's best to roll the stars in prime to insure a complete coating. Now this may not be necessary with some of the more sensitive formulas, but good priming helps the star light all over and not just at a corner where it can be blown out.

So if your break looks ragged, try rolling your stars in prime and if that does not help, reduce your burst in about 10 - 15% increments until you get the right shape.

The above tips are all published in the pyro literature but I think it helps to see them all compiled and may stick in your memory. I know they can help make a good burst into a great burst, if properly applied. MV



MAKING PALM TREE SHELLS

Q. How are Palm Tree shells made? None of my fireworks books mention them. Are they spherical; are the stars same as chrysanthemum stars? What is the bursting charge? DN, Salem, Oregon.

A. When the good Palm Tree shells stopped coming in a few years ago, I started making my own. For the stars I use commercial meal powder or 7FA. I encourage experimentation with the star formulation but here's a sample:

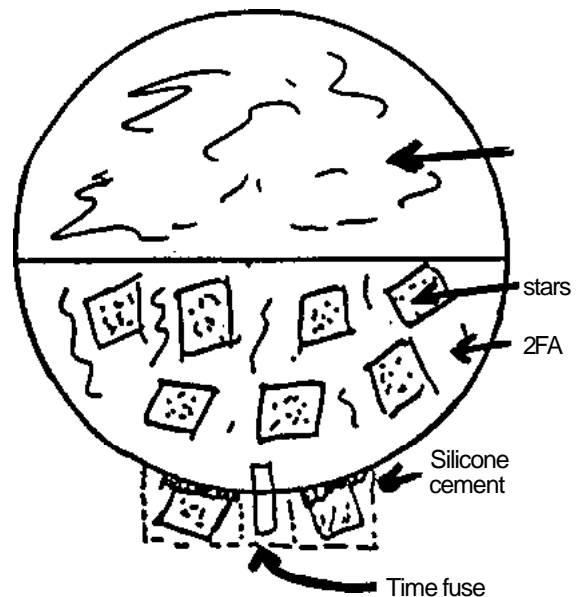
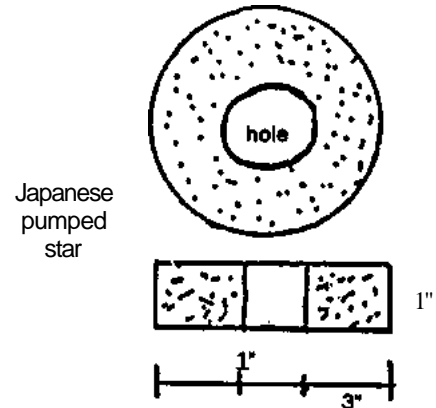
Meal powder	14
Aluminum, atomized, Coarse/med.	3
Strontium carbonate, (or any CO ₃)	1
Antimony Sulfide	1
Dextrin	1

The idea is for a fierce burning star with only a small delay. Titanium or ferro/titanium may work better than aluminum since the Japanese stars perform better than mine.

I cut the cake into large stars, 3/4" to 1" for a 4" ball shell. Not many are needed.

The Japanese used to use a large pumped star attached to the bottom of the shell for the "trunk". For a 4" shell, the trunk star was about 3" diameter, 1" high with a center hole of at least 1". I use 3 or 4 of the Palm Tree stars attached to the outside of the shell with silicone cement for the trunk. Sometimes the shell will spin during flight, resembling the tiger tail shell. That can be remedied by filling the top half of the shell with clay.

I use a mild burst, about an ounce of 2FA. JF





PALM TREE SHELL CONSTRUCTION

Any pyro display worth its saltpeter contains a few Oriental palm tree shells in its repertoire. The graceful, radial development of its 12 to 14 thick, golden streamer arms is an attractive change from a steady tempo of star shells. Particularly impressive are the purple palm tree shells which have purple heads attached to the streamer tails. The display operator can usually afford only a few palm tree shells in his display as they are priced much higher than standard Japanese shells. But their construction is straight-forward and no more expensive to make than a standard chrysanthemum or peony shell.

Since the vast majority of pyros remain unfamiliar with round shell construction, this series of articles will cover the construction process in as much detail as possible. Part 1 will focus on the construction of the round shell hemispheres using an improved method over the previous article "Make an Easy 4-inch Chrysanthemum". Part 2 will cover the preparation of the stars. Part 3 will discuss the burst charge and the final shell assembly.

PART 1 HEMISPHERE CONSTRUCTION

The rationale for the construction of "homemade" hemispheres was discussed in the previous article mentioned above. The idea is to minimize cost and assure a uniform wall strength in all directions in the final shell. A quality set of 4" commercial hemispheres is recommended for use as a form.

I start by tightly wrapping the hemispheres with one layer of thin plastic wrap. I prefer using the plastic bags on a roll that grocery stores offer for produce customers. I tightly twist the wrap on the bottom of the hemisphere as shown in fig. 1. While holding the twist tightly, I cut off the excess wrap with scissors, using several pieces of wide scotch tape to hold the twist down to keep it from unraveling. I place the two wrapped hemispheres together to make a sphere, then tape the sphere's "equator" together with three or four short pieces of scotch tape. I don't tape the edges together all around the equator.

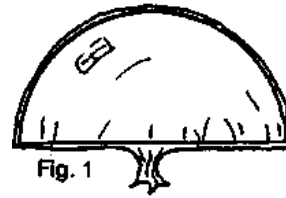


Fig. 1

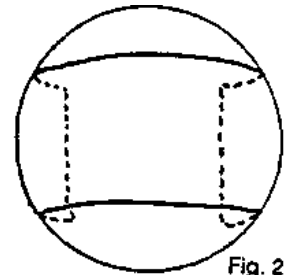


Fig. 2

Pasting the sphere is quick and easy. I cut eight strips measuring $9\frac{3}{4}$ " by $2\frac{3}{4}$ " from a brown kraft bag of 40 lb. weight (.004" thick). Newspaper can be used but ten strips would be required. I apply white glue to the strip with a brush and wrap it around the sphere as shown in fig. 2. The next wrap is placed 90° to the first wrap as shown in fig. 3. This will cover almost all the exposed surface, forming the first layer. I roll the sphere on a hard surface to smooth it down, then repeat the process for three more layers. Wheat paste instead of white glue could be used for layers 2 through 4.

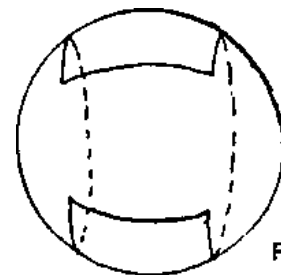


Fig. 3

Now comes the tricky part. It is necessary to relocate the equator hidden under the pasted wraps. I feel around the sphere with my fingers and thumb until I detect a slight ridge under the damp kraft paper (it will be detectable for at least a short straight distance if I didn't cover too much of the equator with scotch tape). Using a sharp razor blade, I poke around the ridge until I feel it cut through the equator with almost no effort. Now I just slice around the equator and the sphere will fall neatly apart into two hemispheres. I let them dry overnight, then cut around the plastic wrap twist, sliding off the hemisphere and it is done. I usually mark the equator with the edges lined up to facilitate the assembly of the two hemispheres in their original orientation.



PART 2 STAR CONSTRUCTION

A 4" palm tree shell will contain six 1 1/4" diameter stars in each hemisphere. A 5" palm tree will require 1 3/4" diameter stars. The composition, used for the stars should be a moderately fast burning glitter or charcoal streamer mix using potassium nitrate as the oxidizer. Aluminum flitter mixes burn too fast and are difficult to ignite. I use ferro-titanium alloy, 100 mesh, as the sparking ingredient as it gives a beautiful golden tail very similar if not identical to the Oriental effect. The formula is:

PALM TREE STAR MIX

Meal powder	40
Potassium nitrate	30
Ferro Titanium	25
Dextrin	5

To make the stars, no fancy star pump is required. I use a 10 dram plastic pharmacy vial which has a 1-3/16" i.d. I just cut the bottom off, then make a rammer out of a short piece of 1 1/4" wooden dowel. I sand the dowel down so it slides inside the vial with ease.

I like to give my stars colored heads so I make up a batch of green, blue or purple perchlorate based color composition. First I dampen the streamer comp and colored comp with 8% water, then set the vial on a small tray with the top edge of the vial down. I place the tray on a balance and add about 6gm of damp colored comp and tamp down slightly. Now I add another 14gm of damp streamer composition, remove the tray from the balance and consolidate the star with a few sharp blows on the rammer. The star will easily push out of the vial. I allow five days to dry.

I now have a tablet shaped star which should be approximately adjusted so the streamer and colored sections burn out simultaneously. It is necessary to tape the edge of the star with two thicknesses of masking tape to prevent separation of the colored head from the streamer tail. If I accidentally used unequally dampened mixes to make the star I should notice cracking between the interface of the compositions due to unequal shrinkage while drying.

When the star is dry I drill a 3/32" hole through the approximate center of the star with a hand drill. The hole accomplishes two things. First, it makes the star highly ignitable because the hole provides a stable burning surface which is somewhat protected from the fierce blast wind. Second, it allows a nearly instantaneous flashthrough to ignite both front and back surfaces simultaneously. The star will burn from the inside out as the edge is protected temporarily by the tape covering.

Some remarks are called for here on the concept of drilling through pyrotechnic compositions. Ferro-titanium compositions are less subject to friction ignition than titanium compositions, but caution should still be exercised. The flutes on a drill bit are designed to channel away the debris during the drilling operation. Pyro compositions will usually fill up and clog the flutes after one item is drilled. If the drill bit is not cleaned it is much more difficult to push the bit through the next item. The composition could crack and the drill can heat up rapidly. I simply drill through a piece of scrap wood after drilling each star. The packed composition usually pops out of the flutes. Then I dip the drill bit in water to cool it down and wash it before proceeding to the next star.

PART 3 BURST CHARGE & FINAL SHELL ASSEMBLY

A good palm tree shell will project its stars with high speeds out to great distances. For a 4" shell it is important to employ a strong burst charge and have a good understanding of the physics of the explosion. Figure 4 shows a section cutaway of one hemisphere filled with palm tree stars. The hemisphere should have the burst charge tightly packed around the stars to give the shell integrity and thus prevent flower potting or star cracking in the mortar during lift. The burst charge that occupies areas "B" in the diagram does not produce any net radial force on the stars upon ignition. Only the burst charge in area "A" is capable of applying outward force on the star. Naturally, the thicker and heavier the star the smaller area "A" becomes and correspondingly less force is available to push the star outward. Sawdust can be used to fill in area "B" with no



change in performance. I generally use a chlorate-charcoal burst charge (H3) in area "A" which is protected from direct contact with the stars by the use of a napkin liner. A perchlorate based burst can be used which doesn't require a liner. The formulas for these types of bursts are:

H3 BURST

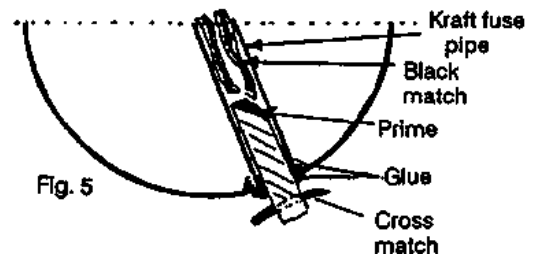
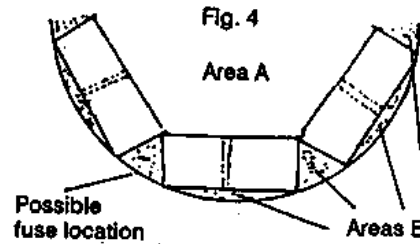
Potassium nitrate	75
Activated charcoal	25
Dextrin	3

PERCHLORATE BURST

Potassium perchlorate	75
Lampblack	25
Potassium dichromate	5
Dextrin	3

These burst charges can be coated on damp rice hulls or they can be dampened with about 15-20% water and pushed through a 10-mesh screen to give a granulated burst. Grain black powder is not recommended as a burst because it provides insufficient explosion force in shells less than 6" in diameter. Air float charcoal is not recommended in the H3 burst formula because the burning rate is too slow. Activated charcoal is available in any drug store or chemical supply house.

I load the stars in each hemisphere with one star placed in the bottom center and five stars around it. I mark a possible fuse location on the inside of the sphere with the stars in place as shown in fig. 4. I remove the stars and drill a 1/4" hole in the fuse location spot, then glue in a piece of time fuse cross-matched on the end external to the shell. The fuse should be cut on a slant 1-1/8" from the cross-matched position and primed with meal paste. Then I prepare a section of "fuse pipe" by rolling a tube made of three layers of 70 lb. kraft around a 1/4" dowel, using white glue. I slip the pipe over the fuse and cut the top off flush with the equator of the hemisphere as shown in fig. 5. I stuff short pieces of black match into the pipe as shown, then glue the pipe in place.



Now I reload the stars with the streamer composition end facing the center of the shell. I pack area "B" with sawdust or burst and then pack area "A" with burst charge. When the burst is packed flush with the top of both hemispheres I am ready to assemble the shell. I place a cardboard square on top of one hemisphere and flip it over while holding the cardboard tightly to prevent the contents from falling out. Then I place the two hemispheres together and slowly pull the divider out with the hemispheres properly lined up. I use strips of glued kraft paper to cover the equator, which will solidify the assembly when dry.

To wrap the shell I use about thirteen layers of 70 lb. kraft, using white glue for the first few layers or all the layers. The method of strip pasting was discussed in the chrysanthemum article. I make sure not to apply more than four layers at one time or the shell wall will shrink on drying.

When the shell is dry I glue a loop of string to the top of the shell, then glue a cone filled with 25 gm of 2FA lift to the bottom, over the time fuse. I cut a small hole in the cone for penetration of the exposed end of a quickmatch leader. I glue a strip of kraft paper over the quickmatch where it connects to the lift cone. Finally, I thread the quickmatch leader through the top loop and I am ready to fire the palm tree shell. DB

CHRYSANTHEMUM 6 & 8

This is an examination of the fundamental black powder compositions known as Chrysanthemum 6 and 8. A brief discussion of these compositions can be found in the Shimizu section of *Fireworks, Principles and Practice*, by Lancaster. The formulas are reproduced below. These formulas can be seen to be essentially black powder formulas which produce a charcoal stream when made into stars because of the excess charcoal in the formulas.

CHRYSANTHEMUM 6

Potassium nitrate	58
Charcoal, air float	35
Sulfur	7
Dextrin	5

CHRYSANTHEMUM 8

Potassium nitrate	52
Charcoal, air float	42
Sulfur	6
Dextrin	5

MANY USES FOR THESE FINE COMPS.

These compositions have several useful properties. They are cheap to make and when used as a priming layer for round stars will allow the star to remain ignited at the very high ejection speeds which are usually encountered in the first fractions of second after a round shell burst. With the single exception of glitter stars, all my round stars have a surface coating of Chr.6 of at least 1 mm thick to serve as a prime. Chr.8 has a slightly lower ignitability and burning speed than Chr.6 and will give a longer, thinner, charcoal tail. 15-20% Ferrotitanium alloy 100 mesh, can be added to Chr.6 to produce a brighter blond colored tail which lingers in the sky longer. The ferrotitanium mix can also be used to make large palm tree stars.

WHY & HOW I TUMBLE

Preparation of these compositions by simple mixing of the ingredients will produce unsatisfactory results. The composition will burn slower and produce few sparks. The charcoal particles must be intimately coated with potassium nitrate to allow each particle to function as a burning ember when it is ejected from the burning star.

I achieve the necessary intimacy of mixing by using a ball mill which is nothing more than a rock tumbler with some .50 caliber lead balls thrown in. A 12 lb. tumbler is capable of handling a 2 lb. batch of composition at one time. A 24 hour tumbling period is usually sufficient. These compositions are probably safer to tumble than black powder but I strongly recommend that the tumbler barrel and the composition be clean and free of any metal particles, chlorates or perchlorates to reduce the possibility of an explosion. The tumbler should be outdoors.

IMPORTANT TUMBLING TIPS

The tumbled compositions have good burning properties but I find them unsatisfactory for immediate use in making round stars. The extremely fine tumbler product will accrete to the surface of a wet round star but only small increments can be added in each successive layering operation during round star formation. The finished round star will take an extremely long time to dry out because of the hard compacted layers. These difficulties can be avoided by wetting the composition with 15-20% water after it comes out of the tumbler. Then I granulate by pushing through a 12 mesh screen. I dry the granulated mix in a shallow pan for 2 days. Then the mix is put back in the tumbler and turned for just a few hours to give a product that has the correct particle size distribution. The dampening also increases the intimacy of mixing by allowing the partly solubilized potassium nitrate to deposit microcrystals on the charcoal particles during the drying process.

Lacking a tumbler, a reasonable substitute for these compositions can be found by substituting commercial meal powder for the potassium nitrate. The compositions given below need not be dampened but the spark density of the tail will be somewhat reduced. See the formulations at the end of the article.

TRANSITION TROUBLES

The common use of these compositions in round shells is to produce a transition from a charcoal tail to a colored core. Layering these composi-

tions on colored cores, especially blue and purple ones, can lead to deterioration of the purity of the color. This is caused by the highly soluble potassium nitrate in the outer layer diffusing into the color core. The only way to control this problem is to dry the stars out quickly in the sun or applying the first few increments of Chr.6 or 8 with a 2% solution of nitrocellulose in acetone in a spray bottle as a binder. After the coated core has dried for a couple of hours the rest of the composition can be applied with the usual water/alcohol solvent spray. The color cores will be protected from aqueous diffusion.

Applying Chr.6 or 8 directly to a perchlorate/aluminum flitter core will not work as the mix is too cool burning to affect ignition of the high

temperature ignition core. It will be necessary to use an intermediate layer of igniter composition. I usually use a mixture of Chr.6 and perchlorate/aluminum as an intermediate layer.

COMMERCIAL MEAL D SUBSTITUTIONS

CHRYSANTHEMUM 6

Meal D	77
Charcoal	23
Dextrin	5

CHRYSANTHEMUM 8

Meal D	69
Charcoal	31
Dextrin	5

DB

PEPPY SHELLS

Regardless of his experience, every pyro is constantly looking for new or unusual effects. Here are a few ideas of mine on how to pep up an otherwise plain aerial shell.

The first thing most pyros put in shells besides stars is often Jumping Jacks. Well, I have mixed the Jumping Jacks with 30% by volume of good glitter stars. When the shell bursts you get a beautiful shower of glitter with the red and green of the Jumping Jacks darting about long after the flitter goes out.

The next popular thing to put in shells is serpents or more often, choked whistles. You can buy small 1/4" or 5/16" i.d. tubes, 1 1/2" long. I ram a little clay in one end then fill the rest of the tube with whistle comp., in about three rammed increments. If I want a ripping noise I use a small 1/16" drill bit and drill into the whistle comp. 1/2". If I want the jet type noise I simply ram the last 3/16" with clay and drill through the clay with a 1/8" drill bit just enough to reach the whistle comp. In all these cases I spray a little arts and crafts glue from an aerosol can on the surface of the whistle comp., and sprinkle a little 3Fg black powder on. This insures ignition when the shell bursts. I use 1% by weight of 40-mesh flake titanium in all my whistle comps. for a silver spray.

There are a number of other things you can put into shells but some Class C items are popular: Small Bees, Colourful Birds, Whistling Jacks, etc. I'd like to mention a few items I have tried. Happy Bees candles will let their insides pour out if you tap them upside down. There is no lift charge to make a mess. The little Happy Bees inside the candle are basically miniature Colourful Birds. A shell full of these babies is sure to stir up the crowd!

Another candle I take apart is the Liling Salute candle. This candle is more difficult to take apart. The easiest way is to cut a slit down the side of the candle tube, though not deep enough to reach the comp. It easily unrolls at this point. The stars (or whatever) are great in shells. You see a nice break of colored stars with multiple reports.

Another candle I think would work well but that I haven't yet tried is the Magnolia candle. It has stars which flower instead of explode.

By using a little imagination, a shellmaker can really pep up his shells with Class C or other small devices. Extra care must go into priming each device to insure ignition. I use either a black powder slurry daubed on the fuse or point of ignition, or I use my method of aerosol glue and 3Fg black powder. MB



AN EASY 5" DOUBLE PETALED ROUND SHELL

The description given here for a double petaled round shell is a simplification of the classical Japanese design.

Most double petaled commercial shells are 6 inches or larger with a concentric layer of burst charge packed between the inner and outer layers of stars. This layer of burst charge can be eliminated for simplicity and space considerations and the inner stars can be placed directly over the outer stars as shown in figure 4. The effect of this system of star placement on the appearance in the sky is to increase the size of the inner shell of stars relative to the size of the outer shell of stars. This technique does not impair the beauty of the visual effect as much as a conventional shell which produces too small an inner petal (i.e. with an inner petal less than 40% of the diameter of the outer pistol). The most attractive shells will be those that: 1) have perfectly spherical and concentric inner and outer petals; 2) use contrasting colors for the inner and outer petals; and 3) with the inner petal burning out before the outer petal.

I have tried building these shells by simply laying an inner layer of stars directly over the outer stars as in figure 3. Round stars rarely have perfectly uniform star diameter so it is next to impossible to construct a perfectly concentric inner shell as the illustration shows. Also I found it was difficult to place the inner petal stars over the uneven terrain of the outer petal stars. The inner stars tended to fall easily from their unstable positions during the filling process. The solution to this problem was to place the inner stars on a thin-newspaper hemispherical liner as shown in figure 4.

The construction of this shell requires a set of commercial 4" and 5" strawboard hemispheres. I wrap each hemisphere tightly in thin plastic wrap as shown in figure 1. The plastic wrap is tightly twisted in the center and taped down with scotch tape. Then I join the opposing hemispheres together to make a plastic wrapped sphere. The sphere is held together with pieces of scotch tape placed around the "equator". I construct the outer hemispheres by pasting two - 4"x11" strips of 40 lb. kraft covered with white

glue in the manner shown in figure 2. The two strips placed at 90 degrees will cover about 90% of the sphere's surface. After rolling the sphere on a hard surface to smooth out the first layer, the next layer is applied.

The process is repeated until I have applied 5 layers requiring 10 strips of kraft paper. Then I feel around the sphere until I detect the equatorial ridge underneath with my fingers. I cut through the equator with a sharp razor blade to separate the hemispheres. After drying overnight the hemispheres are easily removed from the form and separated from the plastic wrap.

The same technique is followed for the inner hemisphere construction using the 4" strawboard hemispheres except only 3 layers of newspaper is used. The newspaper strips are cut to 2 3/4" x 8 1/2". It is neither necessary nor desirable to make a strong inner hemisphere.

The final assembly of the shell begins by drilling a 15/16" hole in the bottom center of one of the 5" hemis. Then I glue in a cross matched Japanese time fuse. A fuse tube made from one wrap of 70 lb. kraft paper (3/8" x 2" long) is glued down over the time fuse. Then I fill both 5" hemispheres with the outer stars. These stars must have a diameter between 12 and 12.5 mm to fit in properly. The inner petal stars are usually around 10 mm, made from a quick burning color composition. I drill a 3/8" hole in the bottom center of the newspaper hemi and push it down over the time fuse tube as shown in figure 4.

After both inner hemispheres are in place I fill them with inner petal stars. A piece of tissue is pushed down on top of the inner star layer. Because the very top row of inner stars has a habit of falling down during this step, it is often easier to omit the placement of the very top layers of stars until the burst charge is in place.

The burst charge consists of rice hulls coated with 4 times their weight of ball milled or commercial meal powder. I sprinkle 6 gms of flash powder (potassium perchlorate 7, aluminum bright flake 3, sulfur 1) throughout the hulls as they are being loaded.



I have discovered that a mixture of rice hulls and flash works better than confining the flash to a bag around the time fuse as nearly instantaneous ignition of the flash is achieved. It is important to pack this burst charge down firmly to eliminate rattle.

I use a 5 x 5" piece of cardboard or thin plastic sheet to cover one hemisphere to allow me to flip it over without the contents falling out. When the two hemisphere are placed over each other and properly lined up I slowly withdraw the divider. The outer hemispheres are joined with pieces of glued kraft paper and allowed to dry.

The outer wall is pasted in the conventional manner using 1 3/4" x 5 1/2" pieces of kraft paper. It will take 8 pieces to paste in one layer. Eight layers are required using 70 lb. kraft and twelve layers using 40 lb. kraft. I generally use slightly diluted Elmer's glue for pasting which will allow four or five layers to be applied at one time. I allow it to dry for 24 hours before applying the next set of layers.

The shell is lifted in the usual manner with 42 gms of 2Fg black powder. If I use 2FA for lifting, it will need more than 42 gms. DB

ADDENDUM

In the discussion of the burst charge above, I mentioned the use of flash powder sprinkled in the meal coated rice hulls as a good alternative to the chlorate or perchlorate based burst charges. I would like to recommend the use of whistle mix (potassium perchlorate 70%, sodium benzoate 30%) as an alternative to flash powder. Tests of several pairs of identical shells in the 4" and 5" sizes, with one using flash and the other whistle mix break, showed that the whistle mix break charge indisputably gave the best symmetry as shown in still and movie photos of the break. I found that 4 gms of whistle composition mixed with meal coated rice hulls was best for a 4" round shell and 8 gms was optimum for a 5". I plan to discontinue the use of flash powder in the future. Many professionals have had good results using whistle mix to break their cylinder shells and it seems especially suited for plastic shells.

DB

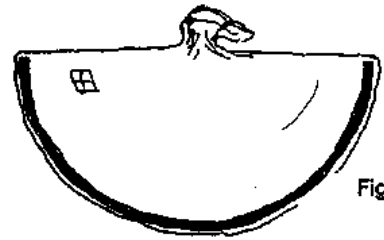
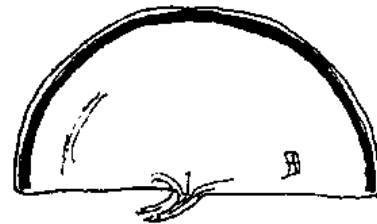


Fig. 1

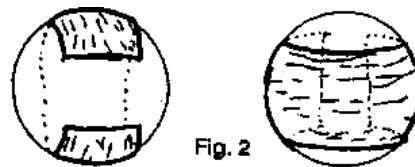


Fig. 2

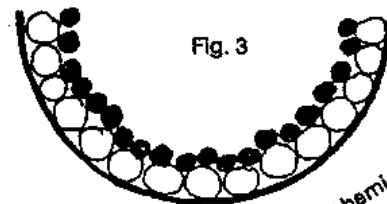


Fig. 3

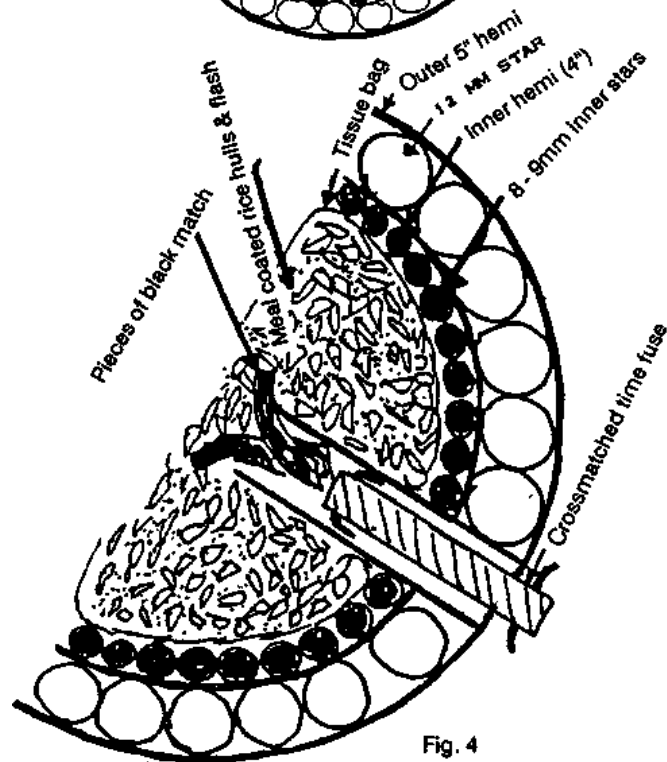


Fig. 4



6" DOUBLE PETALED ROUND SHELLS

There comes a time in the life of the round shell builder when boredom with the limitations of the single petaled shell becomes manifest. Given the fixed number of distinct star types and transitions that can be fabricated, you eventually reach a point in your shell building where repetition begins to set in. The double petaled shell offers a way out of this quagmire and an enhancement to a new level of beauty in your displays. Well made double petaled shells are infrequently used in most commercial displays because of their much higher cost. To witness the best of the effects possible with double petaled shells, it will be necessary to fabricate your own.

The method I use is presented here. It is by no means the only construction technique. It is especially suited for use with plastic shell casings. Other methods, such as the Japanese Nikoshin construction, are specific for use with strawboard hemispheres and are much more time consuming. Their principal advantage over the method described here, which uses two completely filled hemispheres which are mated together, is the absence of the gap of stars between the two hemispheres. The gap of "missing stars" will be noticeable to the observer when certain unfavorable viewing geometries occur. This effect is aggravated by the use of overly large stars. Apart from this aberration, I can see no other advantage to the vastly more laborious Japanese methods.

Six-inch plastic shell casings are recommended for ease of construction. Five-inch diameter cases can be used but present a more cramped environment. The illustration shows a cross section of a 6" shell using 4" newspaper hemispheres to hold the inner petal stars, I use two 4" strawboard hemispheres wrapped in stretchable plastic film and scotch taped together as a form to paste wide strips of newspaper smeared with white glue. Only about 3 or 4 layers of newspaper strips are used. The shell is rolled on a hard surface to smooth out the strips on the sphere. I use a razor blade to cut through the damp paper exactly at the intersection of the hemispheres. The separated hemispheres are allowed to dry overnight before peeling off. A 5" shell will require the use of a 3" strawboard hemisphere as a form.

At this point shell construction can begin. I cut a piece of 1/4" diameter Japanese time fuse 1 3/4" long and punch two holes for the thermolite crossmatch. The holes should be VA to 1-3/8" apart for proper timing. The fuse is hot glued to the hemisphere on the inside and outside. While the hot glue is still soft on the inside, I push a lance tube over the crossmatched inner fuse. The lance tube is then cut at the top of the hemisphere. Then I sprinkle 2Fg black powder into the tube until it is filled to the top. A tiny piece of newspaper is white glued to the top, sealing the black powder in. I would not recommend using homemade black powder in the fuse tube as it is not fast enough and will result in the shell opening prematurely with a disturbed burst pattern.

Now both hemispheres are placed on stands to support them for loading. I use 5/8" stars for the outer petals and load them along the wall until they reach within one inch or so from the top in both hemispheres. I punch a small hole in a piece of kleenex and push it down over the fuse tube until it rests on the layer of stars in the bottom.

The burst charge for the outer burst is the same as the inner burst charge and is composed of black powder pasted on rice hulls. I recommend again using commercial meal if possible as that seems to give the most consistent results. Black powder by itself is not energetic enough to open the shell big enough so I usually weigh a quantity of prepared rice hulls in a plastic bag and add 7% by weight of whistle comp, shaking it vigorously to coat the black hulls with the white powder. Then I spoon in this burst charge so it fills just a small area near the bottom of the shell around the fuse.

A 3/8" hole is cut in the exact bottom of one of the newspaper hemispheres. This hemi is pushed over the fuse tube until it rests on the rice hulls. It is necessary to check that the level of hulls is correct so that the top of the newspaper hemi does not rise above the edge of the hemisphere. The other shell half is partially filled in the same manner. Filling with the rest of the burst charge must be done by carefully, pushing the burst charge in the area between the burst bag and the newspaper hemi. Once the burst charge becomes



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filled near the top, the rest of the outer stars can be wedged into place.

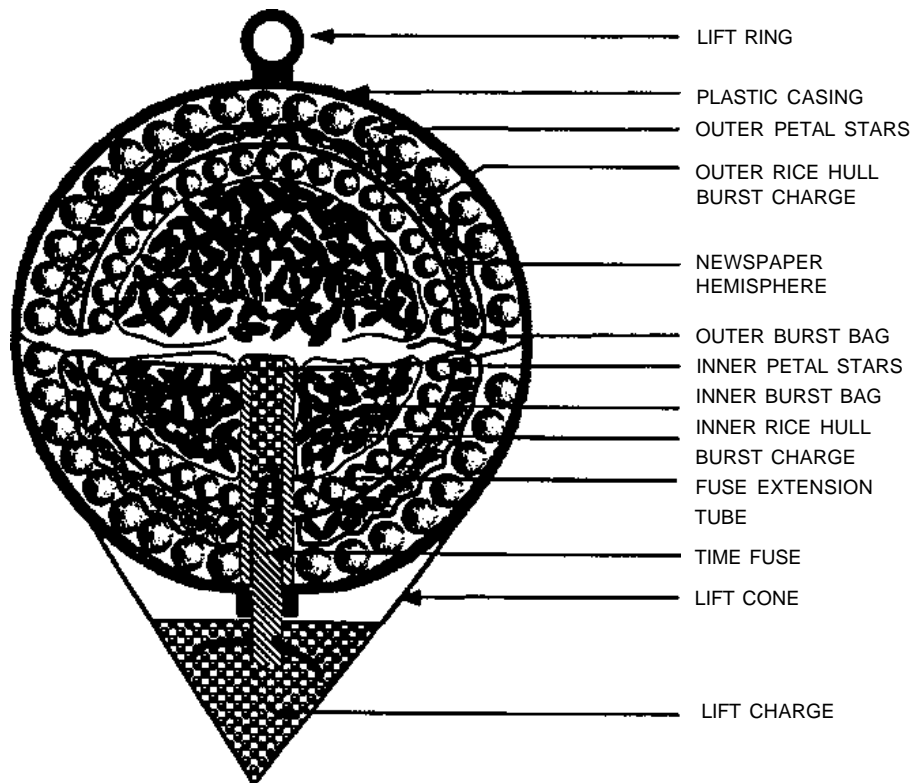
For the inner petal stars, I generally use 3/8" diameter single colored stars. These stars are loaded into the inner hemi within one inch from the top. Now two more pieces of kleenex are used to cover the inner stars and keep them separated from the inner burst. The burst charge can now be dumped into the kleenex bags and tamped down. When the center halves are nearly full, I can add the rest of the inner stars to bring them flush with the top. When both halves are completely filled it is a good idea to tap the outside of the hemispheres to settle and set the contents.

Now comes the moment of truth. I take a thin cardboard square and place it over one of the hemis and hold it with one hand on each side as I carefully turn it upside down. The two halves are centered over each other and the cardboard is slipped out slowly. The hemispheres can now be pushed together but I don't quite close the lip so solvent can run in the crevice., I usually use chloroform but PVC solvent can also be used for good bonding.

I made a special clamp for compressing the shell together while the seams are drying. When dry the plastic lift loop can be glued in with solvent. I don't put the loop in before loading as the shell often needs an air escape for proper seating.

At this point all that needs doing is to measure out about 80gms of 2Fg black powder for the lift which goes in a cone shaped drink cup that is hot glued on the outside of the hemisphere as shown in the illustration. Now I can attach a leader and it's ready to fire.

The inner burst radius as a percentage of the outer burst radius should be directly related to the fraction of the inner and outer radii of the two star layers of the shell itself. So if you desire a smaller inner petal, it will be necessary to use a smaller newspaper hemisphere. I feel a 3" inner hemisphere is too small to give a good aesthetic effect so I am forced to use the 4" inner hemispheres, as I have no forms to make a 3 1/2" newspaper hemisphere. DB



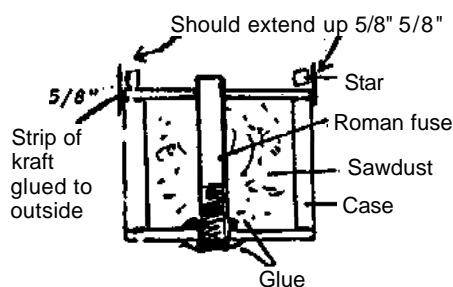
AN EASY RING SHELL

A 4" ring shell is surprisingly easy to construct. It produces an expanding ring of stars in the sky that is most pleasing to watch. Ring shells are rarely used in public displays because of their high cost - up to \$60.00 for a 6" shell. I can make one in a 4" size for only a couple of dollars and an hour or so of work.

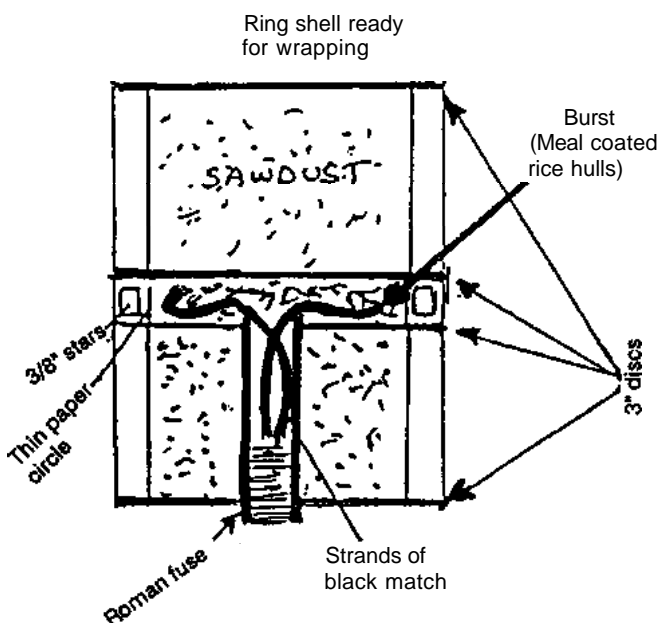
A ring shell is nothing more than a modification of a cylinder shell. The container is made from a 4" salute casing which measures 3 1/2" o.d., 2 1/2" i.d. and 4" long. I cut the case in half to produce two sections 2" long and glue a disc with a 1/2" center hole to the end of one section. Then I prepare a 1/2" o.d. Roman fuse in a 2 1/2" long tube. The Roman fuse should have about 1 1/4" of hard packed composition at one end to give a 4 1/2 second time delay. I glue the Roman fuse to the disc, sliding it so the fuse end sticks out about 3/8" beyond the surface of the disc. I put a filet of glue on the inside of fuse junction to prevent blow-through from the lift charge. Now I fill the case with sawdust flush to the top, then slide another disc with a hole over the Roman fuse and glue it to the top of the case. The bottom section of the case is finished and should look like the bottom section of the diagram. I glue a strip of kraft paper 1" wide by 11" long around the top of the finished case section so that it completely encircles the outside of the case but only 3/8" of the 1" strip is glued with the rest protruding up. See diagram.

This strip creates a wall encircling the top of the bottom section. Then I install a circle of 25 3/8" pumped stars on the disc so that all stars are touching the kraft wall. I push a couple of strands of black match into the Roman fuse hole and bend them flat against the disc as shown in diagram 2. To keep the stars from falling into the center of disc, I cut a newspaper 3/8" wide and make a circle just big enough to create an inner wall next to the stars and glue the inside edges carefully. Next I add the burst charge - I use rice hulls coated with meal - and fill it until it is even with the top of the stars or the inner wall. Now I place another chipboard disc on top and glue the top section of case to it.

Then I fill with sawdust as before and glue the top disc on. Now the shell is ready for wrapping as usual for a cylinder shell. I glue the first wrap to the case firmly and continue with about nine complete turns of heavy kraft. The finished shell weighs about 1/2 lb. and takes about 40gm of 2FA powder to lift it. DB



Bottom Section





RING & CHARACTER SHELL CONSTRUCTION

PART 1

Both round and canister shell makers strive for as large a burst radius as possible in their shells. The apparent burst radius depends on a complex of factors: a) the distance of the burst from the ground; b) the thickness or strength of the shell wall; c) the explosive force, burning speed and amount of burst charge; d) the duration of burning of the stars. The skillful shell maker knows how to manipulate these factors for the desired effect.

A properly adjusted chrysanthemum burst is one in which the stars develop radially outward in straight lines from the center of the shell and burn out just as the star trajectories begin to curve under the influence of gravity. If the stars curve downward before burning out then you have the well known willow-tree effect.

When I first noticed that my 4" chrysanthemum shells were developing noticeably less than the burst radius of commercial Japanese shells I assumed that only the shell wall thickness needed to be increased by adding a few more layers of Kraft wrap.

This resulted in loss of star ignition and a change from a burst to a detonation which pulverized the stars into dust. This test demonstrated that the previous wall thickness was already close to optimum. The problem was with the burst charge itself. The burst used was rice hulls coated with meal powder. This burst is only adequate for shells of 6" or larger. Meal powder has a fast burning speed but it has only half the force of explosion of chlorate or perchlorate burst formulas. To circumvent the problems with the sensitivity of chlorate bursts and the slow burning speed of perchlorate-charcoal burst formulas I chose the following formula which was developed and tested by K. Takada and Y. Kinsei of the Hosoya firework Co. in 1967.

Because of the use of a very finely divided fuel, lampblack, the burning rate is very high. This mix has a greater value for the force of explosion than black powder because of the greater volume of gas produced per gram of reactants.

#46

Potassium perchlorate	75%
Lampblack	25%
Potassium dichromate	5% (add.)
Dextrin	2%

The method I use to prepare this burst is different from the Japanese slurry technique, first I screen the weighed ingredients three times through a 30-mesh screen. I weigh out an amount of rice hulls equal to 1/5th of the weight of the prepared burst powder. I soak the rice hulls in hot water for ten minutes, then strain off the excess water and dump the hulls in a plastic bucket with a top, add about one-half of the burst powder to the bucket, put the top on tight and shake vigorously for about thirty seconds. Then I add more powder and repeat until the hulls appear to be getting dry and are not picking up any more powder. Now I spray with a mist of water from an atomizer while shaking to keep the wetting uniform. Now the remainder of the powder should adhere to the hulls with no problem. I allow to dry completely, remembering that lampblack mixes take longer to dry than charcoal mixes. When dry, I test by lighting the end of an individual hull in a safe place. It should take off and fly around for about five feet like a rocket. This mix has the advantage over chlorate versions because the burst is safe to mix with chlorate stars and stars which contain sulfur or sulfides. It is not as safe as black powder-coated hulls, however. The cost of hulls is much lower than black powder-coated hulls. When used in chrysanthemum shells with stars of two-second burning duration, one should notice the difference in both an improved burst radius and professional looking symmetry.



INTRODUCTION TO RING OR CHARACTER SHELLS

Once I was satisfied with the symmetry of my chrysanthemum shells, I thought, why not take on the challenge of making ring or character shells? The only real difference between a character or a ring shell and a normal chrysanthemum shell is that in the former all the stars are missing from their places inside the shell except for the ones that form the "connect the dots" image in the sky. A 4" ring shell simply has about 25 stars in a ring along the shell wall. A character shell has the stars arranged in the form of a letter on the inner face of one of the hemispheres. Unfortunately, the character often appears upside down or sideways in the sky!

To load these shells with stars it is only necessary to constrain the movement of the stars inside the shell wall so that they don't stray from alignment during handling. I prepare a set of thin Kraft paper hemispheres using just two thicknesses of Kraft (30 lb. for first layer and 60 lb. for second layer).

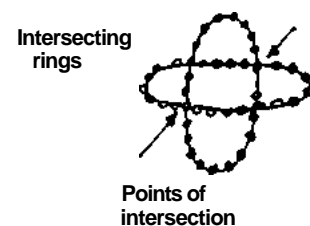
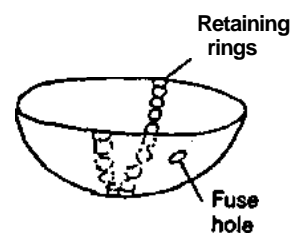
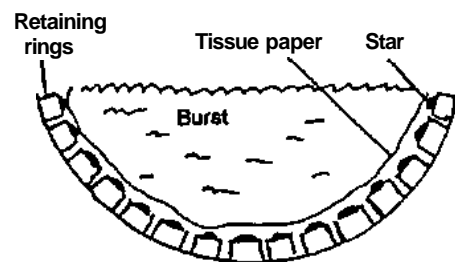
It's a good idea to leave the newly completed hemi's nested on the 4" Japanese hemi formers for a day or so until they dry completely, otherwise they will dry out in an elliptical shape.

I keep in mind that the thinner the hemi the better the symmetry in the break. I prepare a Kraft paper tube using one layer of 60 lb. Kraft on a former that is just slightly larger than the star size. I cut this weak tube into ring "segments" with scissors so that the length of the ring is equal to or slightly less than the star diameter. These "retaining rings" are lightly glued in a straight line on the inside of the hemi as shown in the illustration. The retaining rings have to be fairly flimsy so that they do not alter the wall strength of the shell.

Star ignition becomes an important consideration in ring shells and character shells. If a chrysanthemum shell has only a 75% star igni-

tion it is barely noticed by the casual observer. In a ring or character shell almost every "dot" in the pattern should be lit or the effect suffers. Extra heavy star priming is strongly recommended for these shells. DB

Notice that the fuse hole is moved off to one side of its usual position of bottom dead center so that it misses the row of star holders. I prepare the fuse, slip the stars in the holder and just lay a piece of tissue paper over the row or half ring of stars in each hemisphere. I am sure to mark the points on the equator of each hemisphere where the ring ends so that the two halves will be joined up properly. I fill the shell with #46 burst firmly and finish off in the usual manner. Intersecting rings of different colors give a nice effect as well as opposing rings, one in each hemisphere. A good ring shell will produce a ring of stars all moving or expanding outwards at the same velocity and all equidistant from each other. DB





RING & CHARACTER SHELL CONSTRUCTION

PART 2

The last article gave a short introduction on Japanese-type ring and character shells. These shells are simply modifications of the standard chrysanthemum or peony design using paper collars to hold the stars in the proper positions for the intended design. I should emphasize that the methodology given in this series of articles does not necessarily represent the actual Oriental technique (which is unknown to me) but simply a method that I have found to be successful.

The million dollar PL fireworks show in Osaka features character shells in their display. These shells project into the sky entire Japanese and American characters, according to an eyewitness report from George Plimpton. Unfortunately, proper functioning of these shells depends not only on skilled construction but also on plain luck. More often than not the projection letters will come out upside down or sideways from the viewpoint of the observer on the ground. Another disadvantage of these shells from the amateur viewpoint is that a 5" shell is about the minimum that can be used to create a "letter". Naturally, only a portion of one hemisphere can be used to place the stars that define the letter.

I generally experiment with star patterns that are not as sensitive as letters to orientation in the sky, and can be constructed in a 4" shell. I would recommend the beginner to start with a simple ring of stars placed in collars traversing both hemispheres as previously described.

It will usually be necessary for the beginner to find the optimum number of layers of pasted kraft paper for his shell configuration. Taking a snapshot (not a time exposure) of the shell shortly after its burst will furnish three pieces of important information: 1) The extent of star ignition; 2) The degree of uniformity in spacing between the stars; 3) The degree of radial symmetry, i.e., how equidistant the stars are from the center. Once you are satisfied with a simple ring performance you can proceed to more complex patterns.

Recent experiments I performed have shown that a significant improvement in symmetry results from the use of "blind" stars in these shells. Blind stars are made by using finely powdered clay and lead shot to form round stars. Pumped clay stars will work fine as long as each pumped star has a height equal to its diameter. The sequence of shell assembly changes slightly from the description given last month. 1) I draw lines denoting the star pattern inside the hemisphere(s); 2) Glue thin kraft collars over the lines; 3) Glue in time fuse; 4) Fill the collars with stars; 5) Fill the remainder of the hemisphere with blind stars; 6) Push a circle of tissue paper into the hemisphere and fill with rice hull burst; 7) Assemble the completed hemispheres, being careful to line up the two hemispheres if the star pattern of the upper hemi connects to the lower. The reason for the symmetry improvement becomes evident when you consider that when not using blind stars the burst charge gets packed completely around the stars in the collars. A straight radial motion is imparted to the star only when the gas pressure push from the burst charge comes entirely from the rear of the star. Also by using blind stars you save on burst charge which would otherwise be wasted.

It is recommended that when making these shells to use many layers of medium or thin kraft paper on the outside wall. Sixteen layers of 30 lb. kraft will give better radial symmetry to your stars than eight layers of 60 lb. kraft. The use of many thin layers gives a more uniform wall strength because the local wall thickening from overlapping strips is averaged out.

There are many designs that can be created with these techniques which give interesting effects that are not overly sensitive to orientation constraints. A Saturn shell is a ring shell with two large comet stars (usually of glitter composition) which are projected in both directions along the central axis of the ring. The comet stars simply sit in collars located 90° from the plane of the ring stars. A spiral shell can be made with stars placed in a spiral pattern in one or both hemispheres. DB

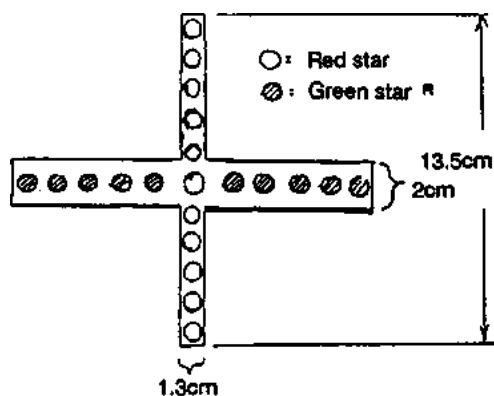


INTERSECTOR SHELL UPDATE

A while back in a previous AFN article I described a method of using a round shell to project two intersecting rings of stars. Perfecting this type of shell has become an obsession with me ever since. Over the last year I have simplified the construction methods and improved the performance considerably.

The current method of construction of a 4-inch intersector begins with the formation of a set of hemispheres. I make the hemispheres by pasting four layers of 40 lb kraft on a plastic wrapped set of commercial hemispheres. The hemisphere construction method was discussed in detail in a previous article on Palm Tree Shell Construction.

Then I cut two "crosses" out of ordinary typing or graph paper as shown in the illustration below:



The crosses should be placed on a flat surface of glass or plastic to prevent sticking during the gluing step. I select, from a batch of round red stars, 22 stars having a diameter of 11 to 11.5 mm. Using stars of poor size uniformity will not produce a good ring as the heavier stars will not travel with the same speed as the lighter stars.

Then I dip the bottom of the red stars in a solution of 10% nitrocellulose in acetone and glue them in a straight line on the paper, maintaining equal spacing between stars as shown in the diagram. The process is repeated for the 20 selected green stars which are placed on the wide strips of the cross. I make sure not to glue the stars down right next to each other on the paper, as the crosses will not be able to conform to the

inside of the hemisphere. The nitrocellulose glue dries in about ten minutes and will not interfere with the ignition or burning of the star.

The hemispheres I make have a mark on the outside, located on the edge, which helps me to line them up during final assembly. The mark also serves to line up the crosses of glued stars so they will be in the correct orientation when the hemispheres are joined. I pick up the crosses and lay them in the hemisphere so that the red star row is aligned with the outside mark of the hemisphere. I don't glue the crosses in as I have found that it causes interference with the star projection symmetry. When properly oriented, all the ends of the cross will be even with the top edge of the hemisphere and the top stars will be flush with the edge of the hemisphere.

I drill a 15/64" hole in the center of one hemisphere in one of the triangular-shaped areas and glue in a time fuse. Now there are four triangular-shaped areas devoid of stars in each hemisphere. I fill these with round "blind" stars made with a mixture of clay and 5% dextrin.

To finish the shell I put a paper napkin liner down into the hemispheres, taking care not to disturb the stars, then push a piece of thermolite through the crossmatch hole in the time fuse.

Now the key to getting good symmetry is to use a strong burst charge and a weak shell wall. After a great deal of experimenting I have found two burst charges to give good results:

1) H3 on rice hulls, using a ratio of 5 parts H3 to 1 part rice hulls (I use activated charcoal to give a fast burning speed but a mixture of lampblack and air float 1:1 works just as well).

2) "Hot H3", which consists of potassium chlorate 67 parts, aluminum German black 4, charcoal 29 and dextrin 2. The Hot H3 is used on rice hulls in a 4:1 ratio. It seems to have improved star ignitability over regular H3 burst.

After filling the napkin inserts with well packed burst, the hemispheres are assembled with the



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help of a 4 1/2" square plastic sheet covering one hemisphere. It is to prevent the stars from falling out when it is flipped over for joining to the bottom hemisphere. The marks on the outside of the hemisphere are lined up and then I pull out the plastic divider. I trim the excess napkin hanging out and carefully join the hemispheres with glued strips.

Careful pasting of the sphere is important to achieve good performance. I use 1 1/4" x 4 1/2" strips of 40 lb. kraft and use slightly thinned white glue for paste. Eight strips are put on evenly around the sphere to form each layer. I roll the shell on a hard surface to smooth the strips down. After four layers are applied I allow the shell to dry before putting on more layers. The optimum number of layers seems to be 12 for the 5:1 H3 and 14 for the "Hot H3".

PLASTIC BALL SHELLS

A couple of years back I had experimented with 2-5/8" diameter plastic ball shells. They are easy to use and assemble but I was never very happy with the burst pattern obtainable from them. A reader wrote last month and reported success in using these plastic shells. He lines the walls of the plastic hemispheres with 3/8" pumped stars. The fuse he uses is standard green visco which is cut at a sharp angle at both ends and glued into the hole provided. He cuts up pieces of black match and places them around the end of the time fuse to insure good ignition. Then the central area of the hemispheres is packed with rice hulls coated with H3. He then joins the two hemispheres and wraps them with glued strips of 70 lb. kraft paper, using a total of six layers. He says a good, wide symmetrical break is achieved and he has experienced no failures in two years.

DB

USING STRAWBOARD CASINGS

Round shell makers at the convention have informed me that they achieve good symmetrical breaks using the strawboard hemispheres imported from Japan. I must confess that I have never used these hemispheres to construct chrysanthemum shells but have used the chipboard hemispheres made here. Although the chipboard hemispheres are considerably less expensive than the imported variety, I have trouble

making them fragment properly as they seem to be too hard and thick. This problem led me to design a method (discussed in previous article on Palm Tree Shell Construction) for the construction of my own hemispheres using shell cases as forms. For those readers interested in using the expensive but convenient strawboard hemispheres I have presented a table below of data submitted by T.G.

Radius of hemispheres	No. of layers of 70 lb kraft paper needed	Type of burst charge used
4 inch	6	Granulated H3 burst
5 inch	8	H3 on rice hulls (3:1) *
6 inch	10	Shimizu #44 burst 3:1 on rice hulls
8 inch	14	Same as above
* 3 parts burst charge composition to 1 part by weight of rice hulls		



REDUCING SHELL IGNITION FAILURE

A shell ignition failure means there will be a live dud in the fallout area after a display. If that dud is not retrieved, is found by a member of the public, and that person is subsequently injured as the result of mishandling the dud shell, an insurance claim against the shooter and manufacturer will almost certainly result. This article presents a discussion of one method which can result in a significant reduction of the number of shell ignition failures.

For the purposes of this article, an ignition failure is any cause or series of causes that results in fire failing to be passed from burning lift gases to the pyrotechnic contents of the shell via a fuse or similar device. This includes:

- * The fuse failing to take fire from the burning lift gases;
- * The fuse failing to burn continuously;
- * The fuse failing to successfully transfer fire to the shell's contents.

Each of these general causes can be further broken down into a number of more specific causes. However, it is not the purpose of this short article to present a discussion of the relative merits of priming vs. cross-matching, cutting fuse perpendicular vs. cutting it at an angle, using fuse vs. using spoolettes, etc. Those are important considerations, but, because of the many variations in technique, each of which can affect the results achieved, that discussion is beyond the scope of this article. We shall discuss a simple technique that is routinely utilized in many fields of endeavor when it is necessary to reduce failure rates. The technique is redundancy, in this case the use of two time fuses on an aerial shell. This is not a new idea; it has been used in this country and abroad for many years, but is not commonly done. With manufacturers under increased products liability pressure, and with many amateurs seeking short-cuts to priming and cross-matching, perhaps this approach is worth further consideration. This is because the reduction in the rate of ignition failures may be considerably greater than might be expected. To understand why this can be the case, it is first necessary to delve a little into Probability Theory.

Probabilities are expressed as numbers ranging from zero (0) to one (1). If the probability of something happening is zero, then it will never happen, ever. On the other hand, if the probability is one, then it will happen every time, always. Obviously, for most things, the probability is somewhere in between. A probability of 0.5 (or 1/2) means it will happen one-half of the time (one out of two times). A probability of 0.75 (or 3/4) means it will happen three-quarters of the time (3 times out of 4).

If the probability of something happening is P , then the probability of it not happening is $(1 - P)$. In the last case above, when the probability of an event happening was 0.75, the probability of not happening is $(1.00 - 0.75)$, which is 0.25.

If the probability of one thing happening is P_1 , and the probability of a second thing happening is P_2 , then the probability of both things happening is $(P_1 \times P_2)$. Take as example a coin flipping. When flipping a single coin, the probability of getting "heads" is 0.50. When flipping two coins, the probability that both will be heads is (0.50×0.50) , which is 0.25.

In order to apply probability theory to the problem of aerial shell ignition failure, it is first necessary to establish the probability of experiencing an ignition failure when using a single time fuse under a fixed set of conditions. A mediocre performance might be considered to be one in which 1 out of 100 shells is a dud, which corresponds to a probability of 0.01. A good performance might be considered to be one in which 1 out of 1,000 shells is a dud, a probability of 0.001. Perhaps the very best that is achievable is when 1 out of 10,000 shells is a dud, a probability of 0.0001. Now consider the case where the same technique is employed that resulted in a mediocre probability of ignition failure of 0.01 for a single time fuse, except that a second identically prepared fuse is used in addition. In this case, the probability of both fuses failing to ignite the shell is (0.01×0.01) , which is 0.0001. That is a 100 fold reduction in the probability of ignition failure, and is the same as had been defined above as the very lowest failure rate achievable.



In addition to the little extra time and the very little extra expense associated with using two time fuses, are there any other costs? The answer is yes; there is an increased probability of shell failure due to fire leaks from the presence of the second fuse. Again, in order to determine the increased probability of fire leaks resulting from the use of a second time fuse, it is first necessary to establish the probability of a fire leak occurring around a single fuse. A mediocre performance in this area also probably corresponds to a failure rate of 1 out of 100, a probability of 0.01. If this is the probability of a fire leak occurring around a fuse then the probability of no fire leak occurring is $(1.00 - 0.01)$, which is 0.99. If two fuses are used, the probability that there will be no fire leak around either fuse is (0.99×0.99) , which is 0.98; which corresponds to a failure rate of $(1.00 - 0.98)$, which is 0.02, a two fold increase in the rate of failure. At this point, the question is whether it is an effective trade-off to achieve a 100 fold reduction of ignition failures at the expense of a 2 fold increase in fire leaks around fuses. However, before considering this, it is appropriate to point out that there are other ways besides leaks around time fuses that fire can leak into the contents of an aerial shell. Thus it should not be assumed that, because there is a 2 fold increase in the number of fire leaks around the time fuses, there will also be a 2 fold increase in the number of fire leaks from other sources. That is to say, there will not be a 2 fold increase in the number of "flowerpots" experienced as a result of using two time fuses. Further, if chlorate-based stars are not used, if the shell is not a salute, and proper firing safety practices are followed, the consequences of the fire leak is likely to be a rather harmless flowerpot. All things considered, a number of manufacturers seem to have concluded that it is an effective trade off, particularly for larger shells. The authors have seen Oriental shells with three time fuses, and have heard of shells with four fuses.

(Note: KSI has offered two hole end disks for aerial shells for about eight years. From time to time, the question has been asked as to why. In part, this article is in response to those questions). KK/BK

THROW AWAY THAT TIME FUSE

I have only been a real PYRO for about 20 months now, yet I think I have come up with an idea to reduce duds.

When I first got into making my own shells, I neglected to order time fuse, so I had to improvise. I hadn't heard of Roman fuse, so I decided that green visco fuse would have to do. I cut various lengths and timed them, but noticed that they seemed to throw sparks out the side. That wouldn't do as those sparks might ignite the burst charge too soon. I decided to try wrapping the fuse in masking tape. It worked and wasn't that much of a bother.

I use 3/4" masking tape about 2" long. I cut the visco 1" long and roll the tape as uniformly as possible around it, leaving 1/8" sticking out both ends. That's all there is to it. I use it in all single break shells; the lift charge will ignite it and I use a loose break charge.

I have used this improvised fuse in round shells as well as canister and R.A.P. shells. With R.A.P. shells the fuse hole is 1/4", and more tape is needed to fill it.

Additional advantages are: 1) The tape protects the visco from water based glue, hot melt glue, methylene chloride (in R.A.P. shells), epoxy, and silicone seal. The same can't be said about 1/4" time fuse; if hot melt is used, the asphalt layer could melt into the core and stop ignition. Also if too much methylene chloride is used, the asphalt could dissolve and migrate into the core, doing the same. 2) There is no need to cross match, however if I feel a prime is needed, I just dip the ends into a meal slurry and then dry powder. The cross matching of 1/4" itself can be the cause of ignition failure if not done properly.

My next project will be a 2-break shell. Maybe one break bottom fused, the other top fused using 1" masking tape and 1 1/4" visco or maybe a little longer. The way I see it, pyrotechnics is only limited by the imagination. JC



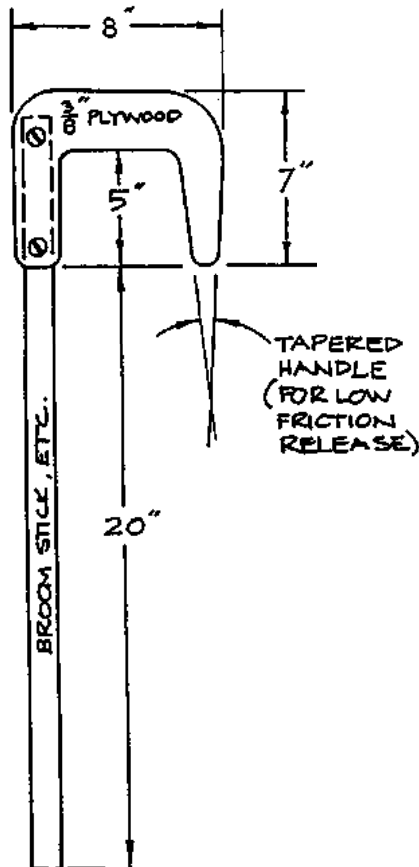
TAMPING STICK FOR MORTARS

Here is my suggestion for an offset mortar tamping stick.

I came up with this idea because I felt uneasy about reloading 3" shells during manually fired shows since some shells always seem to stick half way down into a hot gun and I didn't like to put my hand over the muzzle to tamp them down with a tamping stick. This stick allows you to push the shell fully to the bottom of the pipe, yet your hand will never pass over the top of it.

I don't know for sure if the tapered handle allows for a lower friction release from your hand than a straight handle, should the shell fire. But I would just as well prefer not to find out the hard way.

The 20-inches of usable stick length allow it to also be used to check 4" finale racks for misfires after a show. EMcC



PUSH STICK AIDS LOW BREAKS

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

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

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

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

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

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



THE DREADED DUD

Anyone who has operated a public display and experienced the frightening embarrassment of seeing the tracer sparks of a fired shell die, knows the dread of a dud shell. Several thoughts race through one's mind: ...will it break low? (probably not if the fuse died) ...will it come down and hit someone? (ME?) ...feet, do your stuff! ...shush! I wish the spectators would stop booing so I can hear where it lands ...Oh God, I pray no one gets hit ...here it comes ...no car roofs please ...THUMP! Phew! On the ground safely! ...get another shell up quickly ...find it at all costs later! ...can't let anyone get it, especially children!

Then after the show you find the dud or maybe you have to return at daybreak to search. All the time you are looking, new thoughts creep into your head: was it only an isolated case or are there more? ...only this type of shell or random throughout the inventory? ...Why? ...What caused it?

This subject has played on the minds of shell makers, professional and amateur alike, for as long as aerial fireworks have been made. Yet very little has been written on the subject. Many have isolated the problems and now avoid the causes, with varying success, including this writer. Others are still perplexed and curious.

We will examine some of the apparent causes of the dreaded dud and what some shell makers are doing to avoid the problem. The purpose will be to present and share varied opinions objectively so that readers may form their own opinions and conclusions, or investigate further this controversial subject.

If we broadly define a dud shell as the result of a malfunction that caused the shell to deviate from normal performance or intended design during lift (firing), then we can identify duds in four categories:

1. The "flower pot" effect.
2. Time delay (TD) fuse ignition failure.
3. TD fuse failure after ignition.
4. Shell internal ignition failure after TD fuse burn through.

The "Flowerpot" Shell

The flowerpot shell gets its name from the visual effect of a giant flower bouquet. From the launching mortar, the observer sees a vertical blast of colors in a column which spreads to create a flower bouquet pattern. The cause was the shell exploding in the mortar or within a few feet of the mortar's muzzle. If the shell was a salute or contained flash report effects, a real danger of the mortar exploding is a possible consequence. (A good practice of many experienced display operators is to shoot ordinary flash salutes (aerial maroons) only from cardboard mortars). There have been many factors or perhaps combinations of factors observed which are possible causes of the flowerpot shell. Some of these conditions are as follows:

- Too much black powder lift charge can release excessive shearing forces around the shell that tear at the shell edges, exposing the shell contents to the lift flame. It has also been suggested that the rapid acceleration of the shell causes compression of the shell contents (set back) against the shell bottom, creating interior shear. Another possibility is set back compression, friction or impact, causing stars to collide and ignite, especially with chlorate stars.

- Lift charge particle size may be too small. Generally, 2FA grade black powder is used to lift cylinder shaped shells that are 2 1/2" in diameter or larger. Smaller grain powders burn quicker and can create the same problems of too much lift charge. Ball shells from the Orient are lifted with smaller grain powder than 2FA but the sphere shape makes a much stronger casing.

- Not enough paper pasted around the shell, improper pasting technique, inferior paste, or wrong paper for "pasting-in" have all been suggested as possible causes of the flowerpot. A shell of weak wall strength has flowerpot potential.

- Inferior strength on the end of the shell exposed to lift. Most shell makers are using paper cans these days. With proper design, the paper can shell can be made with dignified performance. Some shell makers place a cardboard



or chipboard disc on both ends of the shell. Some disc only the lift end. Some place a disc inside and outside the paper cap of the can. Others disc only the outside while still others disc only the inside. There are variations within each technique, such as disc thickness, double discing on the outside of the shell or combinations of discing with paper tape sealing or glue sealing. All of the above techniques are used extensively and successfully among shell makers. The key factor is to achieve the required strength to withstand the lift forces when the shell is fired.

- Improperly sealed time delay fuse, especially if the fuse end of the shell is also the lift powder end (shell fired with fuse down). Some people use animal hide glue, some use Elmer's white glue, while still others use hot melt glue. Whatever the glue, the important factor is to seal around the fuse with a fillet that has no gaps of even the tiniest size. A pin hole leak can allow lift flame into the shell or be the weak spot which allows the lift blast to tear into the shell. Remember, the lift is encased usually in a "bag" rolled around the shell (nosing). Even with the TD fuse on top, flame gasses from the lift are guided to and encased around the TD fuse by the nosing paper. One interesting observation is that many shell makers who use animal hide glue exclusively to seal TD fuses also fire their shells with the TD fuse up or opposite the lift charge end of the shell. Could this be because of the brittleness of hide glue and its tendency to crack after drying, especially during the blast of lift? Of course, Roman fuse or "spoolettes" are always fused up because of the tendency of the powder core to blow through from lift pressure.

Whatever the source causes may be, proper design and close attention to detail are necessary ingredients to eliminating the flowerpot shell problem. Once design details have successfully overcome the flowerpot, workers must develop consistent work habits (in a manufacturing situation) to assure quality of each shell, thereby eliminating the random occurrence of the flowerpot dud.

TIME DELAY FUSE IGNITION FAILURE

This is perhaps the most controversial aspect of the dud shell phenomenon. It has been the cause

of many heated debates among shell makers who profess their theories with strong conviction and authority to justify the way they make and fire their shells: TD fuse up or TD fuse down. It appears there is no right or wrong way to fire a shell in this regard as many factors come into play when determining the success or failure of shell performance. I believe most shell makers agree that shells made with "spoolette" or rammed Roman fuse should be fired with the fuse up to avoid flowerpots due to the fuse powder core blowing through under lift pressure. Since the bulk of shells made today are made with the 1/4-inch diameter Japanese TD fuse, this discussion will be based on its use.

Some shell makers crossmatch the TD fuse on the outside of the shell a short distance from the starting end of the fuse. This is done by piercing the side of the fuse and threading a short piece of black match through the hole. When the shell is to be fired fuse-up, a piece of quickmatch is used to transfer ignition fire from the TD fuse crossmatch down along side the shell to the lift powder charge at the bottom of the shell. The long quickmatch shell leader fuse is introduced into the nosing paper at the top of the shell, terminated at the TD fuse crossmatch, and tied off within the gathered nosing paper at the top of the shell. This is surely a successful and reliable method when assembled properly. Yet some disadvantages have been noted:

- The risk of the fuse leader pulling out of the nosing paper connection (top of shell) when shells are handled. For example, when lowering a heavy shell into a mortar or when handling chained groups or bundles such as when loading flights or finales.

- Ignition failure can occur if the quickmatch leader only slips, nearly pulling out of the nosing and the shell is then loaded into a mortar with the problem undetected. The shell leader burns and stops, failing to ignite the crossmatch, extension quickmatch and lift charge. The result is a live shell hung up in the mortar.

- TD fuse ignition failure has occurred when a defective piece of black match was present in the crossmatch hole. During handling, sometimes the black powder coating on the



match cracks, crumbles and falls out of the string. Misfires in this category are rare, but it has been known to happen upon examination of the recovered dud.

- Lift ignition failure has sometimes occurred when the TD fuse crossmatch fired but the quickmatch extension to the lift charge didn't. This can be observed when a shell leader fires, then a delay equal to the burn time delay of the TD fuse, then the shell flowerpots. Similarly, when the quickmatch extension to the lift charge does ignite but for some reason delays lift charge ignition, low breaking shells have been observed. Again, a pause between the snap of the shell leader firing and the discharge of the shell from the mortar was observed which leads one to suspect the TD fuse was burning during the pause.

Some shell makers crossmatch the TD fuse and then fire the shell with the TD fuse down, in contact with the lift charge. The shell quickmatch leader enters the nosing paper at the top of the shell and proceeds down along the side of the shell directly to the lift charge. The side of the shell in contact with the quickmatch piping is dabbed with paste to prevent the leader from slipping during handling. The flame of the lift charge ignites the TD fuse crossmatch. If the shell is made properly and the TD fuse sealed well, the risk of flowerpotting can be eliminated. The major weakness in this method of TD fuse ignition is in the crossmatch. Dud shells have been examined and found to have the TD fuse sheared off at the crossmatch hole from the blast of the lift charge. Apparently the piercing of the side wall of the TD fuse (for the crossmatch) weakens the wall strength such that the lift blast tears off the end of the TD fuse and crossmatch. This too is a rare occurrence but does happen under the right circumstances (amount of lift charge, placement of the match hole from the end of the TD fuse, size of the crossmatch hole, thickness of the crossmatch, how much force was used to insert the crossmatch, etc.).

Another, more reliable method of the fuse down technique is to not crossmatch at all but to trim off a piece of the TD fuse where the crossmatch hole would have been pierced. This is done during the final assembly operation just before

nosing paper, fuse leader and lift charge are assembled. The object of trimming the TD fuse is to eliminate contamination on or in the end of the TD fuse (perhaps from pasting-in the shell) and to expose a fresh powder core to the lift charge. Some shell makers trim straight across while others cut at a 45° angle to expose a greater ignition surface area of the core. When wet slurry primers are used over the end of the TD fuse, a new risk is introduced. The possibility of the dried (hard) primer coating shattering from the lift blast (before the TD fuse ignites) is reason for concern. The most successful method appears to be with no primer.

It should be clearly understood that there may be many other convincing factors, both pro and con to each method of shell making detail, that are unknown to this writer. The "best" method is the method that successfully works for you and by which you feel comfortable at producing. By all means, safety should be your criteria for judgment.

TIME DELAY FUSE FAILURE AFTER IGNITION

The shell is loaded in the mortar, fuse lit, then "thump"! It's air borne with a healthy spark tracer from the 1/4" Japanese TD fuse. The shell is about half way along its flight to the apex when all of a sudden the TD fuse tracer dies. The shell peaks and then falls to the ground.

Upon dissection and examination, more often the fuse quit burning at the point where it passes through the discs and sealing glue. One immediately suspects a defective fuse due to a break in the powder train. However, this is unlikely as the hot burning gases will tend to flash over any small gap. Users of Japanese fuse are generally satisfied with its reliability. Its performance has established a high confidence level among shell makers.

Another thought is the glue (perhaps white or similar types) penetrated the asphalt layer of the TD fuse (under the outer paper wrap) and contaminated the powder core. Again, this too is unlikely. I have conducted my own tests in this regard by submerging several 12" long pieces of fuse in a gallon of white glue for 30 days, leaving



only 1" of fuse on each end unsubmerged. After 30 days the container was opened, the fuse removed and test burned, all without failure. While it is possible an occasional "dead" spot may appear in the core or asphalt layer of Japanese TD fuse, it is highly unlikely it would consistently occur at the point where the fuse passes thru the shell end disc. I suspect I am not alone in experiencing this type of dud situation with Japanese TD fuse. There is a valid explanation.

On a properly pasted shell, the paper will be thoroughly soaked with wheat paste which will be in intimate contact with the TD fuse. Until the shell has dried, the water will saturate the outside layer of paper on the TD fuse and travel within the paper fibers along the entire length of the fuse, much like the wick of a kerosene lamp. When the wetness reaches the inside crossmatch (presumed black match) the black powder and cotton string easily absorb water and conduct it into the TD fuse powder core. The powder core then conducts the water at least as far as the discs and perhaps farther. As time passes and the shell dries, including the outside of the TD fuse, a wet spot remains within the fuse core (you guessed it) at the point where the fuse passes through the discs. This progression of events was observed by taking apart shells at subsequent daily intervals after they were pasted and when not allowed to dry quickly. It was observed that the stars also became wet and mushy in some shells around the crossmatch.

The obvious answer to avoiding and eliminating this problem is to dry shells quickly. Sun drying of shells is not a reliable method in climates with high relative humidity or when rainy days can occur on a random, unpredictable basis. The best method is to dry shells in a safe building or room where hot air is ducted in and circulated, perhaps with the aid of a ceiling fan.

Shells can be thoroughly dried within 72 hours with this method. The air should not be recirculated or ducted back to the hot air furnace as it will be laden with moisture and only serve to increase the humidity of the drying room, thus slowing the drying process. Fall, Winter and Spring are the best seasons for pasting and drying because the cooler the air temperature of the atmosphere, the less moisture it can hold.

Conversely, as the temperature of air is increased, the capacity to hold moisture increases greatly. On a hot, humid summer day, the air would have to be heated 20° or 30°F. higher than the outside atmosphere to gain any drying benefit. Thus, the summer months are not best for shell drying.

If sun drying is the only available, method, it is suggested at least 7 days of direct sunlight, consecutively, be allowed for the best assurance against the occurrence of duds in this category. Allowing for thicker paste (less water) when pasting shells is also helpful. Also be aware, too little water in the paste can reduce the strength of the dried shell walls due to insufficient paste penetration into the paper. The idea of using less water is to not allow the paste to be soupy or runny.

INTERNAL SHELL IGNITION FAILURE AFTER TD FUSE BURN THROUGH

When a single break color shell (cylinder shaped) is fired it will usually spin at a high rate of rpms as it ascends. When this type of shell is made with a "spoolette" or rammed Roman time delay (TD) fuse, shell internal ignition failure has been known to occur. Many shell makers believe the cause of failure is centrifugal force expelling the flame and sparks of the spoolette as the shell is fiercely spinning. Ruggieri of France has overcome the problem by making spoolettes with a conical shaped cavity in one end of the powder core which is placed inside the shell. As the fire burns through the spoolette to the "point" of the cone shaped cavity, a momentary nozzle is formed with the flammable core. This directs a "rocket blast" of flame into the shell to ignite its contents.

On one occasion I had a bad experience with flash bag shells and another time with salutes. On both shells I had used Japanese TD fuse and decided an internal crossmatch was not necessary. When observing a piece of Japanese TD fuse burning, one sees a hot flame burst out of the terminating end of the fuse, misleading one to believe a crossmatch shouldn't be necessary. I especially didn't think so since the end of the fuse was nestled into flash powder. The result was an average of 5 out of 10 shells dudding



THE BEST OF AFN II



(50%). While the terminating spurt of flame coming out of the fuse end is certainly hot enough to ignite flash, I now believe the *duration* of the flame is too short (in at least 50% of the time) to raise the contacting flash powder to ignition temperature. It appears that the temperature and duration of the flame-spurt are on the threshold of flash ignition as the results of 60 shell firings was exactly 50:50 for successful ignition vs. dudding. By following the rule of always crossmatching the shell-internal end of the TD fuse, I have not since experienced a dud of this nature.

In this article on "The Dreaded Dud" I have tried to remain objective in presenting and sharing many ideas and observations. I hope it has enlightened the thoughts of those who have been "in the dark" or perhaps provoked ideas in others who may now investigate the phenomenon from a more exact and scientific study. Until then, the generalized ideas presented here will remain conjecture based on the observed evidence, and readers must form their own conclusions and opinions. WO





WHAT ABOUT FLASH

[This article was written for fireworks professionals - people who work with high energy materials on a daily basis and understand basic safety principles. Hobbyists may profit by reading how pros think about and work with flash comps.]

Of all the thousands of variations available in the elements of fireworks, flash powder is perhaps the most spell-binding fascination to capture the attention of most pyros. Perhaps this is due to the high energy, awesome nature of its effects. The blinding white flash, sometimes followed by a cluster of titanium sparks, then followed by a gut tickling sound pressure wave is somewhat exciting, to say the least. The remarkable aspect is that flash powder is relatively inexpensive and simple to manufacture when compared to stars, for example, fireworks makers (in the U.S.) use more flash and report components in aerial shells than any other single device or color.

When accidents involving flash powder occur, the high energy, violent performance of flash, results in serious and sometimes catastrophic damage. In recent times, the legal as well as illegal fireworks trade has experienced the (high incidence) tragic loss of human life, with almost all involving devastating flash powder explosions. The problems that lead to "accidental" disaster are all too common: complacency, carelessness, forgetfulness, apathy, contempt, and blind trust ("it won't happen to me, never has, therefore never will"). Those who fit this last category, the never-never people, cop a narrow minded attitude of "don't confuse me with facts, my mind is made up!"

Notice that all these categories are products of the human mind: attitude and awareness. Can it then be questioned: are the "accidents" occurring from these problems really accidents? I think not. Irresponsible attitudes where safety is compromised can only be truthfully stated as negligence. When a bolt of lightning strikes the powder shed - that's an accident!

Let's examine some facts about flash and some safety tips on handling. A good quality flash has a critical mass of about 50 grams (less than 2 ounces). This means it will detonate with concussion in open air (no container) when ignited. Less than 50 grams will burn violently but without report. Compare this with black powder which has a critical mass of about 500 pounds!

A three inch aerial salute (2 1/2" x 2 1/2") containing about 4 ounces of flash, when ignited and if held in the hand, will dismember the human torso, not just a hand. Large salutes are very lethal! The thought is rather horrifying, yet we must be realistic to understand the nature of the beast. Be thinking about this and the safety rules before you blend your next 10 pound batch!

In a recent demonstration of the power of flash, 1 pound bag was detonated electrically inside a wood structured shed. The blast and fireball was awesome! The shed was demolished with chunks scattered around where it once stood. Imagine 100 pounds of flash in an accident! Instantly lethal in a 25 foot open air radius and lethal up to several hundred feet if hit by missiles propelled from the blast. Windows will break for a 1/4-mile radius and buildings will sustain structural damage to window and door frames up to 600 feet away. Buildings within 200 feet will sustain structural damage to framing timbers. Think about this: as the size (density) of the flash charge doubles, the force (or energy) of the blast increases 8 times!

Here are some do's and don'ts on handling flash:

1. **Do** mix only in humid weather (above 50% relative humidity) to reduce the hazards of static electricity.
2. **Do** wear only cotton clothing when mixing flash.
3. **Do** remove all jewelry and all metal including belt buckles.

4. **Do** spray yourself down and all tools, tables, etc. with Anti-Static Spray (aerosol cans). This material is amazingly effective in eliminating the chances of static electricity from ever occurring. I have personally tested this material while observing the results on a sophisticated electrostatic field strength meter. Anti-Static Spray is available in cases of 12 cans from Chiswick Trading, Inc. 31 Union Ave., Sudbury, MA 01776-0907. Similar material can also be purchased in supermarkets and is known as Static-Guard laundry treatment spray.
5. **Do** screen all chemicals separately to remove lumps. Never screen flash powder after chemicals have been blended! The risks of friction ignition should always be avoided. A second and very real reason for avoiding screening any mixtures containing large quantities of conductive aluminum powder is that the resulting aluminum dust cloud can and does generate static charges. Although humid conditions reduce the risk here, a life is not worth the risk.
6. **Do** mix flash on a large sheet of paper, rolling the pile of pre-screened chemicals as diagonal corners of the paper are lifted and pulled towards the center. (This is also known as the diaper method of mixing.) This method is common throughout the explosives industry (not just fireworks) and is practiced when making many types of sensitive explosives.
7. **Do** add the titanium last after most of the mixing of each batch is complete.
8. **Do** mix outdoors, isolated, away from people and buildings.
9. **Do** limit batch sizes to no more than 10 pounds (it's now an ATF regulation) or to the smallest batch needed to satisfy your requirements if less than 10 lbs.
10. **Do** limit to one batch and one worker in the work room when charging salute casings.
11. **Do** remove all charged casings from the work room to a magazine before introducing a new batch of flash to the same work room.
12. **Do** wear a dust respirator when mixing flash or charging it into salute casings.
13. **Do** clean up any spills immediately, especially if titanium is present.
14. **Don't** store bulk quantities of multiple batches in the same container, i.e. drums, etc. The larger the container, the heavier and harder to handle, as well as, catastrophic consequences in a mishap.
15. **Don't** mix in plastic bags, (static)
16. **Don't** store in plastic containers!
17. **Don't** use plastic scoops or utensils - use only wood or aluminum.
18. **Don't** screen flash after blending chemicals. Never screen any formula with titanium present.
19. **Don't** mix, handle or use flash formulae containing potassium chlorate, especially if sulfur, antimony sulfide or titanium are included.
20. **Don't** mix indoors where aluminum dust suspended in the air can be ignited by the electric spark of appliances or light switches. The resulting blast has been known to level buildings such as in a gas explosion.
21. **Don't** smoke, even in a safe area, if your clothes are contaminated with flash powder.
22. **Don't** expose too many workers to flash operations. Limit the number of workers to only those necessary to complete the assigned task (usually 1 or 2). Keep all operations in separate sheds or limit one work room to one operation at a time. WO

THINGS THAT GO "BOOM" IN THE NIGHT

Because most closet pyros don't work with large amounts of compositions or have large numbers of finished products on hand at any one time, their chances of being blown up are generally not great. That is not to say they can't get hurt if they are not careful. Avoiding certain compositions will greatly reduce the risk. The following are, in my opinion, the most dangerous.

1) Using non-traditional materials i.e., high explosives. Some have taken a fancy to using "HDP" (cast) Boosters for aerial salutes. What the rationale is for using this type of material in fireworks is beyond me.

The sound level produced by a 3, 4, or 6" salute should be more than enough to satiate the most demanding audience, if not to wear out your welcome.

Some have put forth the argument that commercial explosives are "safer" than fireworks! Presumably because explosives are chemical compounds rather than mixtures of reactive chemicals they are less apt to go off accidentally. However, the important thing to keep in mind is, what happens if something goes wrong? The accidental ignitions, followed by "detonation" of a pound of "flash" would be a hell of a mess! The detonation a 1 lb HDP booster would be one or more tragedies!

2) Flash and report compositions: By their very nature, these are extremely dangerous. If they were not capable of rapid "burning" they wouldn't produce the desired results, "KABOOM". They have very small critical heights/diameters, i.e. small amounts of unconfined mixtures are capable of moving from ignition to "detonation". Indeed some have been tested and found to have TNT equivalences (for air blast) of 80%!

Per McLain, *Pyrotechnics from the Viewpoint of Solid State Chemistry*, all salute compositions are "Class 6" — "Detonate(s) from open burning,

small critical mass, very sensitive to spark and friction, capable of sympathetic detonation."

While there are no "safe" flash and report compositions, some are more hazardous than others. **THAT IS NOT TO SAY THE LESS HAZARDOUS ONES ARE SAFE TO USE.**

Listed in decreasing order of sensitivity:

Potassium chlorate + antimony sulfide (extreme static hazard)

Potassium chlorate + antimony sulfide + aluminum (see note above)

Potassium chlorate + antimony sulfide + sulfur + aluminum (see note above)

Potassium perchlorate + sulfur + aluminum

Potassium perchlorate + aluminum

Others of unknown sensitivity.

Potassium perchlorate + sodium salicylate/-benzoate

Black powder and aluminum

Potassium permanganate + aluminum

Potassium perchlorate + potassium phthalate

Potassium perchlorate + di-potassium phthalate

As there are no safe flash and report comps, one would be well advised to limit the amount of mixture being used at any one time/place.

For more info on flash and report comps read, L.S.O.'s article on aluminum flash in *Pyrotechnica* 1+3.

3) Photoflash: These comps are not used much in fireworks, as who wants to watch a display with



spots before their eyes! No doubt some have/will at one time or another give them a try, so I have included them here.

They have been found by the government to be some hot stuff! A mixture of magnesium-teflon-nitrocellulose was found to have a TNT equivalence (air blast) of 61% and the "standard", aluminum-barium nitrate-potassium perchlorate flash mix when tested, was found to have a TNT equivalence of 59%! Indeed the "detonation velocity" was found to be the same when the mix was ignited thermally, or set off with a blasting cap.

Once again, it is necessary to keep the quantities to a minimum.

4) Star compositions: There is not much info available on the possibility of "detonation" of star comps. Work done in Japan showed that "detonation" could only be obtained in piles of mixed composition, weighing at least 100kg (220lbs) when they were simply heaped upon the floor and ignited with a squib. However the addition of very fine aluminum, caused the detonation of smaller amounts.

Testing done by the U.S. Government after several fatal accidents with a magnesium/barium nitrate/strontium nitrate/potassium perchlorate/sodium oxalate/HCB mixture, showed it had a "tendency to mass detonate", when thermally ignited. (TNT equivalence - 50%!) A White Star mixture of magnesium/sodium nitrate/VAAR (binder), was found to have a TNT equivalence of 43%.

It is possible that star comps not containing aluminum or magnesium will not detonate, assuming you are not using comps containing potassium/barium chlorate, both of which have a bad reputation, and providing the mass is small.

If you look at some of the older formulas, you will find comps using potassium chlorate and sulfur, sometime with copper powder, or copper salts, (CuSO_4 , etc). If you are planning on using such mixtures, I can suggest safer hobbies, such as sleeping on the railroad tracks, sticking your head through the window in the door to see where the elevator is, or African Roulette. The same is true for stars using picric acid.

5) Whistle comps: These may whistle but they are only a short step away from deflagration.

Picric whistles (either potassium or magnesium) are not used today because of the tendency of these compounds to explode from shock. Gallic acid is too expensive, and when mixed with potassium chlorate, it is sensitive to shock and friction.

Mixtures of potassium perchlorate, with either potassium/sodium benzoate, or sodium salicylate, are more commonly used today; they are still "Class 6" compositions and caution is necessary!

6) Mixtures of White phosphorus, potassium chlorate, etc., (i.e. "Son of a Gun") Strangely, the greater danger seems to be phosphorus poisoning! (Not as much fun as being blown up.)

7) Red phosphorus- KClO_3 + Sulfur or Sb_2S_3 , (Armstrong's Mixture - toy cap mix). Learn to write with your other hand, so when you lose a finger or two, you will still be able to write to the WiZ.

8) Potassium chlorate and realgar, (red explosive), make sure your subscription to the AFN is paid up as you may not be able to write out the check for renewal next time.

Remember - "There are in nature neither rewards nor punishments - there are consequences!" n'est-ce pas? DJH

CHEMICAL SENSITIVITY

Sensitivity of chemical mixes relates not only to how easy (or difficult) one can "strike fire" by friction or impact. The level of heat energy required for combustion (ignition temperature) and whether the chemicals are susceptible to spontaneous combustion should also be considered. The choice of fuel and oxidizer may very well be compatible and free of the danger of spontaneous combustion when water dampened or wet mixed. However, in some instances, the choice of fuel and the ratio of fuel to oxidizer can render the mix sensitive to heat by having a low ignition temperature characteristic. The lower the ignition temperature, the easier a spark, electrical or mechanical, can set it off.

I have often heard pyros say, "Oh, that stuff is safe, it's not sensitive, don't worry"! Compared to what? Everything we measure in life is relative, compared to something. So how do we base a judgment on the "relative" sensitivity of fireworks chemical mixes? Unless you have access to a good explosives engineering library, a lot of money for special apparatus, a lot of time to set up and conduct experiments, and a good education to interpret the data of your findings, you can't make an accurate judgment on relative sensitivity.

Attempts at establishing practical measurement standards are being made and that's good! (see *Impact Sensitivity*) However, the fireworks industry generally does not have any practical standards of sensitivity measurement other than government specs for military signals. For the most part, the work of professionals and amateurs alike has relied on the knowledge (or hear-say) of those who are experienced and willing to share. Unfortunately, there are and always will be those who work "in the dark", without regard or ability to conduct controlled experiments for determining relative sensitivity.

Be it a question of chemical compatibility or heat, friction, shock or impact sensitivity, we must presume an inherent and intrinsic danger exists by treating all chemical mixes with equal care. It can be dangerously misleading to use the

words "never" and "always". However, when handling fireworks chemicals, we must never trust the unknown and must always respect what is known.

The following is a list of chemical combinations known to cause sensitivity problems. Next to each listing are letters to indicate the type(s) of sensitivity.

F = friction
HY = hygroscopic
I = impact or shock
SP = spontaneous combustion
U = unstable

The list is incomplete but reflects the most common chemicals used by most pyros. Those who are experimenting with their own formula designs should avoid these combinations within the formula:

1. Potassium chlorate & sulfur, sulfides or sulfates - F,I,SP,U.
2. Barium chlorate & sulfur, sulfides or sulfates - F,I,SP,U.
- *
3. Potassium or barium chlorate & ammonium compounds - F,I,SP,U.
4. Potassium or barium chlorate & calcium carbonate - F,I,U.
5. Potassium or barium chlorate & aluminum powder - F,I,U.
6. Barium or potassium nitrate & aluminum powder - U,SP(when wet)
7. Ammonium perchlorate & most nitrates - HY,U.
8. Untreated magnesium & any oxidizer - SP,U.
9. Barium nitrate & sodium oxalate - HY,U.
10. Barium chlorate & sodium oxalate - HY,U,F,I
WO

DEATH MIX

The bright idea frequently occurs to pyrotechnists to "improve" so called electric green star formulations made with barium nitrate, a chlorine donor and a metal fuel, by adding a quantity of chlorate to the mixture.

Another version of this mistake is adding barium nitrate to an otherwise chlorate-based electric green, thinking that by doing this, the sensitivity of the mixture may be reduced.

Both practices are mistakes and may qualify for the Deathmix Award.

The reason is this: when a chlorate, a nitrate and a metal fuel such as magnalium or aluminum are dampened with water and allowed to stand for a time, there is a high probability that ammonium chlorate may form. Basically, it is just a matter of time and temperature.

In *Fireworks Principle & Practice*, Dr. Shimizu clearly lists ammonia as a reaction product of nitrates, water and aluminum allowed to stand unbuffered for a period of time.

The logic behind adding barium nitrate to a chlorate electric green is a mistaken application of a practice that *may be* sound when applied to resin fuel systems. Since the sensitivity of the mixture increases as the chlorate oxidizer content increases, the reasoning goes, reducing it by using some barium nitrate instead will thereby make a safer mixture. But this runs afoul of chemistry.

The mention of ammonium chlorate will cause veteran fireworks to blanch. For those who are still sorting out the list of demons one may encounter when making fireworks, ammonium chlorate is a highly unstable compound which tends to have a short life, eventually flying apart in a detonation. Having this form in a damp star mixture is the rough equivalent to adding blast-

ing caps to the mixture. If it DOES go, the fact that the mixture is damp is no guarantee of safety: look at nitrate-aluminum blasting slurries; the water actually makes them more powerful!

Traditional "electric" green is usually taken to mean a mixture with 60-70% barium chlorate, 15-20% aluminum and some resin fuel, along with a binder. Blasting slurries also contain about the same amount of aluminum. Now, this mixture is touchy enough to start with - traditional wisdom is that one must get stars made with it dried in a hurry, and in the shade - but if a nitrate is added, it becomes even more treacherous because the addition of nitrogenous material sets up the conditions for ammonium compound formation. Then one is really walking on eggs. Let the mixture sit around damp for long enough at the right temperature and the chances are very good that one will have a true Deathmix.

In a barium nitrate green with metal fuel and, say, Parlon as the chlorine donor, boric acid may be used to counteract the nitrate's reaction with the metal fuel, which is an alkaline reaction. But add a chlorate to the brew and you're going to lose either way: if it goes alkaline, the ammonium chlorate will get you; if it goes acidic from the buffer, you will have the chlorate-acid problem. An amphoteric buffer won't know whether to go left or right.

All of this trouble arising from the chlorate would be one thing if there were no other way to get a good electric green. But it just isn't necessary. Not only are barium nitrate-based electric greens safer to handle than chlorate versions, but also they are far cheaper to make. This may not be obvious to the small scale pyrotechnist who pays hobby/retail prices for his chemicals, due to the seller's having to re-package and ship them to the tune of a considerable time investment.

But at the commercial level, one can make the whole barium nitrate electric green mixture for about the same price as the oxidizer alone costs in a barium chlorate mixture. Or close enough to this to make the chlorate version "premium priced".

Barium nitrate greens using aluminum or magnalium can be water bound, provided that they are buffered with at least one percent boric acid; it seems to be best to dissolve the boric acid in the water/alcohol, which will be used to dampen the mixture, before adding it to the dry composition. This way, the acid is immediately dispersed throughout the mixture and is immediately on the job. If it is added dry, it never gets this well dispersed.

Barium nitrate electric stars should also be dried out as quickly as possible, since it is possible, over enough time, for the limits of the buffering to be reached. If this occurs and the alkaline reaction begins to take place, the stars can heat up. However, in this writer's experience, no reactions have been noticed within about four days, when the boric acid was pre-dissolved.

One problem that sometimes arises with water bound barium nitrate greens is that if the star composition is over-dampened, some barium nitrate can leach into the blackpowder prime. If this happens to a sufficient extent, the prime becomes a "smolder" mix, and the stars may take up to three seconds to ignite after leaving the shell. This can actually be used deliberately to give an effect which seems much like color changing stars, when mixed with another star which ignites immediately. In any case, for rapid ignition, it is best not to over-dampen the star composition and to use as much alcohol as one can without inhibiting the binding ability of the dextrin.

One further note: Deathmixes are not limited to greens. Another potentially nasty one is yellow made with potassium chlorate, barium nitrate and aluminum. Different color, same danger.

FD

AMMONIUM PERCHLORATE- FUMED SILICA HAZARD

I would like to point out a possible hazard that we here, at PyroTechniques, have noticed.

Most of our chemical stock is finely ground and kept free flowing by the addition of small quantities of Aerosil (cab-o-sil, chemite, microballoons, et al.). This has presented no problems to our work. On the contrary, it makes it easier to manipulate the compounds, as well as being an excellent static-reduction material.

After mixing the Aerosil with each chemical, it is monitored closely for several days before being stored with our working stock. It was noticed that upon mixing Aerosil with ammonium perchlorate, deterioration began within 24 hours, with an ammoniacal odor emanating from the mixture. Although no heat was released, and no difference was noticed in stars made using the degraded product, an adverse reaction was initiated and, given enough time, could conceivably result in unpleasant consequences.

When stars are made with pure ammonium perchlorate and other compounds (which already contain Aerosil) no deterioration appears to take place. It must be noted, however, that the star mixture is damped into stars immediately. The effect of allowing the star mixture to stand before damping is unknown.

This letter has been written to increase the awareness of readers to the dangers involved.

SFM

POTENTIAL DEATHMIXES

"Fiore DiSaster" has chosen to call mixtures containing nitrates, chlorates and aluminum "deathmix". I, for one, do not agree with all that the writer has to say on this subject, although the ignition source cited at some recent incidents has been green stars that ignited during drying. As little in the way of aesthetic value would be lost by avoiding the use of these mixtures, it would be better to err on the side of caution and avoid them.

This combination does not seem to be common, as a check of the WiZ's data base (1250 formulas) reveals that there have been published only five formulas that contain at the same time a nitrate (barium), a chlorate (potassium or barium) and aluminum. I found one each in Lancaster, Davis, Weingart and two from Degn. None mention the use of a buffer such as boric acid or a chlorine donor.

Despite Dr. Shimizu's observation that strontium nitrate is even more reactive with aluminum than barium nitrate, I found three formulas in the data base for red compositions that contain all three ingredients, the nitrate being strontium.

In the data base I found no formula that contains at the same time:

(barium nitrate
(potassium chlorate
(magnesium

(barium nitrate
(barium chlorate
(aluminum

(potassium nitrate
(potassium chlorate
(aluminum or magnesium

(potassium nitrate
(barium chlorate

The reason that these combinations are not used may be lack of results rather than safety.

POTENTIAL "DEATHMIXES"

GREEN - SILVER PILL BOX STAR LANCASTER - PAGE 92

Barium chlorate	25%
Barium nitrate	25
Aluminum bright	19
Potassium chlorate	13
Red gum	7
Dextrin	5
Barium carbonate	4
Charcoal 150 mesh	2

GREEN ELECTRIC STAR AND METEOR DEGN

Potassium perchlorate	4 pts
Barium chlorate	8
Barium nitrate	8
Aluminum bright	6
Charcoal	1
Red gum	2
Dextrin	1

GREEN DAVIS [FABER] - PAGE 86

Potassium chlorate	8 pts
Barium chlorate	16
Barium nitrate	16
Aluminum	12
Charcoal	3
Dextrin	2
Red gum	4

WONDERFUL SINTER STAR WEINGART - PAGE 142

Potassium chlorate	32.0 pts
Medium aluminum	7.5
Fine aluminum	3.0
Barium Nitrate	2.0
Red gum	2.5
Fine coal(sic)	0.5
Dextrin	3.0

DH

ALUMINUM-NITRATE REACTIONS

I had an accident with a star formula last May. It was bad but could have been worse. I think this information should be passed on so maybe someone else can avoid what happened to me.

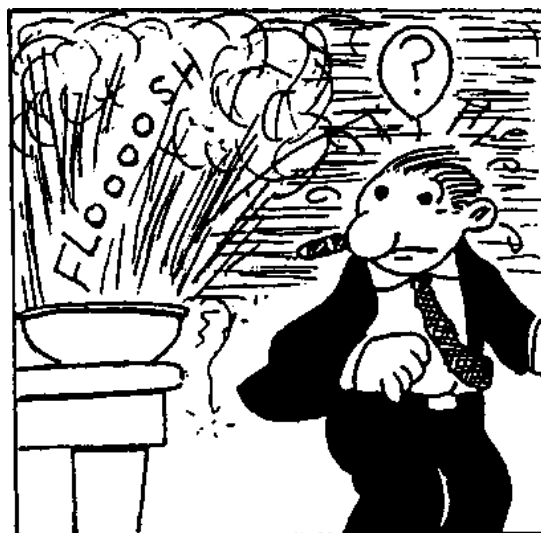


At that point I left for about five hours. When I returned I found the shop filled with a dense smoke and I have never seen such a mess. Everything was covered with, at least, 1/4" of soot/dust, including the walls and ceiling. This mixture apparently heated up to the point that it became extremely hot and caused all the smoke. It scorched the table, burnt a few holes in the carpet, and melted the plastic cover on the fiberglass ceiling tile. I had two other mixtures on the table drying and they too caught on fire or smoldered as well. With only 200 grams of each of the mixes, I was amazed at the amount of soot/dust that was generated from this relatively small amount of material. I think I never worked harder cleaning up such a mess. However, I feel very fortunate that the total damage was less than \$100, except for the labor. I am also very fortunate to have a wife who helped me clean up the mess, rather than kick me and my fireworks out the door. Anon Pyro

I was making up various star formulas and making cut stars. I decided to try a formula that I had never used before. It came from a booklet I had gotten several years ago. The formula was for "Golden Flitter Star":

Potassium nitrate	16
Sulfur	3
Charcoal, fine	2
Sodium Oxalate	4
Aluminum, bright	11
Aluminum, med. (100 mesh)	4
Aluminum, fine, flake	1
Dextrin	4

I substituted 5 parts aluminum 100 mesh as I had no fine flake. As you can see, the formula contains a lot of aluminum which made it somewhat difficult to mix, but really became messy when I tried to dampen it with water. I continued to dampen it until I could form it into a cake. I then set it aside on a table to dry.



[We asked LSO to give us his opinion of Anon Pyro's problem. He responded with an overall picture of spontaneous ignition. See the following very important article.]



COMBUSTION

During the days of chlorate and sulfur compositions, spontaneous combustion during mixing, handling, and storage of fireworks was so notorious a problem that everyone constantly took the problem into consideration. Modern formulations very rarely cause problems, but the problem of spontaneous combustion is still very much with us and ought to be a prime consideration for all pyrotechnists.

In the ignorant days of my youth I used sulfur and chlorate formulations that I found printed in old encyclopedias. Once about five pounds of sulfur-chlorate yellow stars started fire in my bedroom. Carrumba! The smoke! My work table was damaged and my parents very wisely limited my batch size to about a pound. I was twelve at the time. I decided to study more chemistry and, knock on wood, have seen only two no-fire heatups since then. It is absolutely necessary to take every precaution against spontaneous combustion.

The traditional major ingredient of fireworks, black powder, and the "green mixes" (mixtures of potassium nitrate, sulfur and charcoal, particularly powdered charcoal) have shown some tendency to start fires in large storage bins. It was supposed that this might have been the cause of a blast at the French Royal Gunpowder Works in the 1600's. The blast had involved many tons of material; the exact cause remains a mystery. Adding a metal fuel to this type of mix introduces a new, higher risk of spontaneous combustion.

In all cases of spontaneous combustion, two things must occur: 1) a chemical reaction that gives off energy as heat; and often the most critical factor is: 2) the heat must somehow be allowed to accumulate in the materials until actual combustion temperatures are reached. Pyrotechnics would be boring indeed if restricted to mixtures which could not possibly react with each other or with common, innocent things like air and water. So the pyrotechnist must also as-

sume that all possible adverse spontaneous, exothermic reactions have already started, and will continue. I have made this a practice for many years and so far, so good. If this assumption is always made, only two tools or techniques remain to deal with the problem of spontaneous combustion. Fortunately, they suffice.

The first technique is chemical: do whatever is appropriate to slow down the reaction. The slower heat is evolved, the smaller the problem, or the likelihood of spontaneous combustion. There is absolutely no way around having to learn enough chemistry to understand the types of chemical reactions possible for the various ingredients at room temperature. The literature on the subject is extensive, the problem is well covered for almost all of the ingredient combinations. "The only insufficiencies in the literature that I know of are those concerning magnalium (the magnesium/aluminum alloys) and the ammonium perchlorate mixtures with aluminum and/or magnalium. These ingredients simply do not have the decades or centuries of use to have allowed for an extensive literature to be built. All pyrotechnists are born absolutely ignorant. Those who intend to survive should make every effort to fix that first. Our only defense against chemical hazard is chemical knowledge.

The second tool or technique for avoiding spontaneous combustion is the most ignored in the literature, and that is scale of operations. Fortunately, the scale of operations that amateurs engage in is, compared to industry, very small. Small quantities of chemical mixtures must of necessity evolve less heat than massive quantities. The hazard of spontaneous combustion of linseed oil is of little concern to an artist painting miniature portraits, but is very significant to large scale furniture plants. Ever wonder why you cannot find rubbed oil furniture finishes any longer? Home shop sawdust piles have rarely caused fires, but sawmills and wood mills of all types have special equipment and safety people to prevent spontaneous fires in the chips and



dust. Scale of operation is ever so important in spontaneous combustion. The heat must accumulate to drive the temperature of the material to the ignition point. The heat generated inside a large mass of any material is more likely to cause a temperature rise to ignition point, than the same amount of heat released near the surface of a small batch where the heat can be lost to the environment.

This is yet another reason in an amateur lab to store dry stars, etc. between containers of relatively inert pure chemicals. Adequate air circulation around containers can be a big safety factor, finished stars or mixtures ought to be kept in the smallest practical containers. I never put comps, stars, anything chemical and mixed into containers larger than one gallon. Square containers would have more surface area to dissipate heat but cylinders cannot be stacked so densely so as to prevent air circulation on open shelves. I have often seen the industry fill boxes full of materials and pack the boxes into storerooms with no provision for heat loss at all. This is foolish.

Pallets loaded with fireworks should always have at least six or eight inches between stacks of even the most benign goods. Any goods containing metal fuel mixtures should have a walk space for inspection and air cooling between them, fireworks are not building blocks. I have seen pallet stacks twelve feet tall with only the pallets providing air gaps. I remember watching steam come off wet cases in such a stack. That's too close a call for me! Fortunately, amateurs cannot afford to buy accumulations of fireworks such as the industry must handle.

At the present time the metal fuels are the most likely source of room temperature reactions that evolve enough heat in mixtures to be possible sources of spontaneous combustion. The lower the metal content of a mixture, the smaller the hazard, five to seven percent aluminum in glitter stars is not much hazard at all, say only 2,000 times as much hazard as a green powder mix. Higher percentages, say twelve to fourteen percent, can cause a rapid heating to more than the

boiling point of water. At this point the materials require special precautions. I say again, smaller containers.

Smaller containers have higher surface-to-volume ratios and shorter heat paths from center to exterior. Plastic containers melt at below the ignition temperature of most mixtures. This furnishes cooling air and much more efficient radiation and convection of heat. Metal cans dissipate heat rapidly but may cause sparks, and may be reactant themselves in rapid rusting type reactions. Nothing capable of exploding should ever be stored in metal, if it is at all avoidable. Glass jars in small sizes for ounce size batches are acceptable. The most important consideration is air flow around containers. There must be a way to lose the heat. Secondary sources of heat - steam pipes, heaters, wiring, extension cords, windows, etc. - must be considered in any storage situation. Cardboard boxes are insulators. They are not an acceptable substitute for open shelves. Only the great out-of-doors provides better heat dissipation. Plan all storage with escape routes and firefighter safety first and foremost in mind. This means the most likely item to be a hazard should be furthest from the door.

An experimenter who handles only a few grams can work just about anywhere if he does not keep any mixed materials after the lab session. Scraps and leftover odds and ends should be destroyed. There are all sorts of ways to destroy pyrotechnic mixtures. I recommend the fun and educational method of taking it outside and burning it in a safe manner. Without question, this is the most valuable learning experience in all pyrotechny: careful observation of the burning characteristics of the material used is immensely valuable information. Second, find out which conditions are necessary to produce an explosion with every material, and assess the power of the explosion.

The industry is particularly guilty of never observing a full batch burn off in a work-like situation. When an accident occurs, no one at the plant knows what to expect. They never try to find out until after the accident. Find out



THE BEST OF AFN II



firsthand what things do. There is no substitute for that kind of knowledge.

For the past six hundred years, the industry has depended upon amateurs to make their innovations and iron out the bugs. More than nine out of ten improvements in fireworks have come from amateurs. The other side of the coin is that invariably amateurs are inclined to handle new materials and methods, new formulations. These have unknown dangers. They should never be kept in or near your principal storage area. In general, it is better to allow only mixes with at least a fifty year history of use in your principal storage area. New items should be made and stored in very small quantity. It has been my practice to store small quantities of things in question on closet shelves, scattered throughout the house. I put a brick of firecrackers on either side to make a very good fire and smoke alarm that even a deaf pyro can hear. Because the closet has a door, you can easily slow the unexpected fire by shutting the door. This will give you plenty of time to get out of there.

Ideally, all pyros should have at least one main and three or four minor storage buildings spaced far apart and far from the house and garage. But who can afford it, and who would reliably always use it, in bad weather, in the case of that last minute little experiment? Almost anyone would leave some material in an inappropriate place. The incidence of pyro related accidents is far lower than grease fires in the kitchen, electric toaster fires, and about the first two hundred most common causes of house fires.

Speaking from first-hand experience, you don't want a house fire at all, and you had best do everything you can think of to prevent one. The Chinese hang firecrackers over doorways to assure good fortune and protection from sudden adversity. It must be the oldest fire alarm known. The "batteries" are good for centuries.

The accident mentioned above involved a high aluminum content mix that contained sodium

oxalate. Sodium oxalate in water has a rather high pH, near the danger zone for aluminum and nitrate solutions. The conventional wisdom states that boric acid is an adequate buffer for aluminum/nitrate mixes. This is not true of the sodium oxalate or sodium bicarbonate mixture with these ingredients. For these mixtures, I prefer oxalic acid, even though the resulting stars can be more hygroscopic.

The reactions that cause spontaneous ignition in fireworks materials are almost all propagated by or are reactions of water. Careful drying, actual determinations of moisture content, are the first and best defense against moisture reactions. I always crush a few stars and examine them for internal moisture. Even microstars can be "driven in". Flake type aluminum stars are almost as notorious as lampblack stars for difficulty in achieving a truly dry condition. I would never put even slightly damp metal fuel stars or goodies away for storage. They must be checked extensively for uniform dryness.

The newer types of stars and particularly strobe compositions are being bound with cellulose nitrate [in the trade, generally referred to as nitrocellulose lacquer or NC - Ed]. Cellulose nitrate is famous for spontaneous fire and/or explosion. I always include a stabilizer in all cellulose nitrate formulations. Diphenylamine is the most popular stabilizer in military goods. It is used by commercial powder manufacturers and is suitable for them. However, I prefer to use urea. It is cheap and definitely not a biological hazard, which diphenylamine is suspected to be. [*A Compilation of Hazard & Test Data for Pyrotechnic Compositions*, ARRADCOM, 1980 says: Diphenylamine: toxic, symptoms include eczema, tachycardia, hypertension; recognized carcinogen. Urea: non-toxic. Ed].

It is far better to err on the side of over-cautiousness. Let them call you paranoid if they wish. You had best take every precaution; don't be adventuresome without the proper facilities and faculties to make it safe. LSO



MORE ON SPONTANEOUS IGNITION

LSO's article on spontaneous ignition touched a nerve with more than a few of our readers. Several subscribers phoned the AFN office to compliment his work and a few even mentioned that they wished they had read that information earlier in their pyro careers (you really don't want to know why).

Here are two letters that we received on the subject. Apparently this is a very wide spread problem in fireworks, as witnessed by these writers.

"In the February issue, LSO discusses the causes and prevention of spontaneous combustion of mixtures, particularly those including metals such as aluminum. This subject was also touched on in 'Deathmix' (*Best of AFN [I]*) and *Chemistry of Fireworks*, by John Conkling in *Chemical and Engineering News*, June 29, 1981. My interest in this subject is keen owing to a particularly nasty accident I had with a mixture that included potassium chlorate, sulfur and aluminum, among other things. I have also witnessed the spontaneous combustion of a copper sulfate and potassium chlorate-containing mixture. It is very pretty, but not one you would want to be near.

"These two reactions are different, yet may be complicated by competing reactions from other chemical constituents. One category is the formation of an unstable salt such as copper chlorate or ammonium chlorate. The other is what I believe is the reduction of water at the surface of a metal, forming hydrogen and generating heat in the process. Other reactions may occur at the metal surface such as reduction of nitrate to ammonium and subsequent formation of an unstable ammonium salt. In the former chemical reaction, water solubilizes the salts introduced in the mixture and allows formation of new unstable salts upon drying. The second type of reaction is more complicated but clearly involves reaction of water on a highly reactive surface, finely divided aluminum in a very moist atmosphere has been known to combust upon ignition probably due to the formation of hydrogen gas. It is well known among firefighters that you never train water on a very hot fire where aluminum materials are present because of the

risk of spontaneous combustion. In the case of fireworks mixtures the desired affect depends on a clean metal surface. Aluminum oxide coated surfaces reduce this danger but it also inhibits the desired reaction. Increasing amounts of aluminum and large amounts of mixture increase the danger by allowing more heat to be generated and insulation of the heat within the mixture. Of course, it only takes a few molecules at ignition temperature to ignite the whole mess.

"Adding to the confusion in attempting to understand spontaneous combustion is the difference in ignition temperature between fuel/oxidizer mixes and particle size. It would be so beneficial to us if we could know more about the combustion process of our formulas. Unfortunately, we are still very much in the dark about what precisely is going on, which makes this business more of an art than a science." Don B

The second letter: "I am in total agreement with LSO in his assessment of the 'Aluminum-Nitrate Reaction'. I have had hot reactions when using nitrates or chlorates with aluminum, magnesium, and magnalium; luckily combustion never resulted.

"In formulas where any metal fuel is required I always use cellulose nitrate (in a lacquer of 10% cellulose nitrate). Since some formulas require water to cause chemical reactions to occur before a star is ignited, an extra step will help tremendously. For example, in the gold flitter formula:

Potassium nitrate	48%
Air float charcoal	10%
Sulfur	9%
Antimony sulfide	10%
Magnalium	13%
Sodium bicarbonate	7%
Dextrin	3%

"A reaction with the sodium bicarbonate is required to produce a good yellow color. Of course, the bicarb will change the pH of the mixture and affect the magnalium. To achieve this reaction, I mix the formula without including the antimony sulfide and magnalium and wet it with 10%



methanol in water. After rubbing the compound together in a mortar until the mix is consistent (in small batches), the wetted material is spread on disposable paper plates and dried. The dry compound is then carefully crushed (not ground) and screened. Then the antimony sulfide and magnalium are added and the entire batch mixed (not screened). The rubbing procedure, if done carefully and without the antimony sulfide and magnalium added, should produce no problems.

"Using 50 gram batches, I add 15% (added percent of cellulose nitrate is on a weight-to-volume basis) cellulose nitrate and work it until the batch is well damped for pumping stars. Additional acetone may be needed. In the formula noted by Anon Pyro, my use of this formula without water and in a cellulose nitrate binder resulted in good effects. I do, however, believe the formula noted above will give better effects.

"A few more points should not be overlooked. Normally, when wetting a mixture of oxidizer-metal fuel, I can "smell" the slight oxidation reaction that is occurring between the two. Even if this does not cause a violent reaction when the water is added, the oxidation process will ultimately detract from the desired final effect. I do not prepare metal fuel mixes more than a day or two ahead of the anticipated star making. Moisture absorption from the atmosphere or from oxidizers that are not quite dry may cause the same reaction. The addition of cellulose nitrate will stabilize these formulas to such an extent that several year's shelf life is normal." BK

SAVING METHYLENE CHLORIDE

Methylene chloride is a solvent widely used for bonding plastic shell casings. Though a good bonding agent, its quick evaporation in open containers could be a problem. A way to alleviate this is to use a squeeze bottle with a fine metal tube attached called a solvent applicator.

The method used for the shell assembly process is as follows. A shell is constructed in the usual manner making sure to leave a 1/16" gap between seams to be bonded. A small amount of solvent is put into the applicator and introduced into the seam by means of the hollow tip of the applicator. An even but generous amount of solvent is applied to the seam. After the solvent has worked for awhile the casings are pushed firmly together and a raised bead of fused plastic should appear where the gap once was.

That's all there is to it. Hopefully if the caps are kept tight on the applicator and storage container when not in use, that sudden surprise of being out of methylene chloride will be a problem of the past.

The solvent applicator described above is now available from KSI. AK



AUTO IGNITION TEMPERATURE

There seems to be among the readers an interest in the temperature at which various compositions will ignite. Most of this interest has been from those using "Hot-Melt Glue Guns" to seal on end caps and such. Therefore I have dredged up whatever information there was available, "Ex Libris" THE WiZ.

Most would be interested to know that the producers of M800's, Ozark crackers, and etc., use hot-melt glue to secure the end caps/discs on these devices as a safety measure. (Preventing their separation from the case upon ignition.) Because these devices are produced in wholesale lots, entire trays are glued at one time, the glue being supplied from overhead plastic tubes. The glue guns used by avocational pyro's have metal tips, the temperature of which are a great deal higher than the melting point of the glue, a good thing to keep in mind when using these devices.

In general the auto ignition temperature can be no lower than the temperature at which one of the components of the mixture begins to melt, usually the oxidizer, although a low melting point fuel may also have some effect. In addition, it would be well to remember when working with chlorates, changes in crystal form taking place during drying can have a marked effect on reactivity, and therefore the comp's auto ignition temperature may be lower than given here. For more complete discussions of the factors that affect reactivity see McLain, *Pyrotechnics* page 31, and Shimizu's *Fireworks, The Art, Science & Technique*, especially page 89.

Compounds such as ammonium chlorate and copper chlorate have decomposition temperatures that are at or near the boiling point of water. Although neither of these are intentionally used, they may be formed when star comps are dampened with water. The reaction between aluminum hydroxide, potassium hydroxide and potassium aluminate, can generate sufficient heat to boil off the water. The reaction also produces ammonia (gas) and hydrogen. Should any chlorate compound be present, the formation of ammonium chlorate is all but guaranteed. This coupled with the elevated temperature is sure to lead to not a little grief! The combination

of chlorates and copper or copper compound can lead to the formation of copper chlorate which has been shown capable of spontaneous ignition, if not detonation. This compound also has a decomposition temperature near the boiling point of water.

Listed below in order of increasing temperature in degrees centigrade are the melting points of the more commonly used oxidizers and fuels.

OXIDIZERS

Ammonium nitrate	170
Sodium chlorate	248
Sodium nitrate	307
Potassium nitrate	334
Potassium chlorate	356
Barium chlorate	414
Sodium perchlorate	482
Barium perchlorate	505
Strontium nitrate	570
Barium nitrate	592
Potassium perchlorate	610

ORGANIC FUELS

Stearic acid	69
Naphthalene	80
Shellac	120
Sucrose	188
Laminae	200

METAL FUELS

Zinc	420
Magnalium 50/50	460
Aluminum	660
Iron	1535
Titanium	1660

The only information that I have been able to locate on the auto ignition temperature of compounds has been for those compositions that are now, or have been used by the government. None of the compositions contain barium chlorate, and the only potassium chlorate containing compositions are those used for the production of colored smoke, where a low temperature fuel in combination with a low temperature oxidizer is desired.



THE BEST OF AFN II



You will notice that this combination also has a VERY LOW ignition temperature! (Indeed the combinations of potassium chlorate and sugar have been used as commercial explosives.) It can be assumed that these auto ignition temperatures were obtained using chemicals that meet Mil. Specs. As most of us are not in a position to determine what, if any, adulterants are present in the chemicals we use, the auto ignition temperature of our comps may be lower than those presented here. This is to say, just because a composition is listed here as having a high auto ignition temperature, or your stars use ingredients with high melting points, don't be a-drying your stars in the oven.

The recipes that follow were obtained from a source believed to be reliable, however as none of them has been used or tested by me, I make NO representation as to their safety, or utility. They are listed in order of increasing ignition temperature, once again in degrees centigrade. One would do well to remember; THERE IS NO RELATIONSHIP BETWEEN IGNITION TEMPERATURE AND SPARK, FRICTION, OR IMPACT SENSITIVITY. A high auto ignition temperature therefore, is no guarantee that a composition is otherwise safe to use. DH

YELLOW SMOKE - 125°C

Potassium chlorate	30%
VAAR	2
Sugar	17
Vat yellow 4 dye	51

GREEN FLARE - 340°C

Magnesium 50/100	16.8%
Magnesium 30/50	16.8
Barium nitrate	40.1
Potassium perchlorate	9.5
VAAR	4.2
Dechlorane	12.6

RED FLARE - 376°C

Magnesium 50/100	29%
Potassium perchlorate	9
Strontium nitrate	43
Laminae	7
Polyvinyl chloride	12

RED STAR - 399°C

Magnesium	23%
Potassium perchlorate	22
Strontium nitrate	41
Gilsonite	8
Hexachlorobenzene	6

GREEN STAR - 448°C

Magnesium	15%
Linseed oil	2
Hexachlorobenzene	15
Copper powder	2
Barium nitrate	66

YELLOW STAR - 532°C

Magnesium	18%
Strontium nitrate	16
Barium nitrate	17
Sodium oxalate	17
Potassium perchlorate	17
Hexachlorobenzene	12
Linseed oil	3



LEAD CHEMICALS

[The November '88 issue of AFN contained a frontpage article titled THE MICRO-BANGERS. In it, author Oglesby described his enthusiasm for the pyrotechnic processes involved in the Hellzapoppin and Dragon Eggs fireworks items. He also strongly cautioned about the toxicity of lead compounds and promised another article about handling them. His investigation for that article caused him to revamp his original opinion of the use of lead compounds in fireworks. The latest information, he says, shows lead to be perhaps 10 times more toxic than was generally held a few years ago. Mr. Oglesby's very sobering and most important article follows. All fireworkers who use or are exposed to lead compounds are urged to read it carefully].

Two recent studies have made lead their topic. One study of school children found that there is a significant reduction of brain function and learning ability in children at one-tenth of the previous "safe, background" lead levels. Even findings of 1/100th of the old levels showed reading levels two grades behind previous levels.

One report clearly stated that the urban school dropout rate was due probably more to lead levels than any other cause, including race, income and drug use.

Another less well known study by kidney specialists showed the relation between kidney failures and lead (at lower levels than had been possible to analyze previously) to be nearly linear.

All of the studies seem to indicate that no lead at all is best, and that "traces", 1 mcg/100ml blood, are of some detriment. Note that city dwellers often have levels of 10 to 20 mcg/100ml! Children, and people who work or exercise outdoors have the lead levels; they were previously considered normal. One small study hopefully showed that persons with this previously considered normal level, when treated for lead poisoning, had an increase in their IQ scores of twenty to thirty points.

Try to visualize the tiny amounts of material we are talking about. A large man of 220 lbs. (100

kilograms) ingests and absorbs 1 milligram of lead. His blood level would be 10 micrograms per centiliter (10 mcg/100ml). Remember that the old standard for normal was 1 milligram per person? **New studies show effects at 100 times less lead.**

Now if we make a small pellet of lead oxide (about the size of a matchhead), it will weigh about 100 mg. Red lead oxide compressed in a tube shows a volume of 0.02 ml, or about the size of a drop of water for the same 100 mg. This means that the pyrotechnist should concern himself with amounts of lead compound mixtures that have a volume of 0.002ml. Fifty of the micro-banger micro stars made for my November article were weighed - they contained about 140 mg of lead. Injected into that 220 lb man, the blood level would be 1400 micro-grams per centiliter; medical intervention would be required to extract the lead as it would be a clear case of significant lead poisoning.

Were those microstars burned in fireworks, the lead would be diluted as smoke in air, and by the time it reached the nose, the smoke plume would be about 1500 liters. A viewer might inhale a liter or two of that smoke, or about two-tenths of a milligram. Not all of the lead would be in a form that could dissolve in the body in the next few hours, and from watching smokers, you know that not all of the smoke stays in the lungs. Still, even though only a few micrograms of lead would be involved, I do not think these items should be used in fireworks shot at ground level, or be hand-held by children. Perhaps if they exploded twenty feet in the air, there would be no problem. If this sounds extreme, remember that studies of lead in American children show that they already have too much. An average city the size of Denver receives a couple of tons of lead compound vapors every rush hour morning, and about two more tons of lead in the evening. Children are at enough risk from automobile lead.

I am a careful chemist, well trained in handling poisons. I have handled the most deadly toxins, some a million times more deadly than lead. Yet after the lead compounds for the Dragon Eggs



and Hellzapoppin article, I spent \$90 to have my blood checked. Even with my careful precautions, I had apparently picked up some lead! Although still subclinical, the level was 10 to 100 times above what is now recommended, depending on which study you use, and whose guidelines you wish to consider valid. My problem: I had not bought the expensive respirator I should have. The lead accumulation was the consequence, despite my otherwise very careful handling.

For fireworkers, the difficulty in handling red lead oxide results from the remarkable ability of the compound to generate and hold static charges. It is used in microscopy to detect piezo and pyro electric charges on tiny crystals. The old mineralogist examination for pyro electric effects involved warming a crystal of tourmaline or quartz and almost touching it to a mixture of sulfur and red lead. The ends of the crystal would become coated with yellow sulfur or red lead oxide and thus reveal the static electric charges.

This ability to take a high charge makes the material hard to safely handle; even though it is very dense, tiny particles will float off in air from even a gently disturbed mass of red lead oxide.

Since the body of a healthy person can eliminate only a few tenths of a milligram to a few milligrams of lead per day without special medical therapy, lead is considered *cumulative*. One mg of red lead on a sheet of paper might fill up one of the "o"s on this page. In one pile, it would be easy to see if you were looking for it, but spread out evenly over the page or your hand, it would require a microscope to find, even though it is brightly colored material. Working without an adequate respirator, but otherwise observing all precautions usually taken with extremely toxic materials, I have always noticed the characteristic metallic, almost sweet, taste of lead, every single time I have used red lead. Sieving, or even dropping red lead from a spatula onto a balance pan results in a tiny quantity becoming airborne, due to the static charges generated. At the industrial level, red lead is handled by persons in full Tyvec suits that have clean air pumped into them. For the person occasionally handling the material, all this gear is probably unnecessary, but a really good respirator is a MUST. Don't be a fool. Apply handcream or lotion to all exposed

skin, cover your hair, shower as soon as possible - thoroughly. Clothing is not dust proof; as a rule it cannot offer adequate protection, so the head-to-foot scrub with soap is a very good idea. The clothing worn should be removed slowly, respirator still in place, then laundered at once, separated from other clothing.

If all of this seems a little silly to you, read the symptoms of lead poisoning. A few calculations should have you happy to smear your face with cold cream so that the respirator is well sealed, and the skin easier to clean. Keep in mind that toxicology data older than 1981 are out of date. If you want to worry, read some of the recent testimony to Congress by EPA advisors.

The evidence so far indicates that if you live in or near city, you already have a lead problem and should not handle lead compounds at all. In the 1970's, 10 to 30 mcg/100 was considered "normal background" levels. Now mental and other effects in children have been positively associated with levels as low as 1/10 of a microgram per centiliter! It is perfectly possible that the mass paranoia of the 50's and 60's were made far worse by lead from automobiles.

Worldwide studies have shown that humans naturally contain *NO* detectable lead. Likewise, the learning ability of children have been shown to be related to their proximity to cities (and lead levels). Both effects have been shown to correlate to the air pollution plumes of cities. Most of these effects are not noticeable to the victims, and until recently, were not noticed by physicians. Clinical lead poisoning is still considered to begin at blood levels of 30 to 100 mcg/100. For most persons, this would correspond to 3 to 10 mg of lead ingested in a few days. Even at these levels, only an alert physician would spot lead poisoning. At ten times this level, any physician could spot the toxemia, but most doctors have never detected or treated lead poisoning. It is usually misdiagnosed as diarrhea, intestinal flu, depression or other psychological difficulty. Many cases of cumulative or low level lead poisoning are not properly diagnosed until the autopsy, or when utter collapse results in a long hospital stay. It is suspected that even most of those cases go undetected. Fortunately, this situation is changing here in the U.S. LSO



IMPACT SENSITIVITY

Many myths, half-truths and superstitions exist on the subject of the impact sensitivity of firework compositions. The standard apparatus used in the military and commercial explosives industry is too expensive for the average fireworks enthusiast. You can do it yourself.

THE APPARATUS

A very simple and inexpensive apparatus can be made from materials available at most hardware stores. The apparatus is made from 1/2" dia., 36" long steel bar; a yard stick and aluminum foil. A hot rolled steel bar (the type with a rough black surface finish) is preferred over the galvanized cold rolled steel because it is tougher and does not abrade as easily. Do not use tool steel as it tends to shatter and produce shrapnel. The only other thing needed is a piece of mild steel to act as an anvil. Any soft steel that is flat and weighs more than the bar will suffice.

It is most convenient to set aside an area to do the testing in and mount the yardstick permanently. If you mount the yardstick 36" from the anvil, you can measure fall distances from 0 to 6-feet by measuring from either the top of the bar or the bottom.

TEST CUP

Residues from previous explosions often form very sensitive mixtures with fresh samples so it is important to provide a fresh, clean hammer face for each drop test. A piece of aluminum foil crumpled over the end of the bar works well and can be replaced easily for each drop. Another piece of foil formed around the bottom of a glass test tube makes a very nice sample cup. The rounded end helps to compensate for small deviations from vertical when the bar is dropped.

HOW IT WORKS

The sample cup (with sample) is placed over the foil-capped end of the bar and lightly compressed to hold it in place. The sample should have a thickness of 1 to 3mm. If the sample is thicker than 1/4", some cushioning effect is noticed and the explosions are very loud. The bar is simply

lifted to a predetermined point and released, allowing it to fall cup first against the anvil. You can test stars, primed stars, paper wrapped and other compressed compositions as they are. The impact energy is primarily at the surface for solidly compressed compositions and the thickness is not very important. You should try to keep the surface area constant for each batch and note it in your records.

INTERPRETATION

Impact sensitivity is a statistical process. You will need to determine the height where *all* 15 out of 15 explode, the height where 15 out of 15 do *not* explode and the height where 50% of the trials explode. In general, if the *all fire* point is near the 50% height, the mixture is reasonably consistent in sensitivity. If the 50% height is near the *no fire* point, then the mixture is quite erratic and more dangerous to handle.

There is very little published data on the sensitivity of firework compositions. Results can vary widely and often the cause is very hard to find. Trace impurities in the parts per million range can make dramatic sensitivity differences. No two batches of chemicals, even from the same company, are dependably alike.

Sulfur usually contains traces of arsenic and sometimes antimony. The sulfur recovered from oil is very low in arsenic and its mixtures with chlorate oxidizers are surprisingly insensitive to impact. If traces (below 1%) of arsenic are added to this melted sulfur, allowed to crystallize and is powdered, then the mix with potassium chlorate is more sensitive than most antimony sulfide/-chlorate mixes.

The military has found that shellac sometimes contains orpiment. Orpiment improves the color of shellac and therefore improves the grade, which increases the price. Orpiment is cheap in India and is often added to the shellac from that area of the world.

You probably cannot afford a chemical analysis of each batch of chemicals you buy, but you can run impact sensitivity and avoid nasty surprises.



Many people think that substituting red gum for shellac is safe; my results indicate otherwise. All the combinations of the three lots of barium chlorate, four lots of red gum and two lots of shellac indicated that the red gum mixes were more sensitive.

The control of pH, which helps control heat up reactions, does not necessarily make the mix less sensitive to impact. In my tests with barium chlorate, red gum and barium carbonate, the addition of carbonate made the mix more sensitive - especially if wet for a long time or was sun dried.

The size and shape of oxidizer particles make large differences in sensitivity with the same batch of fuel. For example: potassium chlorate in very fine, well formed crystals is usually more sensitive than material ground to the same size range in a ball mill. Potassium perchlorate is usually finished by drying in a rotating drum, by centrifuging or crushing. Each shows different impact sensitivities with sulfur.

Don't ask an "authority" - test it and find out for yourself. Test each batch and keep notes. Ranges I have seen:

Chlorate compositions:

Most sensitive: All fire 1/4" - potassium chlorate & red phosphorus.

Least sensitive: No fire above 30-ft. - barium chlorate, aluminum & plastic binder.

Potassium chlorate & Sulfur:

Most sensitive: All fire 9".

Least sensitive: No fire 18".

Potassium chlorate & Antimony sulfide:

No two batches of antimony sulfide have yielded the same range.

Most sensitive: All fire 10".

Least sensitive: No fire 20".

Ammonium perchlorate:

Most sensitive: All fire 4" - ammonium perchlorate & resin binder.

Least sensitive: No fire 6-ft. - ammonium perchlorate blue star. LSO

WARNING ON DRAGON EGGS FORMULATION

Two of the hits of the '88 PGI convention were *Dragon Eggs* and a similar product, *Hellzapoppin*. These Class C devices are indeed fascinating effects, worthy of further development. We have learned of several people who are attempting to duplicate the formulation. We have also heard of an "authentic" Chinese formulation that is being circulated.

B.R. of Fireworks reports that the formulation in circulation is extremely dangerous to work with in that it can go into instant detonation. Further, ignition of the loose powder is difficult, and delayed, encouraging the experimenter to carelessness. Sensitivity to friction and impact seem to be high.

Mr. R. reports that in recent experimentation a loose pile of composition failed to ignite from direct contact with Ignitercord, but eventually ignited from a piece of inserted black match. The delay between contact with the fire train and ignition of the composition was about four seconds. And the result was not burning, but detonation!

The formulation uses lead oxide, a seldom used, poorly understood, but particularly vigorous and strong oxidizer. Experimenters should be aware that the formulation is sensitive to friction and impact, as well as flame. The effect, at least in loose piles, seems to be similar to Armstrong's Mixture, which instantly goes into detonation,

NOTES ON POTASSIUM CHLORATE

We have often heard the warnings, KEEP CHLORATES AWAY FROM THE SULFUR COMPOUNDS!!! It's been said so often that a ban potassium chlorate paranoia has crept into the minds of many a pyro. I personally believe that potassium and barium chlorate do indeed have a place in making fireworks as long as Mother Nature's chemical rules are strictly followed. As Dr. Takeo Shimizu states so well in his book, *Fireworks - The Art, Science and Technique*, pp 90, "It would be ideal to reject this material (potassium chlorate) from fireworks, but it is quite difficult even at present, because no other oxidizer can surpass potassium chlorate in burning speed, in ease of ignition or in noise making, using the smallest amount of composition." Potassium chlorate is also an ideal oxidizer for colored stars because it produces a high temperature flame rich in chlorine atoms which intensify colors. This allows commercial fireworks manufacturers certain economics as well. One thing is for sure, chlorates are here to stay. Fortunately, advances in the learning and sharing of knowledge within this industry over the past 30 years have lead to a decline in the number of accidents involving the chlorates. There probably aren't any professionals worth their salt today that are not aware of the ingredients that sensitize barium and potassium chlorate. Even so, there are those who go so far as to promote the use of a few percentages of barium carbonate as an acid neutralizer (buffer) in meal powder and then dust their chlorate stars with this primer.

Accidents attributed to the use of the chlorates should not be blamed on the chlorates but to the

carelessness of the user. Perhaps the user was ignorant of the "potential" dangers or if he knew, he forgot or was apathetic, in which case his future in this life and industry is limited. We've seen a lot written on the dangers of chlorate mixtures with sulfur, sulfates, sulfides, ammonium compounds, etc. But I haven't seen too much written about the dangers of ultraviolet light - the sun!

From time to time, we see articles written or hear someone talk about the (unconditional) merits of drying fireworks in the sun. Certain conditions do exist where the sun can be a direct cause of a pyro disaster. Sulfur reacts with water to create a weak form of sulfuric acid (H_2SO_3). Potassium or barium chlorate reacts with sulfuric acid to form chlorine dioxide (ClO_2) which is decomposed explosively by sunlight into chlorine and oxygen. If there are any fuels present, spontaneous combustion is a definite certainty! Think about this the next time you are considering sun-drying chlorate stars dusted with meal or pulverone, barium carbonate or not!

Chlorates demand to be understood. Beginners to the art should definitely avoid fooling around with the chlorates until they understand the nature of the beast. There are many other warnings and cautions regarding chlorates and their incompatibility with other substances besides those mentioned here, which make them potentially dangerous. However, in the hands of trained professionals, chlorates have for many years produced some of the most beautiful effects offered in the fireworks art. WO

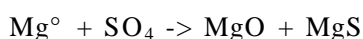
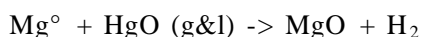
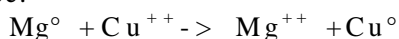


HAZARDS OF BLUE STAR METALS

I have had several letters inquiring about metal fuel blue stars. The chemical potential for reactions between magnesium (or magnalium) and any copper-plus-two salt or compound is large. All of these reactions are quite exothermic, enough so to make a fella worry. All of these reactions are thermodynamically spontaneous and most are chemically spontaneous at 20°C, especially in the presence of good old water. For instance if you mix powdered copper sulfate pentahydrate and fine magnesium powder, pour the mix into a tube and squirt water into the tube, it will undoubtedly heat up, almost always steam, frequently catch fire with surprising violence and occasionally go bang with a convincing report. If the chemicals are not perfectly dry to begin with or the day is very humid, the reaction may start before you apply the water.

TESTING REACTIVITY

The reactions involved in the order of their appearance:



To observe the first reaction safely, all you need is a good heat sink, so go to the sink and fill a glass with water. Dissolve a teaspoon or so of copper sulfate or any other soluble copper salt in the water, measure the temperature of the water. Stir the water vigorously and add slowly a teaspoon of magnesium powder. You will notice the almost instant appearance of a red, brown or black precipitate of copper powder. Take the temperature of the water again. By increasing the amount of chemicals used or decreasing the amount of heat sink, water, you can easily reach the boiling point of water. You can easily arrange for a surprisingly violent steam explosion which makes a nice outdoor demonstration, tossing the contents of the glass into the air a good many feet. If you don't mind poisoning the grass with copper, you might try it. Remember that the reactions are a bit difficult to regulate and the shower is boiling water with chemicals. To arrange for the sudden "bumping" type reaction, it

is best to wipe the glass with oil, which eliminates the points on the glass where active sites help bubbles of steam form, and thus dissipate the heat harmlessly without the dramatic "bump". Put water and magnesium in the glass, pour in suddenly a saturated solution of the copper salt and prepare for the sudden "bump" explosion that will cause rather nasty rain. Don't do this in the kitchen, unless you want to paint your wife's ceiling, scrub walls, etc. The form of copper powder that those reactions produce is excellent for pyrotechnic use, if distilled water is used. Any excess magnesium present can be dissolved with acetic acid. Traces of acetic acid will cause the copper to react with air forming "vertigris" so very thorough rinsing is required.

Not all of the bubbles formed are steam or pure steam. Hydrogen is liberated when magnesium is in contact with boiling water or steam. This reaction is exothermic and in insulated containers can become explosive. Hydrogen and steam are sometimes generated in the laboratory by boiling large turnings of magnesium or small quantities of magnesium ribbon in a large flask of water. With magnesium flake or powder, the reaction is much too fast and explosions are very likely. Most universities lock up the magnesium powder after one of these or a nice violent reaction complete with ether explosion. Maybe the boring "no risk" chemistry taught nowadays is the reason so few students become chemists. It USED to be exciting, and fun.

You may have guessed by now that these first two reactions can start the third reaction and at that time a new container will be necessary for the next experiment.

You can try the steam and magnesium powder reaction on an almost safe scale in foam plastic cups with very fine magnesium powder. It is necessary to line the cup with aluminum foil as the plastic fails structurally at the temperatures involved. By nesting two plastic foam cups together (as they are in the package), a well insulated device is quickly formed that is convenient for spontaneous reaction studies. For very slow or low heat value reactions, two small cups in one, or two large cups is usually enough insula-



tion. Place two tablespoons of magnesium powder in a cup of aluminum foil formed inside one of the two cup devices, pour quickly a similar volume of boiling water on the magnesium powder and cap this with another two cups nested together; start back quickly as a small explosion of the boof or whoof type is quite possible. Short of an explosion, a melting of the cups and a lot of steam evolving is evidence sufficient. This same apparatus is suitable for studies on sulfur and chlorate mixtures or any other spontaneous reaction of pyrotechnic interest and is quite inexpensive. Try the above with warm water, cold water, various grades of magnesium. Try them again in the presence of salt water, because all electrolytes accelerate the reactions. Try nitrate solutions with magnesium. These demonstrations are an excellent means of remembering magnesium safety precautions. It is a much wiser course to educate yourself with such experiments than to depend upon the judgment of another, especially since that person probably heard it, well, somewhere. There must be a fact somewhere?

Try putting the copper sulfate in gelatin capsules, then place a capsule in the magnesium powder and water "foam cup calorie bomb". For protracted studies, such as the chlorate sulfur reaction that can take months or years, it is wise to glue the cups to a heavy board so they don't blow away and wind up burning in the trash dump or neighbor's hay stack.

The first reaction, the reduction of copper compounds to metallic copper is obviously a hazard where the compounds are soluble in the working fluid used as a solvent for star forming. The rate of this reaction at low temperatures is directly related to the solubility of the chemical in the working fluid. Therefore, one way of reducing the problem to a controllable hazard level is to use "insoluble" compounds. Copper carbonate and copper oxychloride are too soluble, even though they are often listed as "insoluble". EVERYTHING is soluble in water to some degree, even though it may be a very small degree. Indeed, it could be significant for a particular system. Copper sulfide and copper oxide are so very slightly soluble in water that normally they are considered "quantitatively" insoluble. Copper metal is similarly "insoluble". If you don't believe that

copper metal is at least to a very small degree soluble, try this experiment. Place equal volumes of distilled water in identical containers, thoroughly clean and polish a small piece of copper and place it in one water container. Wait a day or two and taste both. Even traces of copper have a noticeable after taste. Copper is a required nutrient and a deadly poison. You can safely "taste" most copper compounds very cautiously, but don't try to compare ten of them in one day. Copper normally leaves the body in fecal material.

The second reaction, magnesium and water, is greatly accelerated by the presence of another conductor of electricity being in contact with the magnesium, since the first reaction deposits tiny crystals of copper at the surface of the magnesium. All salts of copper will cause this condition to a degree. Essentially what happens here is the formation of an electrically shorted cell, or a "battery" (cell is proper) that has been "short circuited". The less active metal provides a surface for the hydrogen generated to accumulate on, thus localizing the charge differential due to chemical potentials. You may have noticed that when the water was very warm in the first experiment the black, red or brown copper powder began to float and give off small bubbles. The gas was hydrogen. If copper salts are added to the boiling flask for the water and magnesium reaction (hydrogen generator), it evolves hydrogen at a lower temperature and at a greater rate at all temperatures. Technically, this reaction of magnesium and water takes place at room temperature and below, but the rate is very small. In the presence of the second conductor this is no longer true. So Problem Reaction #1 has made Problem Reaction #2 much more of a problem. So would the use of copper metal powder. Thus, of the copper compounds normally used in fireworks only the sulfide and the oxide would be useful and even those would be expected to give storage problems eventually.

DON'T BE FOOLED

We have so far considered only chemical problems involving the ubiquitous water, magnesium and the copper salts. You might falsely suppose that these could be eliminated by simply using cellulose nitrate in acetone or MEK as a



binder, but cellulose nitrate is not sufficiently insulating electrically, not a good enough water barrier, and both acetone and MEK solvents commonly contain water and attract water from the atmosphere. Acetone, in fact, must contain water to preserve it, and prevent it from polymerizing, or dimerizing. Also cellulose nitrate slowly decomposes to yield a very hygroscopic coating on the magnesium.

AMMONIUM PERCHLORATE PROBLEMS

As my old friend and teacher William McGavok, Ph.D (God rest him well) would say, "we aren't out of the woods yet". In fact, we haven't even met all of the dangerous beasts therein. Ammonium perchlorate gives such beautiful blues in low temperature flames that it would be nice to try it in high temperature flames. It is an excellent chlorine and HCl donor. Since the flame of magnesium can consume chlorine and hydrogen chloride, we will need extra to achieve a good blue. Ammonium perchlorate is hygroscopic enough that the powder mixed with magnesium powder commonly evolves ammonia and makes a puddle of magnesium perchlorate. If you mix a tiny dab of both in the palm of your hand and close your hand on it for a few minutes, the reaction will start from moisture on the skin. In a few more minutes you can smell the ammonia. Quickly wash it off if you notice rapid heating!

DICHROMATE'S TURN

Takeo Shimizu introduced the use of dichromate to limit the rate of this reaction by physically blocking off the surface of the magnesium with magnesium chromate and chromite. This is a common trick among painters of machinery and metal buildings etc., for zinc and magnesium, at the same time protecting the metal and giving the coating a good bond to the metal, which is usually coated next with dichromate primer. It cannot and does not stop the adverse reactions but it can retard the rate of the reactions severely and therefore is of practical use where the items will be used in less than ten, preferably less than five years. Copper precipitates with chromate and chromites. Pigments, "catalysts" and oxidizers for organic reactions are made of these compounds. These precipitation reactions are of only small concern since we have already

eliminated the soluble forms of copper. It is possible that pre-treatment of copper powder could render a high electrical resistance coating and make the direct use of copper powder possible. Both copper oxide and copper sulfide would be attacked by ammonia evolved from the reaction of magnesium and ammonium perchlorate and could be rendered sufficiently soluble to become not only a storage hazard, but a heat up problem that could lead to fire and explosion. The copper-chromium oxide ion salts are very strong oxidizers. Of concern would be the possibility that one or more of them could oxidize the ammonia to water and nitrogen - yet another exothermic reaction that could proceed at significant rates at room temperature or slightly elevated temps. This has not been studied for its pyrotechnic significance, to my knowledge. Until it is, the question of advisability of dichromate treatment of the magnesium in blue star formulas is guesswork. As you might expect, the presence of other chemicals such as dextrin, red gum, etc., make the guess work much more complex. In view of this I refuse to make recommendations without more facts. The published activation curves in kinetics studies of the copper chromium oxide ion salts are frequently very sharp, which means nothing happens until some condition is met and suddenly the reaction starts. Proceed, if you must, with great caution: small batches, isolated storage, full precautions. Distrust simple answers to complex questions.

N/C LACQUER & OTHERS

Cellulose nitrate films can be made more water impermeable by the use of toluene in the solvent. Toluene works with water and several other solvents that might be used to dissolve the cellulose nitrate to form triple azeotropes, thus "trapping" the water and forcing it to evaporate with the solvents. Too much toluene will cause "drop out" of the cellulose nitrate.

Also the addition of damar resin helps greatly. The original formulation for Deft varnish was 50% damar/50% cellulose nitrate. Even 10% damar resin renders the cellulose nitrate much more water impermeable. Manila copal is also of help but not so effective in small percentages. The copal and damar help stabilize the cellulose nitrate so other stabilizers are unnecessary.

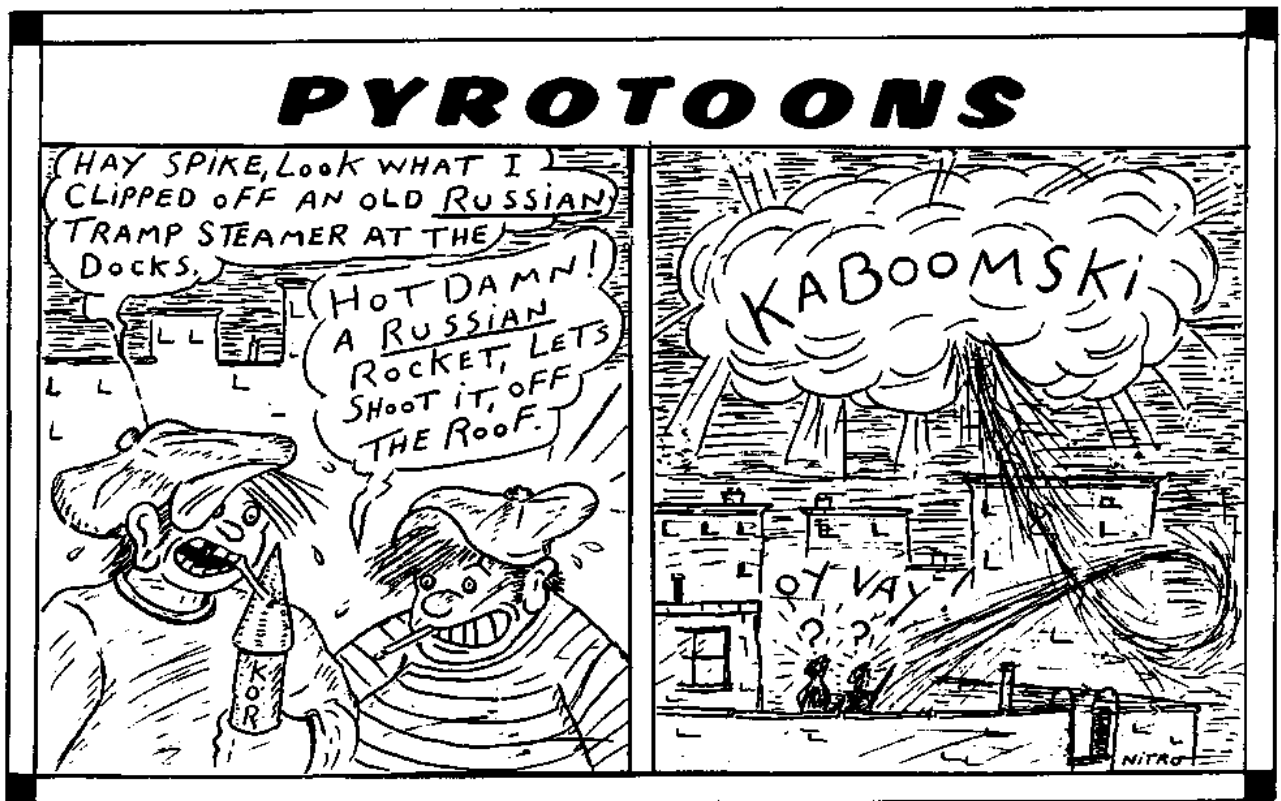


Parlon films are much more water resistant, have a higher electrical resistance and would be, in addition, a chlorine donor. Parlon dissolved in toluene would be superior to parlon in acetone, MEK, ethyl acetate.

Shellac in alcohol is hygroscopic. The film deposited is highly variable in waterproofing characteristics. The same can be said of red gum in alcohol. Red gum in alcohol is sufficiently acidic to attack magnesium. A coating of the products adheres to the magnesium and makes a fair water barrier. Pine rosin similarly forms a thin film of magnesium salts on magnesium. East Indian resin produces a similar coating superior to both of the above, but due to its cost is rarely used in fireworks. Shellac, pine rosin, East India resin and red gum can all be added to a parlon solution. The red gum would be the least desirable, as it would make the parlon more water permeable. Parlon can be added to cellulose nitrate to improve the waterproofing value of the cellulose nitrate. Damar and East India resin can be added to this combination.

Obviously, the possible workable combinations are very large and it will take a great deal of experimentation to establish what the very best will be, but it is equally obvious that there is always a chemical solution to a chemical problem.

One further suggestion. The resinates coatings on the magnesium form rather slowly. It may be best to dissolve the resin (say pine or East India) in a suitable solvent and let the magnesium powder stand in this solution for some time before use. This will ensure a thick enough water barrier of magnesium resinate. The reaction that forms the resinate will release water in the case of the magnesium oxide often found on magnesium powder, but there is no problem for water miscible solvents like acetone. So if you choose a water insoluble copper compound, use a waterproof binder and first "waterproof (it is not perfect!) your magnesium. It is possible to formulate a wide range of metal fuel blue stars. These should still be considered experimental and quite hazardous in all stages. LSO





ARMSTRONG'S MIXTURE

A letter of some months past detailing a reader's experiences with nitrogen tri-iodide, has occasioned this missive on its potentially lethal cousin, Armstrong's mixture.

Dear WiZ,

"Quite some years ago (30?) I happened upon the following in the Popular Science Book of Formulas: Recipes. Methods & Secret Processes. (1932) 'A sensitive detonating mixture is made of potassium chlorate 10 parts, black antimony sulfide 5 parts and red phosphorus 1 part. Mix without friction and at some distance from the operator's face. It is quite sensitive to blows, very unlike (?) the potassium chlorate-sulfur mixture.'

"In those bygone days it was easy to obtain chemicals either from the local druggist (who was probably amazed at the amount of potassium nitrate my mother required for "preserving meat") or any chemical supply house. One local chemical supply house would even give me a discount for being a student. Therefore, obtaining the required reagents was not difficult.

"I started out by putting the mixture in 0000 gelatin capsules. Just throwing them up into the air was sufficient to cause detonation upon impact with the ground.

"One day a friend and I loaded quite a large amount into a cardboard tube that BB's come in. We backed off quite a bit and fired upon it with a Daisy pump action BB gun. The second or third pellet found the mark, resulting in a tremendous blast which rocked us back on our heels and caused the propane gas tanks next to the house to ring as though they had been struck by a hammer!

"This progressed to placing the material into a (you don't want to know). Threw one off the roof of my friend's apartment house one night toward the vacant lot directly behind. However, its errant trajectory caused it to land/detonate on the fire escape of an adjacent building! Scared the S— out of someone who was peacefully watching TV with the window open.

"For the ultimate and final folly, had taken to adding magnesium to increase sensitivity! (Bet the second thing you did with your Chem-Craft chemistry set was to find all the fun things you could do with magnesium!) At that time our families both had country homes to which we adjoined each summer. In the surrounding woods my friend and I had constructed a small shack. On this fateful day while seated on the ground at the back, my friend was seated on a stone wall directly in front mixing, when KA-BOOM — WHAT A BLAST!!! The smoke blew away, and HE WAS GONE!!!! GOOD GRIEF, what am I going to tell his mother???? He blew himself up and I can't even find the pieces?!?! ~ I am happy to report my grief was short lived, for those few seconds of no little anguish were relieved by a plaintive cry of 'Pssst - Pssst - I'm over here', coming from some yards away. For as luck would have it, we (he) were using a cardboard container, and "all" that happened was the bottom blew out, resulting in numerous small holes in his blue jeans from the unreacted phosphorus, and a not-a-little-bit-sore, blackened hand. There is, in retrospect, no doubt in my mind that had mixing been completed and the whole batch detonated, he would not have been able to play the piano. Regards,"

Name withheld under pain of having flaming arrows being sent in the WiZ's direction while he is making flash and report.

Yes, indeed. I would add the following quote from the *American Pyrotechnist* for March 1978. "[a PGI member] dry-mixed about a teaspoon of potassium chlorate and (red) phosphorous, put it in a plastic 35mm film container, and it ignited or exploded violently just from the slight friction of snapping the cap on! He says that he has learned his lesson, but the injuries to both hands were so disabling that he will not be able to correspond for about two months."

Some time ago an outfit called Xxxxxx Xxxxxxxxxxxx, Folly Beach, S.C., sold thru an advertisement in the Shotgun News information on a "frictional impact explosive". The information turned out to be five small photo-reproduced



pages on the compounding of Armstrong's Bombs" (booby-traps), "Smoke Screen" (combined with ammonium chloride), "Impact Grenades" (gelatin capsules), "Explosive Rodent Traps" ("It let's you know when a mouse or rat has been caught."), and "Impact Detonator", and "Explosive Paint" ("This explosive paint lends itself well to practical jokes.") "Sure!" One-and-one-half pages were devoted to safety in compounding, with the admonishment that "A pencil eraser sized piece will put the loudest fire cracker to shame, while a thimble full will rival a stick of dynamite." Perhaps somewhat over stated, but not by much.

An accident involving a substantial amount of Armstrong's mixture was reported in Explosives and Their Power. Translated and condensed from the French of M. Berthelot. London 1892.

"The explosion which occurred in Paris, in the Rue Beranger, on May 14, 1878, may also be mentioned, in a store containing amorces (caps) intended for children's toys. These amorces were composed as follows: - One kind, called single, of a mixture of potassium chlorate (12 parts), amorphous (red) phosphorus (6 parts), lead oxide (12 parts), and resin (1 part); the others, called double, consisted of a mixture of potassium chlorate (9 parts), amorphous phosphorus (1 part), antimony sulfide (1 part), flowers of sulfur (0.25 part), and nitre (0.25 part). The latter, more sensitive to friction, averages 0.01 grm. in weight. From six to eight millions of these amorces pasted on paper slips, in lots of five each, were piled up in the warehouse in boxes. A few of these having become ignited by an accident, the origin of which was never clearly ascertained, caused the whole to explode. One building suddenly gave way, the facade being blown out, and the stonework hurled some distance. One stone, measuring a cubic meter, was thrown to a distance of fifty-two meters. A great part of the adjoining building was also destroyed, fourteen persons were killed on the spot, and sixteen received injuries.

"These terrible effects are explained when we consider that the weight of the entire explosive

matter contained in the amorces amounted at about 64 kgms., and that its force, owing to the composition of this matter, was equal to a force of 226 kgms. of blackpowder. (These facts have been taken from the report presented by the Committee of Inquiry).

"It is essential that persons having explosive substances under their charge should never lose sight of the conviction that, from the facts and general truths which have just been stated, preventive measures should always be prescribed on the hypothesis of an explosion." (Amen.)

I hope that these experiences point up the folly of working with combinations such as Armstrong's mixture, its cousin, the red explosive mixture, and other less than safe and sane mixtures, i.e., potassium chlorate and sulfur, or potassium chlorate and antimony sulfide, which, by-the-by, was used during the Civil War in land mines! Further, although Armstrong's mixture and the "red explosive" can be compounded "safely" when wetted...what are you going to do with them when they have dried out??

Although the word "detonation" is commonly used in connection with pyrotechnics, the only comp that has been tested and found to produce true detonation is potassium chlorate and sulfur. However, it is my firm belief that if Armstrong's mixture were to be tested, it too would be found capable of detonating.

Other than toy caps and such, the only modern use for Armstrong's mixture I have been able to locate are three US Patents (4,372,210, 4,191,947, 4,130,082) describing intrusion alarm systems using the radiant output from MAGICUBE flash lamps to initiate a quantity of Armstrong's mixture or SUPER BANG CAPS (potassium chlorate, red phosphorous, manganese dioxide, and glue) to produce an audible alarm.

Finally, A Thought for Today: There are old pyro's and there are bold pyro's but there are no old unlucky pyro's! DH



ARMSTRONG'S MIXTURE - PART II

Armstrong's mixture redux.

Lasciate ogni speranza, voi ch'entrate!

Two letters have been received detailing their writers' experience with this mixture. I have taken the liberty of editing them to protect the identities of the authors.

"In the mid 1950's, the local 5&10 cent stores were selling for 10 cents each, cap guns of tin plated steel, somewhat thinner than the tin plate in good cans, embossed to look somewhat like revolvers. All parts except the hinge or pivot pins and two springs were of tin plate. No paint was applied.

"Caps were 1 cent a roll and had 50 shots per roll. They were narrower than common roll caps. The tissue cover readily pulled off, once carefully started, revealing reddish lumps (Armstrong's mixture?) about 20% the mass of common roll caps of the day. These lumps could be scraped off using a razor blade or an Xacto knife and were considerably more friction sensitive than the American black cap mixture.

"While watching late-nite TV movies one summer, I amassed enough of this red mixture to fill a Jetex fuse tin, about 3/4 or possibly 1 tablespoon of mixture. It was then ignited inside the tin via Jetex fuse thru a hole in the lid. (Note minimal containment of charge.)

"As an adult pyro, now with some considerable experience, I can say that it was absolutely THE MOST POTENT MIX I've ever played with."

The second letter reads as follows:

"I also have a copy of the Popular Science Book of Formulas. I leafed thru it this morning; the pages describing "fireworks" were blackened with charcoal. - Ah memories!

"When I was 14 I worked in the local drug store. The owner, a pharmacist, would sell me anything and everything - even acid and glycerin to make nitro, which I never did. I also bought gelatin capsules, and made torpedoes. Some of the capsules were meant for animals, and were at least

an inch long and 1/2-inch wide. God, were they loud when made with Armstrong's! I almost killed myself and gave it up."

Jack Stutting of Advanced Pyrotronics, Greenville, Michigan has provided the following on the origins of this dreaded composition:

"Sir William Armstrong, an engineer from Newcastle, England. Originally known for inventing types of hydraulic machinery and strengths of materials and applied the results to making several types of modern artillery. He was one of the first developers of rifled gun barrels and also developed several successful breech loading guns, (artillery). He was appointed to the post of Superintendent of the Royal Gun Factory in Woolwich. This first production guns went into the field in 1860-61. To work with his new designs in gunnery, new propellants and primers for these propellants had to be developed. Among many compounds developed and tested, Armstrong's Mixture was one used quite often in priming the propellant charges for large guns. Many of his designs still influence the manufacture of modern artillery."

The Ordnance Manual of 1862, provides instruction for producing "friction-primers for cannon" using "chlorate of potassa" and "sulphuret of antimony", however, there is no mention of phosphorus in the book.

Dr. Ben Harriman, of Florida, was kind enough to supply a copy of a letter received from Herbert Ellern (March 1976) in which he states: "Nobody seems to know who the 'Armstrong' was who first made the deadly mixture. I have no doubt that soon after the discovery of red P in 1844, its tremendous activity with oxidizing salts and some oxides such as PbO₂ was discovered. The Wm. G. Armstrong (1810-1900) mentioned in the Britannica, an English engineer much engaged in ordnance, could have been it, but he surely was no chemist."

Ellern, Shimizu, and Tenney Davis have the following to say in their respective books:

ELLERN - "One combination of two solids exists



in which a flaming or even explosive reaction may take place on merely pushing the powders toward each other or on exertion of very light pressure. This reaction occurs when the powdered components are completely dry and the fuel is not superficially oxidized. The two materials are red phosphorus and potassium chlorate and a demonstration of their reactivity should be performed only with a few milligrams of each component. When the phosphorus has been kept for some time in an ordinary reagent bottle, the spontaneity of the reaction may not be so obvious, but the final effect may be just as disastrous, as has been shown many times when high school students have appropriated and mixed together the two chemicals, [emphasis added]

"This reaction is undoubtedly the most fascinating, and perhaps theoretically the most interesting, solid reaction. It has been ingeniously tamed in the modern safety match.

"Red phosphorus and chlorate can be mixed in comparative safety in the presence of a liquid vehicle, provided both reactants are thoroughly moistened by the vehicle before they come into contact. Using an aqueous binder solution, small dabs of such a mixture form the explosive ingredients of toy caps.

"[The] phosphorus/chlorate/binder combination are at the borderline between spontaneous reaction and manageable, easily initiated, but stable systems of reactive fuels and oxidizers."

SHIMIZU - rates the sensitivity of "fundamental two component firework compositions" on a scale from 1, to 5 the most sensitive. The combination of potassium chlorate and red phosphorus rated 5; realgar and sulphur were rated 4; milk sugar 3; while aluminium and charcoal were both rated 1.

DAVIS - "Toy caps are commonly made from red phosphorus and potassium chlorate, a combination of the many with which the pyrotechnist has to deal. Their preparation ought under no conditions to be attempted by an amateur.

"Mixtures of potassium chlorate and red phosphorus explode from shock and from fire. They

do burn in an orderly fashion as do black powder and most other pyrotechnic mixtures."

Here in basement D of the Schloss Zaubuer a quick check of the arcane Bibliotheca WiZardae (perhaps the finest private collection of esoteric pyro publications and nudist magazines in the western world) has turned up seven US patents using either Armstrong's mixture or red phosphorus, exclusive of those designed primarily to produce smoke.

Charles Nelson's 1867 patent (65,764) for an "Improved toy torpedo and explosive compound", provides the following: "The explosive material which I prefer and have used successfully with my moulded bodies is compounded of as follows: One-third amorphous phosphorus, one-third chlorate of potash, one-sixth sulphur, one sixth pulverized chalk." Compared to modern formulae this 33/33/17/17% combination is long-on-phosphorus and short-on-chlorate, perhaps to decrease sensitivity, or to increase the amount of smoke.

Issac Milband's patent number 157,856 of 1874, provides for a fulminate compound composed of red phosphorus, potassium chlorate and charcoal, for use in caps, primers and cartridges.

Patent 592,227 of 1897 for a "Match and composition for same", used red phosphorus, potassium chlorate, antimony sulphide, charcoal, lead chromate, gum-benoin, dextrine and gum-sandarac!

Charles Kalber's "Flashlight powder" patent number 2,098,341 makes references to his British patent, 419,658 in which is provided a detonation cap using a potassium chlorate, phosphorus mixture.

USP number 2,122,488 of 1938, describes a "Blow-out imitator and the method of packaging the same". Assigned to the Victory fireworks and Specialty Co., the patent describes a device used to imitate the explosion of a tire blow-out through the use of detonator in the form of a fireworks torpedo.

"With this device one can safely plan an amusing trick by attaching the device to a tire of a friend's



THE BEST OF AFN II



car. When the car is moved and the rotation of the wheel brings the detonator into engagement with the pavement it explodes with a loud bang which is a perfect imitation of a tire blow-out.

"It has been found that the explosive will detonate without fail and thereby create an amusing (?) situation and quite a joke upon the driver of the car when he gets out and looks in vain for the blown tire.

"The explosive mixture is composed of red phosphorus and chlorate of potash with gum-arabic as a binder and when first placed in its carrier it is of liquid form and hardens into a cake or tablet. Continued setting of the explosive mixture results in its binder drying out to such an extent that handling the torpedo or any jar thereof will result in breaking down the cake or tablet so that the explosive assumes a granular form.

"Ordinary toy torpedoes carry sand, pebbles, or some abrasive mixture in conjunction with the explosive mixture to cause the same to explode when struck. The present mixture however when

it becomes of granular form, will explode readily by even a slight blow without the use of sand, pebbles or any abrasive mixture, with the result that the device is much safer in use as it eliminates the flying particles of sand or the like, which has always been incident upon the explosion of toy torpedoes as now manufactured and sold."

A 1940 patent (2,194,480) for a "Noncorrosive priming composition", substitutes barium nitrate for potassium chlorate, in the red phosphorus antimony sulphide mixture.

Fumio Hosoya's patent of 1966, (3,233,544) describes a "Signaling Device" and more particularly an impact detonated, smoke or flame emitting device, i.e., a torpedo. The "detonating material includes approximately 1-2 parts red lead, 1 part to which a binding agent is added." Here the composition is intended not to produce noise but sufficient heat to volatilize a smoke dye. The combination of red lead and (ferro)-silicon is, of course, a thermate (Goldsmith's) type composition. DH

I think
I'll check the
directions
again.





AMERICAN FIREWORKS NEWS

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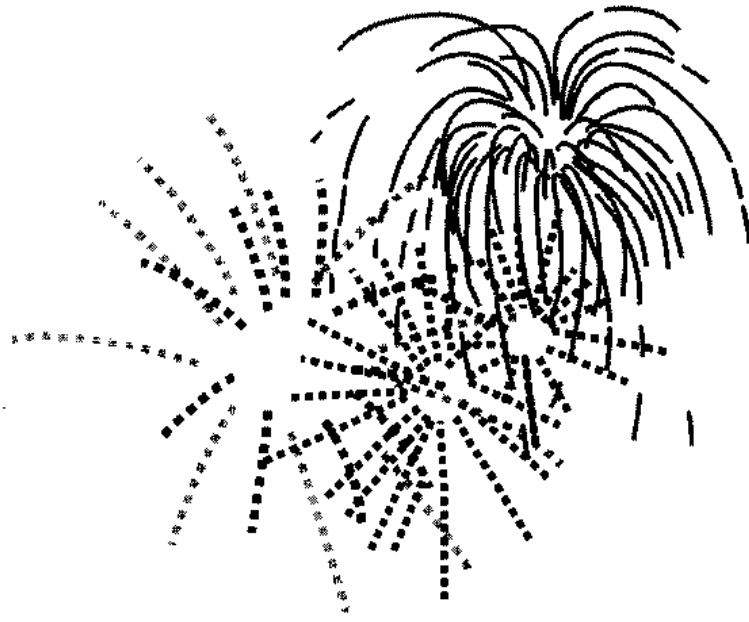
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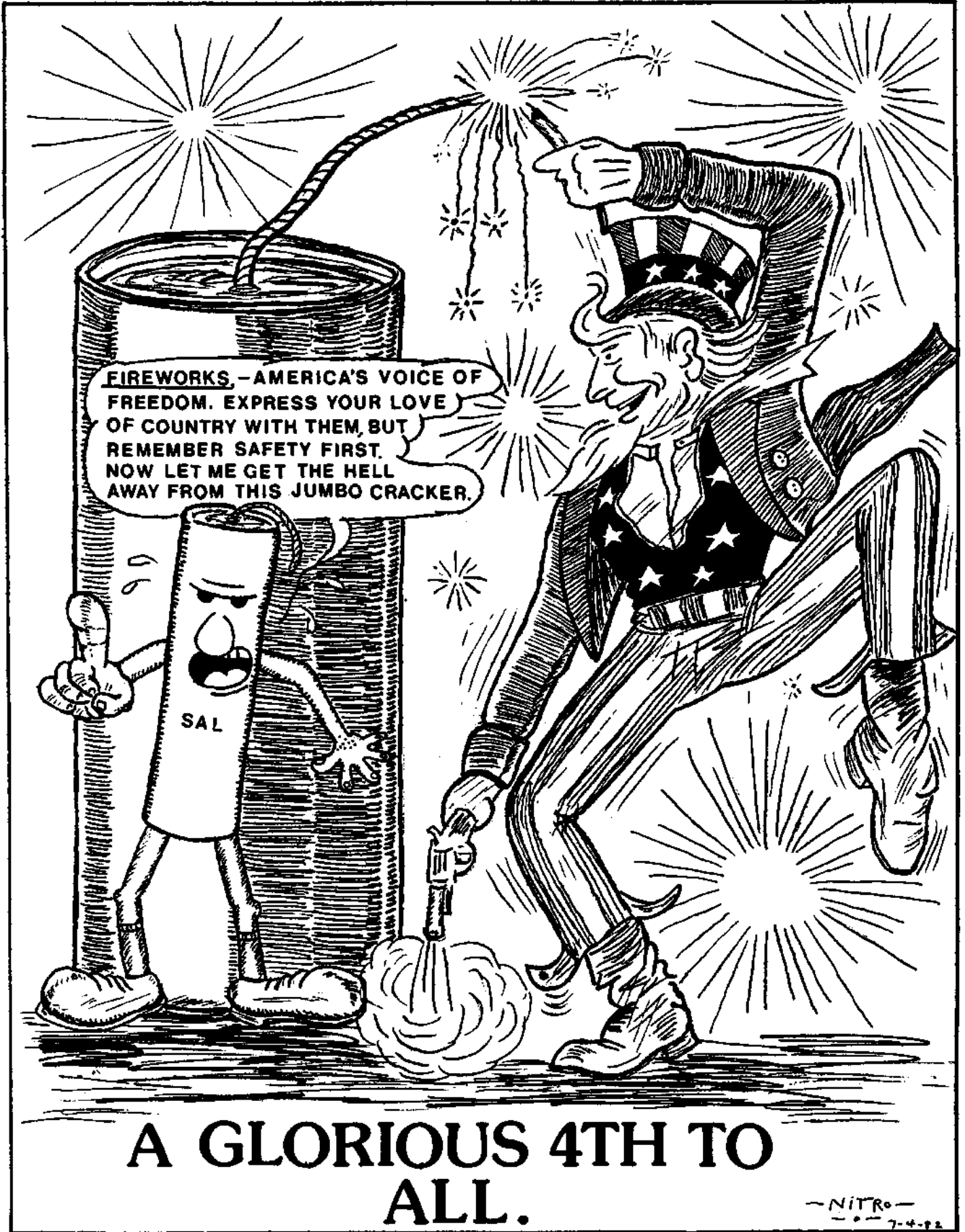
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A GRAND AND GLORIOUS 4TH TO ALL

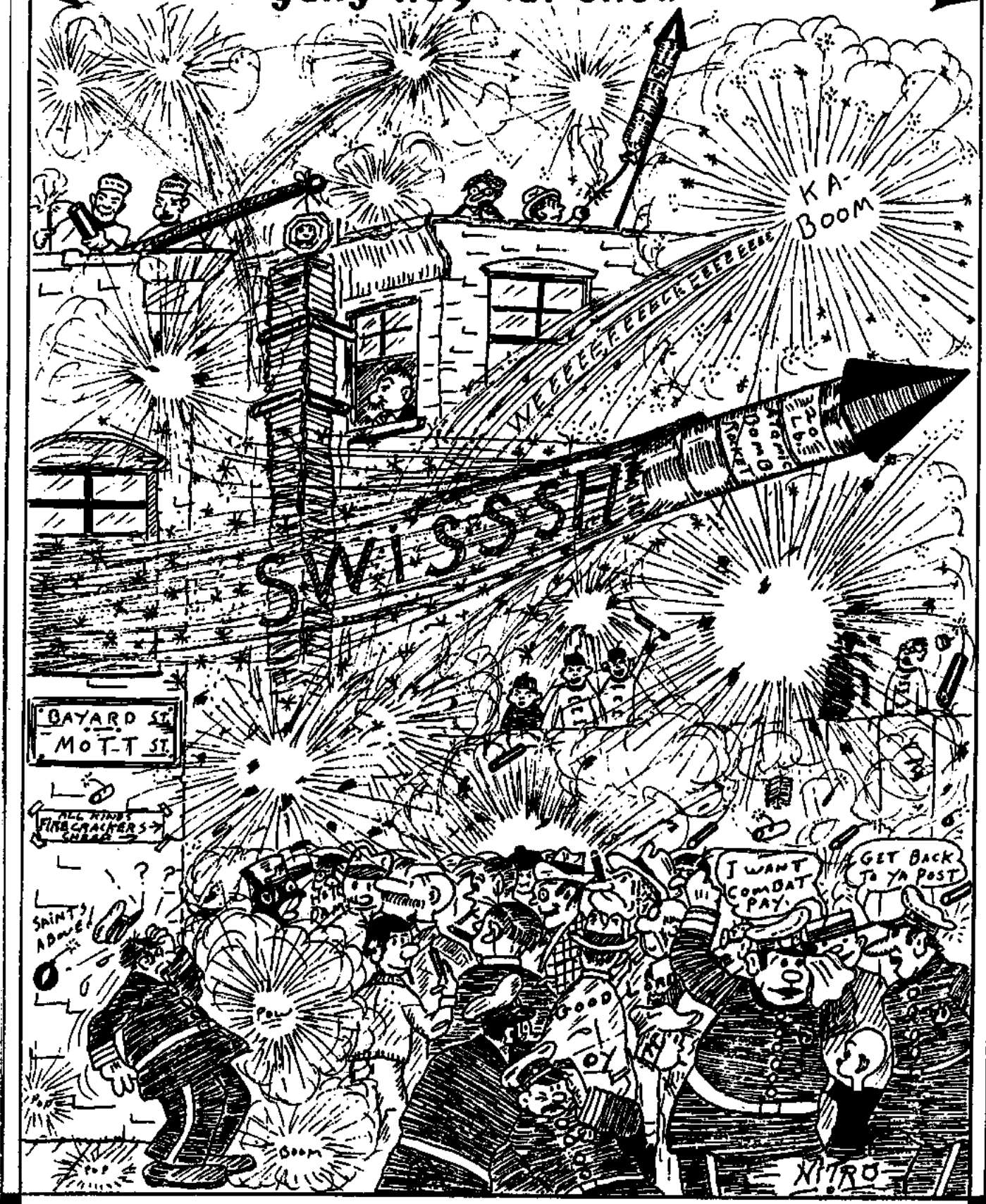


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V8g, Pressed Inserts for Shells video
V8h, Palm Tree Shell Construction video
V8i, Indoor Fireworks Applications video
V8j, Blast Waves & Flash Powders video
V8k, Round Shell Construction & Finishing video
V8L, 4", 3-Break Color & Report Shell video
V8n, Display Shooter's Course, Part 1 video
V8o, Crossette Rocket Construction video
V8p, 5" Crossette Shell Construction video
V8Q, Pyro Tools & Basic Fountains video
V8r, Star Rolling Machine video
V8s, Abbreviated Shooter's Course, Part 2 video
V8t, Mine Construction video
V8u, Girandola Construction video
V8v, Exhibition Candle Construction video
V8w, End Burning Rocket Construction video
V8x, White Strobe Rocket Construction video
V8y, Holiday Crackers video
V8z, Blue Strobe Rocket Construction video
V9a, Display Site Hazards video
V9b, Star Making Troubleshooting video
V9c, Paper, Paste & String video
V9d, Pyro 101 video
V9e, Mini Whistle Rockets video
V9f, Toy Exploding Ice Cream Cones & Table Fireworks
V9g, Secrets of Pyrotechnic Whistles video
V9h, Smoke, How & Why video
V9i, Ball Shell Construction video
VB1, Best of Fireworks Video Magazine - Instructional
FTH, Fire in the Hole video

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*“He who
hath once
smelt
the smoke -
is ne’r
agin free”*



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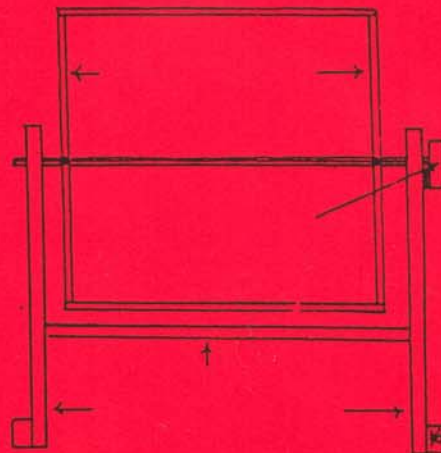
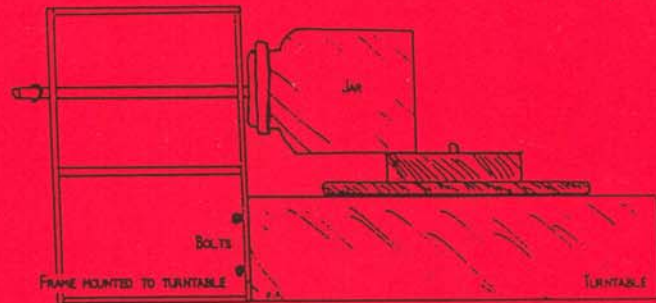
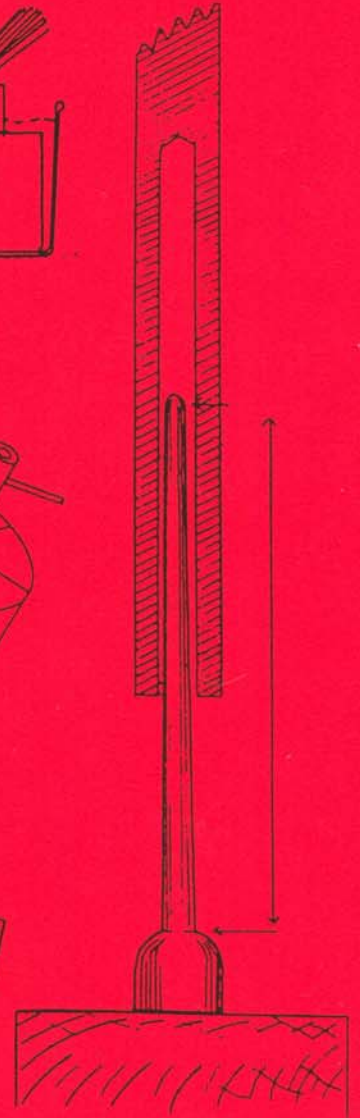
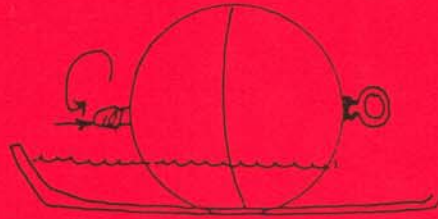
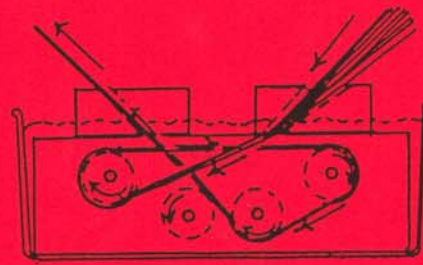
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